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THESIS SUBMISSION

Title: Evaluating Construction 4.0 Attributes in South African Higher Education Curriculum: An Activity Theory Perspective

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Submitted in fulfilment of the requirements in respect of the Doctor of Philosophy with specialisation in Higher Education Studies degree in the Department of Curriculum Studies & Higher Education in the Faculty of Education at the University of the Free State

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Declaration

I, **Hendri Blignaut du Plessis (Student number: 2005108812),** declare that the thesis, *Evaluating Construction 4.0 Attributes in South African Higher Education Curriculum: An Activity Theory Perspective* (three interrelated, publishable articles[1]), submitted for the qualification of Doctor of Philosophy with specialisation in Higher Education Studies at the University of the Free State is my own, independent work.

All the references I have used have been indicated and acknowledged by complete references through this non-traditional article-option doctoral thesis. The Harvard referencing technique is utilised throughout the thesis (however, it is amended according to each individual article according to the Journal specifications when submitting to the proposed Journals). The list of references is placed after each chapter/article, with the attached Turnitin report as Appendix H.

Kindly refer to Section 1.1 (Introduction to the structure of the study) for a detailed overview of the thesis layout. The thesis uses UK English and will subsequently be amended according to the individual journal requirements. In this thesis, the structure of headings and subheadings occasionally omits intervening paragraphs, particularly within the data analysis sections of the interrelated articles, as explained in Section 2.3. I confirm that the language editing of this thesis has been completed by a professional editor, as evidenced by the accompanying editor's letter in Appendix I.

I further declare that I have not previously submitted this work to another university or faculty to obtain a qualification.

06 January 2025

SIGNED DATE

[1] Current (2025/05/12), status of publications: Article 1 & 2 - under review and Article 3 – accepted.

ABSTRACT

The Fourth Industrial Revolution (4IR) has brought about profound changes in the field of Construction and the Built Environment (CBE), requiring attributes that are aligned with Construction 4.0 (C4.0) technologies. This doctoral study investigates the evolution and integration of C4.0 attributes at South African Higher Education Institutions (HEIs) with a focus on Quantity Surveying (QS) and Construction Management (CM) curricula. The research applies Cultural Historical Activity Theory (CHAT) to explore how students, lecturers and Industry professionals perceive, understand and react to C4.0 developments.

The study employs an explanatory, sequential, mixed-methods design, combining quantitative and qualitative data from semi-structured surveys, with qualitative data from focus-group discussions and interviews. The Quantitative analysis utilised a combination of descriptive statistics, Cronbach's alpha for internal reliability, and inferential methods such as one-way ANOVA and Pearson correlation to explore relationships between variables. Qualitative data were thematically coded and analysed through content analysis to identify patterns, perspectives, and emergent themes across stakeholder groups. Quantitative analyses assess the awareness and preparedness of students and lecturers regarding C4.0 attributes, while qualitative analyses explore deeper insights into the integration of the understanding, relevance and approach needed to develop C4.0 attributes and their influence on Construction 5.0 (C5.0) developments. C5.0 is the human-centric framing of future industry practices, emphasising ethical, collaborative, and socially responsive engagement with digital technologies.

While findings reveal that South African HEIs are progressively aligning curricula with emerging industries, there is still a gap between academic programmes and the practical application of C4.0 technologies in the workforce. Students and lecturers recognise the importance of digital literacy, problem-solving and adaptability. Still, there is a need for HEIs to enhance technical and soft skills further to improve the preparedness of graduates for the evolving construction industry. This research contributes to the existing body of knowledge by offering two frameworks for integrating C4.0 graduate attributes into HEI curricula with a special focus on expansive learning (EL). Additionally, it emphasises the importance of industry collaboration in shaping higher education that responds to the dynamic demands of the CBE. The study's findings can assist educators in aligning higher education programmes (i.e. QS & CM) to foster the required C4.0 attributes for the CBE.

This research contributes to the existing body of knowledge by offering a proposed preliminary framework for integrating C4.0 graduate attributes into HEI curricula, emphasising the importance of industry collaboration in shaping education that responds to the dynamic demands of the CBE.

Keywords: Construction 4.0 (C4.0); Construction 5.0 (C5.0); Cultural Historical Activity Theory (CHAT); Expansive Learning; Graduate Attributes (GA); Higher Education (HE); Quantity Surveying (QS); Construction Management (CM).

DEDICATION

To my Heavenly Father and everyone that He has sent over my path, shaping me like a pot of clay:

"I keep six honest serving-men; (They taught me all I knew).

Their names are What and Why and When and How and Where and Who.

I send them over land and sea, I send them east and west.

But after they have worked for me, I give them all a rest.

I let them rest from nine till five, for I am busy then,

As well as breakfast, lunch, and tea, for they are hungry men.

But different folk have different views; I know a person small—

She keeps ten million serving-men, who get no rest at all!

She sends 'em abroad on her own affairs, from the second she opens her eyes—

One million Hows, two million Wheres, and seven million Whys!"

(Rudyard Kipling, cited: The Kipling Society, 2024:online)

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LIST OF ACRONYMS

4IR	Fourth Industrial Revolution
5IR	Fifth Industrial Revolution
AI	Artificial Intelligence
AR	Augmented Reality
AT	Activity Theory
BIM	Building Information Modelling
C4.0	Construction 4.0
C5.0	Construction 5.0
CBE	Construction Built Environment (Referring to the South African perspective – distinctly towards the Quantity Surveying and Construction Management Professions)
CHAT	Cultural Historical Activity Theory
CHE	Council on Higher Education
CI	Construction Industry (Referring to the global perspective)
CIDB	Construction Industry Development Board
CIOD	Chartered Institute of Building
CM	Construction Management or Construction Manager
CPD	Continuing Professional Development
CPM	Construction Project Management or Construction Project Manager
CPS	Cyber-Physical Systems
CPAE	Continuous Professional Attributes and Engagement
CDE	Common Data Environment
CL	Change Laboratories
EL	Expansive Learning
GA	Graduate Attributes
HE	Higher Education
HEI	Higher Education Institution
HESA	Higher Education South Africa
ICT	Information and Communication Technology

IoT	Internet of Things
I4.0	Industry 4.0
KSA	Knowledge, Skills, and Attributes
KSCA	Knowledge, Skills, Competencies, and Attributes
LoDI	Law of Diffusion of Innovation
NQF	National Qualification Framework
NSFAS	National Student Financial Aid Scheme
PI	Principal Investigator
PLC	Project Life Cycle
QS	Quantity Surveying or Quantity Surveyor
SA	South Africa
SACPCMP	South African Council for the Project and Construction Management Professions
SACQSP	South African Council for the Quantity Surveying Profession
SoTL	Scholarship of Learning and Teaching
T&L	Teaching and Learning vs Learning and Teaching (L&T – as some authors suggest)
UAS	Unmanned Aerial Systems
UFS	University of the Free State
USA	United States of America
VR	Virtual Reality
WIL	Work-Integrated Learning

BRIEF CONTENT

DETAIL CONTENT

LIST OF TABLES

LIST OF FIGURES

PART 1

ORIENTATION & INTRODUCTORY LITERATURE TO THE STUDY

1

ORIENTATION OF STUDY

1.1 INTRODUCTION TO THE HOLISTIC STRUCTURE OF THE STUDY

With the presentation of this doctoral thesis in the format of three interrelated, publishable manuscripts/articles (hereafter only referred to as articles), it was regarded as crucial to provide the reader with some background that could serve as an orientation to the study. One of the prerequisites is that the three publishable articles produce a holistic whole, indicating these articles' interrelatedness and shared goals [see Part 3: Epilogue (Section 6)]. Even though a clear rationale for and coherence among articles are implicated in all three articles, additional clarification may enhance the presentation, as evident in the epilogue (see Part 3: Section 6). Additionally, it is important to clarify that this article-option doctoral thesis structure should not be viewed as entirely synonymous with the traditional introduction of a doctoral thesis, despite certain similarities (e.g. no chapters, but four parts divided into six sections). The primary aim is to provide a concise overview of the study, focusing on key aspects such as the background and rationale (see Section 1.2), problem formulation (see Section 1.3), and problem statement (see Section 1.3.1). This was followed by the outline of the paradigmatic, disciplinary, and theoretical framework (see Section 1.4), the research aim and objectives (see Section 1.5), and research questions (see Section 1.6). Furthermore, it addresses the research methodology and design, alongside data analysis, interpretation and reporting (see Section 1.7), which was adopted in both sections within each article, the study's value (see Section 1.8), ethical considerations (see Section 1.9) and the researcher's positionality (see Section 1.10).

1.2 INTRODUCTION, BACKGROUND AND RATIONALE FOR THE STUDY

The Fourth Industrial Revolution (4IR) or Industry 4.0 represents a paradigm shift towards technological development (Newman et al., 2021:558-560), characterised by digital, physical, and biological systems convergence (Schwab, 2016:12). It is driven by emerging technologies such as artificial intelligence (AI), robotics, big data, the Internet of Things (IoT), sensor based technologies, 3D printing, cloud computing, cyberscecurity, and advanced data analytics (Newman et al. 2021:558-560). In the context of the built environment, these technologies form the foundation of what is now referred to as Construction 4.0 (C4.0) (Sawhney et al., 2020).

The South African Construction Built Environment (CBE) could ideally embrace the efficiencies that Construction 4.0 (C4.0) promises by producing new higher education scholars equipped with well-balanced, scholarly attributes towards the Fourth Industrial Revolution (4IR) (Barrie, 2007; Sawhney et al., 2020). However, the reality of the divergence of the South African socio-economic and Industry backdrops requires further consideration than just apparent institutional restructuring (Mbodila, 2020:online; Pillay et al., 2022). With the emergent nature of C4.0 and the development of terms such as Construction 5.0 (5.0) (Marinelli, 2023:1-2), there appears to be a knowledge gap between the approach offered at South African Higher Education Institutions (HEIs) and the Construction Built Environment (CBE) regarding the advent of C4.0 and C5.0 education and its realities. This is supported by Posillico et al. (2023:4143), which highlights the general lack of cohesion in the body of knowledge within construction management curriculum development.

With C4.0 conceptualised *as "an innovation platform for the Built Environment"* and stems from industrial production, cyber-physical systems, and digital computing technologies (Sawhney et al., 2020; Schwab, 2016:12). The Construction Industry (CI) is traditionally slow to respond and adapt to change, while it remains a complex business with several role players and relatively high stakes or risks [Risks include, but are not limited to economic, financial, structural, technological, contractual, quality risks, etc.] (Orstavik et al., 2015:3-11). With the growth of the 4IR or Industry 4.0 (I4.0), the fragmented integration of teaching, research and the professional Industry within the CI remains a challenge (Sawhney et al., 2020:5). Loosemore (2015:65-77), also indicates that construction produces a unique product every time – unlike routine-based production – while mass production has the advantage of task specialisation, repetition, and learning. Additionally, modularisation, standardised designs, and institutionalised specifications and routines are efforts to make the complexity manageable (CIDB, 2019:79). It is further observed that many graduates only start to grasp the complexities of the CBE after entering the workplace. Not to mention new terms such as C5.0 that are emerging, calling for the refocused human element of these technological developments (Marinelli, 2023:1) and calling for the CI to keep agency of these developments within the CI (Koc et al., 2020:474).

In the prelude to the 4IR, South Africa has an immense skills shortage compared to other nations, not to mention the difficulties regarding infrastructure, weak governance, state capture, and an unemployment rate of 33.5% (Sutherland, 2020:233; Trading Economics, 2024:online). Additionally, the COVID-19 pandemic has exacerbated the challenges of higher education worldwide, affecting poorer students and weaker higher education institutions more severely (Paterson, 2021:online). Confirming the increasing shift towards automation, computers and robotics technologies are anticipated to replace routine manual labour as the 4IR unfolds progressively (Schwab, 2016), rephrasing workforce demands and skill requirements globally.

Although the 4IR builds on the past eras of industries, its influence will be profound, irreversible, and much more rapid than the previous three revolutions (Morrar et al., 2017:12). O'Neill et al. (2023:1) highlight that HEI departments in Ireland's construction industry experience difficulties towards change:

> These include difficulties in the number of boards and committees involved in change, a lack of incentive for lecturing staff undertaking what is considered additional work, the disparity in the definition of a "successful program" within the Higher Education Institutions, extensive amounts of reports required for change proposal, lecturing staff being largely overworked, and organisational structures that do not facilitate collaboration between departments.

Similarly, there is a need to carefully assess the possible effect of the 4IR, particularly in South African industries, HEIs, and existing systems. As Barrie (2004:273) suggests, such frameworks can play a crucial role in navigating the complexities of curriculum reform, fostering adaptability, and promoting sustainable practices within HEIs that align with the demands of the transformative era.

1.3 PROBLEM FORMULATION

Employers are increasingly seeking a broader range of skill sets from fewer employees, demanding advanced thinking and communication abilities (Levy & Murnane, 2005, cited in Saavedra & Opfer, 2012:8-13). The construction industry (CI) is no exception; research by Ahmed et al. (2014:240) indicates that Construction Management (CM) undergraduates must possess five key attributes: knowledge of health and safety regulations, the ability to interpret contract documents, strong listening and attention to detail, familiarity with building codes and regulations, and practical time management skills. The challenge lies in developing these competencies in students from diverse social backgrounds to align with industry requirements and available resources within HEIs. As Barrie (2007:439) notes, “Universities are increasingly concerned with developing attributes that will better equip students for the work environment.” For instance, the literature emphasises diverse skillset requirements: RIB Software International Limited (2016:online) identifies seven essential traits for a successful Quantity Surveyor, including effective communication, critical thinking, attention to detail, composure, organisation, humility, and teamwork. Moreover, Wagner (2008:67) proposes seven fundamental skills for students, which include critical thinking, collaboration and leadership, adaptability, initiative and entrepreneurship, effective communication, information analysis, and fostering curiosity and imagination. Similarly, Saavedra and Opfer (2012:8-13) outline nine key lessons for 21st-century learning that focuses on pedagogical needs, emphasising relevance, skills development, and leveraging technology to support creativity and teamwork. Notwithstanding the above, accredited programmes play a vital role in the Construction Building Education (CBE) sector in the South African context. Quantity Surveyors (QS) typically register with the South African Council for Quantity Surveyors (SACQSP), while Construction Managers (CM) and Construction Project Managers (CPM) register with the South African Council for the Project and Construction Management Professions (SACPCMP, 2023:online; SACQSP, 2023:online). Other notable accreditation bodies, such as the Royal Institution of Chartered Surveyors and the Chartered Institute of Building (CIOB), lend international recognition to HEI programmes (CIOB, 2024:online; RICS, 2024:online). These bodies focus primarily on a competency framework that defines the required knowledge and skills for curriculum accreditation (CIOB, 2018; RICS, 2019; SACPCMP, 2020; SACQSP, 2014). However, while attributes encompassing behaviours and attitudes are acknowledged, they remain underdefined (Griesel & Parker, 2009). This gap presents an opportunity for HEIs to play a significant role in developing a workforce competency framework, particularly when considering Warier's (2014:7) definition of competency as "the knowledge, skills, and attributes (KSA) that differentiate superior performers from others in every sphere of life".

Further exploration of the necessary attributes within the construction industry (CI) has revealed a mixed understanding of knowledge, skills, competencies, and attributes (KSCA). Various research studies (see the summarised table in Part 4 Appendix B – Table B) demonstrate a global interest in how KSCA are integrated into construction education across countries such as Australia (Sunindijo & Kamardeen, 2020; Vaz-Serra & Mitcheltree, 2021), South Africa (Aliu et al., 2023), the USA (Ahmed et al., 2014; McCord et al., 2023), Thailand (Kaewsri & Tongthong, 2014), and Ireland (O'Neill et al., 2023). While some studies highlight the necessity of soft skills such as interpersonal competencies and resilience, others focus on technical knowledge and industry-specific competencies. Nevertheless, the inconsistent definition and application of graduate attributes (GAs) remains challenging.

Trigwell (2021:286) questions how the Scholarship of Teaching and Learning (SoTL) can support HEIs in the CBE, especially when many lecturers from the industry may lack familiarity with these teaching principles. Considering the five W's of journalism (who, what, where, when, and why) can possibly assist in addressing this comprehensive narrative (Georgia Institute of Technology, 2024:online).

1.3.1 Statement of the Problem

Ideally, the South African CBE could embrace the efficiencies that Construction 4.0 (C4.0) promises by producing new higher education institutional scholars with well-balanced graduate attributes towards the 4IR. However, the reality of the divergence of the South African socio-economic and Industry backdrop requires more focused and cohesive considerations within curriculum design than existing restructuring considerations, such as the focus on knowledge, skills and competency, to address the evolving workplace influenced by emerging technologies.

1.4 DISCIPLINARY, PARADIGMATIC AND THEORETICAL FRAMEWORK (HISTORICAL AND PRACTICAL APPLICATION)

Creswell and Plano Clark (2018:39) highlight four levels of research study development: paradigm worldview, theoretical lens, methodological approach, and data collection methods. Similarly, Saunders et al.'s research highlights the layered nature of research design choices through the 'research onion', which aids researchers in clarifying their philosophical stance and methodological alignment across various stages of the research process (Saunders et al., 2023:129). However, because of the unconventional (research by articles) approach, it was found that a more iterative (or explorative) approach through writing and thinking about the paradigm worldview could only be reflected in depth in the epilogue (Section 6.2) after evaluating the process (Creswell & Creswell, 2018:5). This, however, does not mean that the pragmatist worldview did not influence the ontology, epistemology, axiology, methodology and rhetoric language used within the thesis (Creswell & Plano Clark 2018:42). The theoretical lens (Section 1.4.1) is thus discussed first before the summary of the conceptual and theoretical framework (Section 1.4.2). The choice of a mixed method (in particular, the explanatory sequential) was initially confirmed as a pragmatic approach to the study (Creswell & Creswell, 2018:18).

From the pragmatic worldview, the scope of this doctoral study is framed within the fields of the Construction Built Environment (CBE) and Higher Education (HE), with a particular emphasis on Construction 4.0 graduate attributes from a Quantity Surveying (QS) and Construction Management (CM) perspective. This focus overlaps with key international HE themes, such as student experience, academic work, knowledge and research (Teichler, 2015:815-847; Tight, 2012). South African HE research is increasingly interdisciplinary, focusing on student experiences, transformation and socio-cultural responsibilities, course design, and ICT integration (Wilkinson et al., 2016). These themes are particularly pertinent to the current study. Additionally, the construction sector has recognised an increasing demand for soft skills (Van Heerden et al., 2023:2), a shift that underscores the need for a comprehensive framework to explore how these trends intersect with technological and educational advancements.

1.4.1 Activity theoretical framework

Building on this shift, adopting Activity Theory (AT)[2] presents a suitable lens for examining these developments. It originates from Vygotsky's concept of the zone of proximal development in 1978, which emphasises the role of social interaction in learning, to its recent formulation in the form of Cultural Historical Activity Theory (CHAT) (Spinuzzi, 2020:5). The latter is regarded as the most appropriate theoretical framework for this study because the AT's foundation on the cultural-historical paradigm, which emphasises the importance of social and cultural contexts in shaping human behaviour and cognition (Fleer, 2016:1). Further developed by researchers like Leont'ev and Rubinstein, AT views human activity as a systemic unit that is mediated by tools, social interactions, and the environment (Engeström et al., 1999:41). Additionally, the theory posits that individuals engage in purposeful activities shaped by their cultural environments and that these activities are fundamentally social and collaborative (Fleer, 2016:5-6). In this study, CHAT focuses on understanding the C4.0 graduate attributes necessary/required by CBE students, lecturers and industry practitioners to interact with their CBE surroundings, tools, and the social norms that influence their actions within the 4IR.

Historically, Vygotsky's (1978) idea of the zone of proximal development highlights that learning occurs most effectively when learners are supported to move beyond their current abilities with the guidance of more knowledgeable others (Mcleod, 2014). This notion (Engeström, 2001) laid the groundwork for developing first-generation AT, which focused on individual action mediated by tools and signs (Engeström, 2001:136-137). Leont'ev (1978) expands upon Vygotsky's work by introducing the second generation of AT, which moves the focus from individual action to collective activity systems. Leont'ev emphasises the importance of the division of labour and community, arguing that human

[2] The term AT is used as an umbrella term through-out the study with CHAT forming part of the AT Framework – please see Part 3, Section 6.4.1 (Figure 6.2).

activity is always part of a more extensive system with various stakeholders involved (Engeström & Sannino, 2010:1). This collective aspect of activity created a framework through which the broader social, historical, and cultural contexts of learning could be examined. Lastly, CHAT (applied in all three articles) was developed as the third generation of AT by Engeström (1987), from which the concept of expansive learning (EL) was developed. EL addresses the limitations of traditional learning models by focusing on how contradictions within activity systems drive innovation and change (Engeström, 2001:136-138). Expansive learning (EL) occurs when learners acquire new knowledge and transform their understanding of the object of their activity, leading to the creation of new practices. This process is often cyclical, progressing through seven stages (also refer to Section 6.7): questioning the existing practice, analysing its limitations, modelling a new solution, testing and examining the solution, implementing the model, reflecting on its efficacy, and finally consolidating and generalising the new practice (Engeström et al., 1999:384).

Expansive learning allows for integrating formal and informal learning experiences in educational settings (Engeström & Sannino, 2010:9). It emphasises collaborative problem-solving and the transformation of social practices, making it highly relevant to the modern demands of Construction 4.0 and 5.0. This approach is particularly pertinent in the context of the South African CBE, where the need for adaptation to emerging technologies, such as Building Information Modelling (BIM) and the Internet of Things (IoT), require a shift not only in technical knowledge but also in the underlying learning processes (Begić & Galić, 2021:16). Through CHAT, it becomes possible to explore how students (see Part 2 Section 3, Article 1), educators (see Part 2, section 4, Article 2), and industry professionals (see Part 2, section 5, Article 3) interact within activity systems, allowing for the mediation of new tools and technologies as part of the learning process (Spinuzzi, 2020:5) [Please see Section 6.2.2 and 6.7 where the study's culminating frameworks are discussed].

In summary, the evolution from Vygotsky's proximal development to Engeström's expansive learning (EL) framework reflects a shift towards understanding learning as a dynamic, socially situated process. This shift is critical in addressing the challenges posed by rapid technological advancements in the construction industry and preparing graduates for the evolving demands of Construction 4.0 and beyond (Sawhney et al., 2020a:12). See more detail in Part 2 with the three articles and Part 3, section 6, which reflect on the use and evolutionary understanding of the AT framework with its different layers.

1.4.2 Conceptual and theoretical framework

Given the study's unconventional structure and exploratory approach, the conceptual framework, initially developed before the implementation and compilation of the three main articles in Part 2, could only be finalised during the reflective process in Part 3 (Section 6.2); including an extended conceptual and theoretical framework just before the synopsis of the three main articles (section 6.3) assisted in the logical flow and alignment of the different reasoning approaches during the reflection process.

This study integrates Graduate Attributes (GAs) into student-centred teaching (UFS, 2019:4), self-directed learning (Fink, 2013:5), and course design using Sinek's "Golden Circle" framework of ‘why’, ‘how’, and ‘what’ (Sinek, 2009:41). Guided by the Activity Theory (AT), the research examines the South African Construction Built Environment (CBE) students' social, systematic, and professional development (Gedera & Williams, 2016:xi; 20-21). The dissertation adopts inductive, abductive, and deductive reasoning across three articles focusing on students, higher education institutions, and industry practitioners, respectively (Creswell & Plano Clark, 2018:12), with a pilot study providing critical insights, grounding the framework in a pragmatic worldview (Creswell & Creswell, 2018:5-6; Jacobs & Cornelius, 2022:110), while highlighting the importance of GAs in bridging Construction 4.0 and 5.0 innovations with sustainable professional and cohesive practices (Engeström, 2001:137; Koc et al., 2020:474; Marinelli, 2023:1; Najafi, 2023:online;Click or tap here to enter text. Posillico et al., 2023:4165). The reasoning styles employed in each article are as follows (Creswell & Plano Clark, 2018:12):

- Article 1: Focuses on students (“why”) and uses inductive reasoning.
- Article 2: Focuses on higher education institutions or lecturers (“how”) and uses abductive reasoning.

- Article 3: Focuses on the CBE or practitioners ("what") and uses deductive reasoning.

Although Article 3 adopts a deductively informed structure, it does not test a formally stated hypothesis in the conventional sense. Instead, it confirms patterns and observations derived from earlier phases of the study, providing the final empirical input required to develop the proposed framework. The findings reinforce rather than test assumptions, offering a basis for synthesis rather than generalisability.

1.5 RESEARCH AIM AND OBJECTIVES

The study aimed to determine, by utilising the CHAT perspective, the most important or relevant approach to C4.0 attributes for transforming South African CBE student learning and development in HEIs; furthermore, considering the three different stakeholders, how these C4.0 GAs might be managed or implemented best by HEIs to address the technological progress in the workforce. The objectives of the three articles are as follows:

1. Identify, evaluate and measure student experiences towards the most important South African Construction Built Environment graduate attributes through the CHAT perspective and provide a rationale for the existence of these graduate attributes (Section 3, Article 1).
2. Through the CHAT perspective, evaluate how critical graduate attributes are for lecturers in the South African Construction Built Environment and its implications (Section 4, Article 2).
3. The CHAT perspective evaluates the relevance of graduate attributes needed in the South African Construction Built Environment for the workforce and its implications (Section 5, Article 3).
4. Integrate the literature and empirical research results, compile and substantiate learning, teaching and professional development directives for managing or implementing graduate attributes needed in the South African Construction Built Environment that contribute to integrating knowledge and practice, and determine why (Part 3, Section 6).

1.6 RESEARCH QUESTIONS

This three-article option doctoral study formulated the following three questions:

Article 1, titled: Fostering Graduate Attributes for Justice in South Africa's Construction Education Curriculum Amid the Fourth and Fifth Industrial Revolutions.

How do university QS and CM students perceive and experience the learning of GAs, and how do these perceptions assist in the preparation towards C4.0 to form the human-centric foundation for C5.0 developments? (Section 3, Article 1).

Article 2, titled: Integrating Graduate Attributes within a Construction 4.0 Framework: Insights from South African Quantity Surveying and Construction Management Educators.

How do university lecturers perceive the importance of graduate attributes in the South African Construction Built Environment, and how can these attributes be adapted to meet the needs of Construction 4.0? (Section 4, Article 2).

Article 3, titled: Graduate Attributes' Contribution to Improved Collaboration within Quantity Surveying and Construction Management Curricula in the 4IR era.

What is the relevance of graduate attributes in preparing South African Construction Built Environment professionals to address the needs of the evolving workforce in the context of Construction 4.0? (Section 5, Article 3).

In Section 6 (Part 3), the Epilogue is driven by the question:

Through the Activity Theory perspective, how can the teaching, learning and development of South African Construction Built Environment graduate attributes be transformed to contribute to the world of work?

1.7 RESEARCH APPROACH, DESIGN AND METHODOLOGY

This study followed an explanatory sequential, mixed-methods design within a pragmatic paradigm, integrating quantitative and qualitative data collection and analysis methods.

The research approach was exploratory and iterative, aligned with the three-article format, and focused on evaluating graduate attributes aligned with Construction 4.0 (C4.0) within South African Higher Education Institutions (HEIs). Due to the non-traditional structure of this article-based thesis, the full details of the research design and methodology are elaborated within each article (see Part 2, Sections 3–5). However, this section provides a synoptic overview of the overall design, including the participant selection, data collection methods, analysis techniques, and quality assurance strategies that guided the study.

In general, the literature for this PhD was gathered through a comprehensive and systematic approach, utilising various resources to ensure a broad and relevant collection of scholarly works. Primary tools included EBSCOhost (EBSCO is the abbreviation for Elton B. Stephens Company), accessed via the University of the Free State (UFS) library and Google Scholar. Assistance from UFS librarians was instrumental in refining search strategies and identifying key databases. Focused searches were conducted for high-impact journals and articles aligned with the research objectives. This multifaceted approach ensured a robust foundation of peer-reviewed sources and contemporary studies to support the research. The following section focuses on the research's empirical sections, starting with identifying research groups through a systematic review of the relevant stakeholders.

1.7.1 Selection of research participants

The Quantity Surveying (QS), Construction Management (CM) and Construction Project Management (CPM) professions form part of the South African Construction Built Environment (CBE). [The CM and CPM professions are grouped from time to time to improve the flow of discussions. The SACPCMP governs both professions – defined below]. For perspective, professionals within the SA CBE are regulated by the following professional bodies (Hauptfleisch, 2024:44; Maritz & Siglé, 2016:7; SACPCMP, 2019:2):

- *South African Council for the Architectural Profession, established by the Architectural Profession Act, 2000* (SACAP);

- *South African Council for the Project and Construction Management Professions, established by the Project and Construction Management Professions Act, 2000* (SACPCMP);
- *Engineering Council of South Africa, established by the Engineering Profession Act, 2000* (ECSA);
- *South African Council for the Landscape Architectural Profession, established by the Landscape Architectural Profession Act, 2000* (SACLAP);
- *South African Council for the Property Valuers Profession, established by the Property Valuers Profession Act, 2000* (SACPVP); and
- *South African Council for the Quantity Surveying Profession, established by the Quantity Surveying Profession Act, 2000* (SACQSP).

The study is limited to a QS and CM professions perspective, and subsequently, only HE institutional programmes accredited by the SACQSP and SACPCMP councils were considered through purposeful sampling, a subset of probability sampling (Du Plooy-Cilliers et al., 2014:142). For Articles 1 and 2, the SACQSP lists twelve HEIs offering accredited programmes, while the SACPCMP lists eleven HEIs (SACPCMP, 2023:online; SACQSP, 2023:online). When considering HEIs offering a Bachelor's degree at a National Qualification Framework (NQF) level 7 (Hauptfleisch, 2024:79-81), the number of possible HEI departments is reduced to 8, as depicted in Table 1.1 below. For the proposed international journals and audiences, the international accreditation of these HEIs was also considered, with five being internally accredited (CIOB, 2024:online; RICS, 2024:online). The study proposed a stratified selected sampling process (Du Plooy-Cilliers et al., 2014:139; Taherdoost, 2016:237); however, through collaboration with individual departments at other HEIs, a purposive sampling method proved more practical (Du Plooy-Cilliers et al., 2014:142) to access students and lecturers groups to provide insight into the applicable undergraduate programmes mentioned above. Seven HEIs were selected and approached (Du Plooy-Cilliers et al., 2014:139), of which five took part in the study after the required ethical processes. The following data were retrieved from the two respective councils and summarised in the following table as found on the respective councils' websites (names of HEIs have been left unchanged as retrieved from the websites):

Table 1.1: Summary of Proposed Institutions

SACQSP	SACPCMP	RICS	CIOB
University of the Free State (UFS)	University of the Free State (UFS)	University of the Free State (UFS)	
University of Cape Town (UCT)	University of Cape Town (UCT)	University of Cape Town (UCT)	University of Cape Town (UCT)
Central University of Technology (CUT)	Central University of Technology (CUT)		
University of Pretoria (UP)	University of Pretoria (UP)	University of Pretoria (UP)	University of Pretoria (UP)
Nelson Mandela University (NMU)	Nelson Mandela Metropolitan University (NMMU)	Nelson Mandela Metropolitan University (NMMU)	
University of Johannesburg (UJ)			
University of the Witwatersrand (WITS)	University of the Witwatersrand (WITS)	University of the Witwatersrand (WITS)	University of the Witwatersrand (WITS)
Durban University of Technology (DUT)			

Source: CIOB (2024:online); RICS (2024:online); SACPCMP (2023:online); SACQSP (2023:online)

Article 3: This study is limited to registered Quantity Surveyors, Construction Managers and Construction Project Managers in the South African Construction Built Environment (CBE) and, in particular, individuals who are registered with the SACPCMP and SACQSP as candidates or professionals. The sampling techniques differ from the previous articles due to the size of the population and affiliations. For the first data set, a probability sampling method, particularly a simple random-sampling technique, was proposed through the collaboration of the Professional Councils mentioned above (Du Plooy-Cilliers et al., 2014:140). For the second data set, maximal variational purposeful sampling (Creswell, 2015:77) aligns with an explanatory sequential mixed-methods design (Creswell & Creswell, 2018:218).

1.7.2 Data collection

All studies followed a similar methodological framework and amended according to the practicality of the empirical data sets. Each article utilised distinct, yet interconnected methodologies to explore the integration of Construction 4.0 (C4.0) attributes and

Graduate Attributes (GAs) within South African Higher Education Institutions (HEIs), distinct with the transformative design of the explanatory sequential mixed method (Creswell & Plano Clark, 2018:70).

1.7.2.1 Pilot study

Incorporating a pilot study (see full details in Appendix C) proved useful in testing the planned methodology by using a semi-structured survey questionnaire (Naoum, 2007:44) to distribute to students and lecturers. The primary objective of the survey was to establish a baseline on which the focus-group discussions might be compared; an added advantage of this approach included anonymity toward sensitive questions (Creswell & Creswell, 2018:143; Du Plooy-Cilliers et al., 2014:160; Kumar, 2014:181), particularly towards the background questions of students. The second phase included conducting focus-group discussions with students and lecturers at a specific HEI where Quantity Surveying and/or Construction Management programmes are taught. The main focus of the focus groups included attitudes, behaviours, and preferences towards Construction 4.0 and the students' attributes (Du Plooy-Cilliers et al., 2014:183). For the pilot study, a non-probability sampling method known as convenience sampling was employed at one of the Higher Education Institutions (HEIs) (Du Plooy-Cilliers et al., 2014: 138), targeting students and lecturers to gather essential information that would inform the subsequent three main articles (see Section 2). This approach is commonly utilised in qualitative research within the higher education and social sciences, as it allows researchers to easily access a readily available population to capture perceptions and attitudes, conduct pilot tests for surveys, and formulate hypotheses for future studies (Nikolopoulou, 2023:online; Rahi, 2017:2). According to Golzar and Tajik (2022:72), convenience sampling involves selecting participants based on their accessibility, offering a practical and cost-effective approach for data collection. For the pilot study, convenient sampling was done using one of the HEIs, focusing on students and lecturers to retrieve enough information to inform the subsequent main articles. Focus groups usually comprise eight to twelve participants selected according to the first data set (Du Plooy-Cilliers et al., 2014:182), with the specific number of participants highlighted in the individual Articles. The pilot study informed the subsequent studies' data collection and the formulation of the relevant arguments and focus. Subsequently, including industry stakeholders was deemed premature for the pilot study, which focused on the HEIs' perspective. This process, however, assisted with the improvement and effectiveness of the questionnaires and focus-group discussions (see Part 4; Appendices D–F).

1.7.2.2 Main research

As a result of the pilot study, the three main articles were more focused with a targeted online sampling approach (Wright, 2005:online). Table 1.2 below details the relevant instruments used for each article (also see Figure 1.1, how the data analyses were implemented):

Table 1.2: Summary of Methodological Approaches and Data Collection Instruments: Articles 1–3

Article	Target Group	Phase 1 (Quantitative)	Phase 2 (Qualitative)	Remarks
Article 1	Students	Semi-structured survey questionnaire	Focus-group discussions	Focused on attitudes, behaviours, and preferences towards C4.0 and Gas (see Appendix D).
Article 2	Lecturers	Semi-structured survey questionnaire	Focus-group discussions and semi-structured interviews	This allowed for triangulation and deeper exploration of the lecturer's perspective towards C4.0 and Gas (see Appendix E).
Article 3	Industry Professionals	Semi-structured survey questionnaire	Semi-structured interviews	Interviews replaced focus groups due to practical considerations towards C4.0 and Gas (see Appendix F).

As illustrated in Table 1.2, separate, semi-structured survey questionnaires (Johnson & Onwuegbuzie, 2007:127) were developed for students and lecturer groups (see Appendices D–F). Both have distinct and overlapping questions, and within Article 1's second phase, focus-group discussions were utilised following the protocol (Creswell & Plano Clark, 2018:235) developed from the quantitative results. Article 2, however, utilised both semi-structured interviews and focus-group discussions, although not ideal for triangulation purposes (Flick, 2018:39); however, if the same protocol is used, it may assist in a deeper understanding of the data, according to Flick (2018:45).

Article 3 excluded the focus-group discussions for Phase 2 and relied on a semi-structured survey questionnaire for Phase 1 (Naoum, 2007:44). The survey questionnaire reasonably overlapped with the prior studies' questionnaires (Articles 1 to 2), which allowed for a comparison between the groups of stakeholders (Creswell & Creswell, 2018). Semi-structured interviews proved more practical than focus-group discussions, allowing for maximal variational purposeful sampling (Creswell, 2015:77).

1.7.3 Data analysis, interpretation, reporting and quality assurance

The data analysis followed the explanatory, sequential, mixed-methods approach, sequentially combining quantitative and qualitative data (Creswell & Plano Clark, 2018:215-220). The analysis, interpretation, and reporting are structured to ensure comprehensive statistical and thematic insight coverage. The processes are summarised in Figure 1.1 below.

1.7.3.1 Quantitative data analysis

The quantitative data were analysed using descriptive statistics and supplemented by inferential statistics where applicable. The statistical methods employed across the pilot study and articles were included because they informed the subsequent articles' analyses:

- Means and standard deviations to summarise the data sets (Johnson & Christensen, 2014:527-533; Naoum, 2007:99) [applicable to the pilot study and Articles 1, 2 & 3].
- Spearman's Rank Order Correlation to evaluate the strength of relationships between variables (Du Plooy-Cilliers et al., 2014:214; Pallant, 2020:204) [applicable to Article 3].
- Various significance tests to assess any significant differences in groups and data (Du Plooy-Cilliers et al., 2014:167; Johnson & Christensen, 2014:573) [applicable to the pilot study, Articles 1, 2 & 3].
- Non-parametric testing to relate variables between groups (Creswell & Creswell, 2018:159; Pallant, 2020:183-190) [applicable to Article 1].

- Power analysis towards statistical power of the data (Cohen, 1988:71; Lakens, 2013) [applicable to Article 1].
- Cronbach's alpha (Coefficient alpha) is used to assess the internal consistency and reliability of the scales used (Johnson & Christensen, 2014:170) [applicable to Articles 2 & 3].

1.7.3.2 Qualitative data analysis

For the qualitative component, reflexive thematic analysis was employed to uncover patterns and themes in the data (Braun & Clarke, 2022:13). The qualitative data derived from focus-group discussions and in-depth interviews were transcribed and analysed following Braun and Clarke's (2006:5 & 14; 2013:3-4; 2022:5 & 9) as a reference point. The process involved several steps, applied in all three articles:

- Transcription and data familiarisation (OtterAI, 2024:online; Creswell & Creswell, 2018:194; Saldaña, 2009:92).
- Organising and coding the data into meaningful categories (Creswell & Creswell, 2018:194).
- Identifying themes (Braun & Clarke, 2022:6).
- Interpretation and validation of these themes using a reflexive process to ensure that they accurately represent participants' perspectives (Johnson & Christensen, 2014:308).

1.7.3.3 Interpretation and reporting

The findings were interpreted by comparing the quantitative and qualitative data, ensuring a robust triangulation of results (Flick, 2018:38). The quantitative findings provided baseline statistical data on participants' awareness and perceptions of C4.0 technologies and Graduate Attributes (Sawhney et al., 2020:14; Warier, 2014:19). These were then complemented by qualitative insights, offering a deeper understanding of participants' attitudes, behaviours, and preferences towards the integration of these technologies in educational and professional contexts (Engeström & Sannino, 2010; Rogers, 2003:168).

Each article discusses these interpretations and reports in more detail; however, Figure 1.1 provides an overview of the overarching analysis processes.

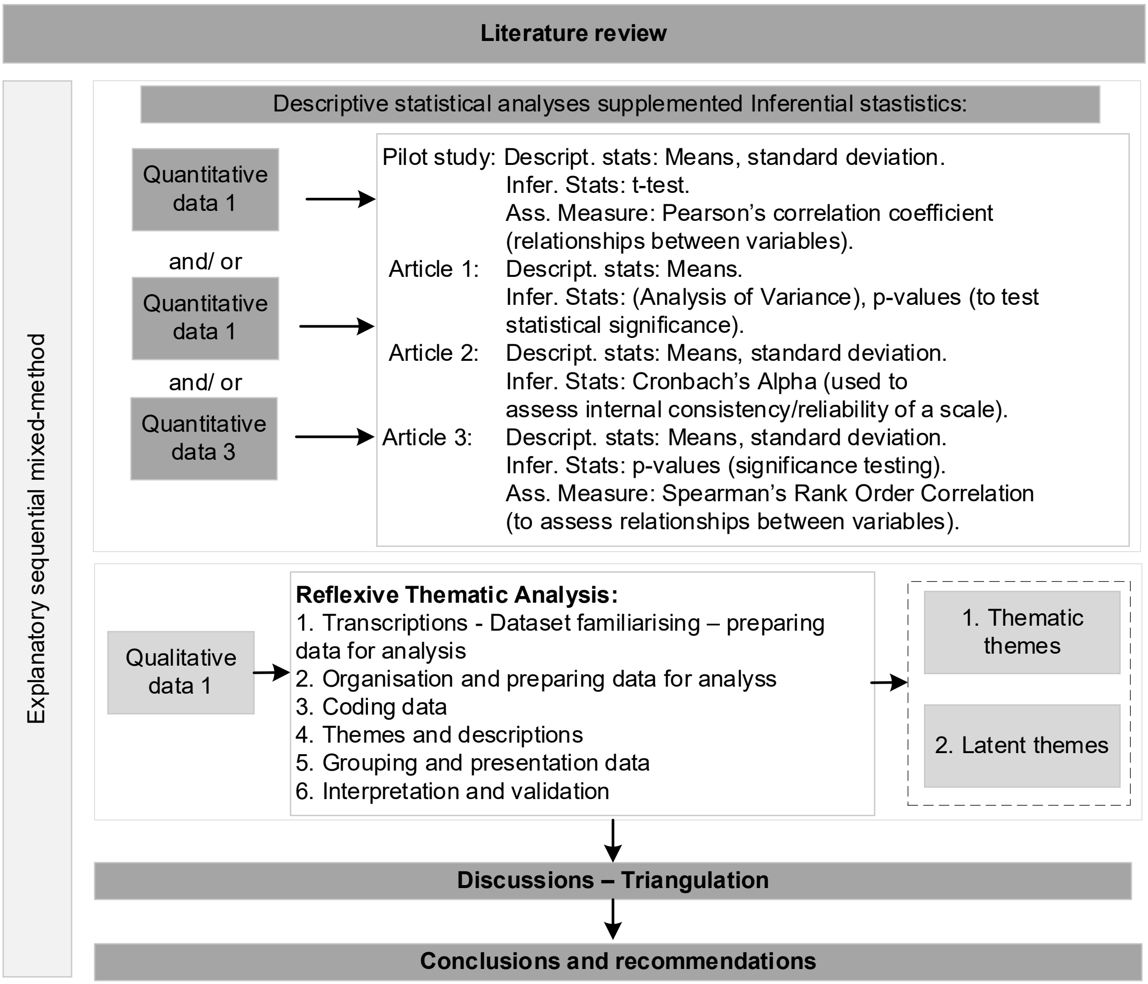

Figure 1.1: Summarised data analysis processes

Source: Braun & Clarke (2022:6); Creswell & Creswell (2018:1940); Johnson & Christensen (2014:518-580)

Ensuring the accuracy and reliability of the findings required careful attention to quality assurance throughout the study, as summarised in 1.7.3.4 below. It was also found that this process provided an added level towards interpretation the data.

1.7.3.4 Quality assurance

Several quality assurance practices were adhered to throughout the study to ensure the findings' reliability and validity. These measures were employed to support the rigour and accuracy of both quantitative and qualitative data:

- The reliability of quantitative data was evaluated through Cronbach's alpha, relevant power analysis and significance measures, where applicable (Lakens, 2013; Johnson & Christensen, 2014:170-171). These methods assisted in consistently measuring the survey items with the same underlying construct across different respondents. Validity was maintained through multiple layers:
  - Content validity was assured by aligning the survey questions with established theoretical frameworks and industry expectations. The survey design carefully integrated key attributes, such as adaptability, critical thinking, and problem-solving (Griesel & Parker, 2009; Van Heerden et al., 2023).
  - Construct validity and reliability scores were considered to evaluate quantitative data. These tests determined the statistical significance between observed data (Creswell & Creswell, 2018:153; Kumar, 2014:181).
- For the qualitative data, in addition to the mixed-method quality measures below, further criteria for assessing the validity of qualitative research were considered, including credibility, dependability, confirmability, and transferability, each contributing to the robustness and trustworthiness of the study's findings (Stenfors et al., 2020:598).
- Triangulation was utilised to enhance the validity of findings, incorporating data from various sources such as surveys, focus groups and interviews. The multi-method approach contributed to robust conclusions, minimising biases and capturing diverse perspectives on the role of C4.0 GAs (Creswell & Plano Clark, 2018:75; Johnson & Christensen, 2014:307).
- Reflexivity played a critical role in maintaining the objectivity of the analysis, which assisted in providing as accurate a reflection of the qualitative data as possible, mitigating the researcher's bias in interpreting the data (Johnson & Christensen, 2014:308). The study further reinforced reflexivity by involving external reviewers

(critical readers) and leveraging peer feedback from the UFS Department of Mathematical Statistics and Actuarial Sciences, contributing to the grounding of the interpretations of the data and minimising preconceived notions or researcher bias.

- Ultimately, the explanatory, sequential, mixed-method design further strengthened the study's quality assurance by combining the quantitative data with the insights from the qualitative data (Creswell & Creswell, 2018:2018).

1.8 SIGNIFICANCE OF THE STUDY

The councils mentioned in 1.7.2, including the SACQSP and the SACPCMP, are overseen by the Council for the Built Environment Construction (CBE) (Maritz & Siglé, 2016:7). These councils play a pivotal role in ensuring the accreditation of HEIs, which is critical for maintaining competitiveness in the South African education sector. Accreditation with these councils fulfils a large competitive requirement in South African HEIs (Hauptfleisch, 2024:43-44). Accreditation criteria set by these councils are primarily driven by industry requirements, with increasing emphasis on addressing the ensuing Construction 4.0 (SACPCMP, 2022:4-9). The stakeholders in the CI must consciously seek out new opportunities and develop the required skill sets and adaptability to adequately respond to the changes triggered by the innovations accompanying the 4IR (Sawhney et al., 2020:46).

I4.0 is a relatively novel phenomenon and research mainly focuses on managerial practices (Newman et al., 2021: 569). Within this context, professionals within the CBE must proactively seek new opportunities and foster the adaptability required to meet these technological challenges, with Koc et al. (2020:474) calling for the CI to keep up with these developments. The Construction Industry (CI) faces an urgent need for graduates who possess technical knowledge and critical soft skills such as problem-solving, communication, and digital literacy (Van Heerden et al., 2023:2). The attributes are necessary for navigating the complexities introduced by digital tools like Building Information Modelling (BIM), the Internet of Things (IoT) and other C4.0 Innovation (Begić & Galić, 2021:7).

The study addresses a gap in the research on teaching and learning within HEI curricula for QS and CM programmes, which require a louder voice towards its contribution towards the CBE's trajectory within the C4.0 developments, in this case, GAs. While many HEIs are increasingly developing specific student attributes to meet industry requirements (Barrie, 2007:439), a limited body of research focuses specifically on C4.0 and its relationship with GAs. Furthermore, as shown in section 1.3 above (see also details in Appendix B), the understanding of the contribution of GAs towards the knowledge, skills, competencies and attributes (KSCA) relationship is underdeveloped within the CBE HE. The research contributes to the body of knowledge by:

- Exploring the alignment between current educational practices and the industry's evolving needs, particularly C4.0.
- Providing insights into how HEIs can recalibrate curricula to improve graduate preparedness with the necessary skills, competencies, and attributes for the rapidly changing CI.
- Offers a framework for integrating technology advancements into QS and CM education, balancing theoretical knowledge with practical, industry-relevant skills [please refer to Articles 2 (Section 4 – Annexure 4.1, Figure 4.5), Article 3 (Section 5.5, Figure 5.5) and the epilogue (Section 6.7)].

Ultimately, the study aims to inform future curriculum development with the South African HEIs, ensuring that graduates are not only employable but also equipped to thrive and become future leaders in the environment shaped by C4.0 and future developments like C5.0 (Marinelli, 2023:2; Van Heerden et al., 2023:3).

1.9 ETHICAL CONSIDERATIONS

Ethical clearance was obtained (Ethical Clearance number: UFS-HSD2022/0241/22) through the University of the Free State's General/Human Research Ethics Committee (GHREC), and I adhered to the UFS researcher's guidelines (see the detail of the original approval in Appendix A1, Gatekeeper letter – Appendix A2 and Extension letter – Appendix A3). Further ethical clearance approvals from the four additional universities are stipulated below (see all ethical clearance approvals are enclosed in appendices):

- University of Johannesburg (see Appendix A4)
- Central University of Technology (see Appendix A5)
- Nelson Mandela University (see Appendix A6)
- University of Cape Town (see Appendix A7 – including general approval, access to students and access to lecturers)

1.9.1 Ethical principles

As a researcher, I adhered to the following ethical principles:

1. Respect for persons, beneficence and justice are constant considerations for the study and identified respondents [BelmontReport 508c (Health & Services, 1979)]. These ethical considerations include the researcher's integrity and are thus related to the researcher's professionalism (Du Plooy-Cilliers et al., 2014:262).
2. This qualitative research respects respondents' rights, needs, values, and desires (Creswell & Creswell, 2018:89-90), such as consent and approvals in line with the research objectives, which we conveyed verbally and in writing, along with written consent and exemption forms (see Appendix G).
3. Data collection findings were reported anonymously via pseudonyms (Creswell & Creswell, 2018:90; McKinney, 2013:42), and all verbatim transcripts were locked via passwords on a computer for privacy and security purposes.
4. Respondents could choose pseudonyms during the discussions, and numeric pseudonyms were allocated during transcriptions.
5. Participants could withdraw from the study at any time by emailing the Principal Investigator.

1.9.2 Data management

A data management protocol was also developed, in line with feedback received through the ethical approval processes, namely:

- Data would be stored by the principal investigator (PI).
- The PI will store one set of the data.
- Data will be stored for five years for reference, quality, and validity purposes.

- Data will be password protected.
- If data have to be shared with the representatives, only transcribed and coded information will be shared.

1.10 RESEARCHER'S POSITIONALITY

As a professional QS and CPM, the concept of the study evolved from the researcher's role as Programme Director at the Department of Quantity Surveying and Construction Management, their confrontation with accreditation audits of their programmes and their recent involvement with a SoTL programme at the University of the Free State:

In conducting this research, it is essential to clarify my position as the researcher, as it directly affects my interaction with participants (students within our programme for whom I hold responsibilities as lecturer and Programme Director, lecturers as peers and industry participants I have worked with before). By recognising the influence of researcher positionality, this section outlines my insider-outsider role, which enables both access and insight but requires critical reflexivity to mitigate potential biases. As described by Holmes (2020:3-4), positionality reflects one's worldview and influences research choices and interpretation of findings. Being an insider to the educational environment allows for deeper rapport with participants, yet it necessitates reflexivity to maintain objectivity and credibility (Yip, 2024:224-225). Reflexivity enables an ongoing assessment of how my role and perspectives shape data collection, analysis and interpretation. Such transparency enhances the study's reliability, aligning with best practices in qualitative research (Holmes, 2020; Yip, 2024).

1.11 CONCLUSION

This chapter provided an overview of the key aspects of this unconventional study by three publishable articles, framing it within the context of the Construction of Built Environment (CBE) and Higher Education (HE) in South Africa, with a specific focus on the integration of Construction 4.0 (C4.0) graduate attributes. Section 1.1 introduced the background and rationale for the study, highlighting the need for educational transformation to the Fourth Industrial Revolution (4IR) and the evolving demands of the construction industry. The problem formulation in Section 1.2 outlined the core challenges higher education institutions (HEIs) face in aligning curricula with C4.0 requirements. In contrast, the research aim and objectives in Section 1.5 clarified the focus on developing graduate attributes necessary for the modern construction workforce.

The conceptual framework presented in Section 1.4, based on the Cultural Historical Activity Theory (CHAT), provides a theoretical lens through which the integration of C4.0 attributes can be evaluated across student, educator, and industry perspectives. The study's significance, addressed in Section 1.8, emphasises its contribution to the body of knowledge on curriculum development in the Quantity Surveying (QS) and Construction Management (CM) programmes.

The research methodology, outlined in Section 1.7, supports the study's explanatory sequential mixed-method design, integrating both quantitative and qualitative data to ensure comprehensive insights into the preparedness of students and lecturers for C4.0 and C5.0 developments. The chapter also identified the importance of reliability and validity of the data analysis, supported by triangulation and reflexivity (Section 1.7.3.4), which is applied in subsequent chapters to ensure rigour and credibility in the findings.

In summary, this chapter laid the groundwork for understanding the critical role of graduate attributes in the CBE within the context of C4.0, providing a foundation for the investigations presented in Part 2, Sections 3, 4 and 5 (i.e. Articles 1, 2 & 3). Section 2 in Part 1 delves into the data collected from the various stakeholders to explore further how these attributes can effectively be integrated into higher education curricula.

Section 2 of Part 1 further provides a short synopsis of the pilot study (see Appendix C for the full pilot study), which played a fundamental role in the approach to the three main articles for this study. Section 2 of Part 1 highlights areas this chapter has not covered, which informed the line of reasoning towards the main articles.

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2
A BRIEF REFLECTION ON THE LITERATURE REVIEW AND PILOT STUDY

2.1 INTRODUCTION

Section 2 of Part 1 focuses on the literature review and pilot study to explore the gap and potential integration of Construction 4.0 (C4.0) attributes within undergraduate programmes in the South African Construction Built Environment (CBE). A literature review in a thesis aims to critically assess and synthesise existing research on a particular topic (In this case: Bridging Construction 4.0 and 5.0 In South African Built Environment Education – see Section 2.2), identifying gaps in knowledge and providing a context for the current study. This background detail aids in establishing the relevance and significance of the research question (see Section 1.4) and provides a rationale for the necessity of the study (see Section 1.8).

The pilot study (for comprehensive details, please refer to Appendix C) plays a critical role in evaluating the research methodology and collecting preliminary data and insights. This foundational step is instrumental in refining the overall approach of the thesis. Both the pilot study and the main research components are vital for situating the research within the existing body of scholarship and illustrating its potential contributions to the field. Furthermore, the pilot study links these attributes with the emerging Construction 5.0 (C5.0) framework, emphasising a collaborative and human-centred industry. Applying an explanatory sequential mixed-methods approach informed by the Activity Theory (AT), the pilot study analyses quantitative data through descriptive statistics and gathers qualitative insights via focus-group discussions. The findings indicate a curricular emphasis on C4.0 competencies while also revealing the necessity of aligning them with C5.0 ideals, particularly in developing soft skills such as problem-solving and critical thinking. A revised curriculum promoting technical and soft-skill development is advocated to prepare students adequately for roles that require technological proficiency, leadership, and collaboration. This work contributes to the ongoing discourse on educational adaptation in response to industry evolution, proposing a framework for harmonising C4.0 skills with C5.0's human-centric approach.

2.2 CONTEXTUAL BACKGROUND

The study started contextualising the research topic using the relevant literature as a foundation, as described in Section 1.7. Through these processes, it was found that the construction industry is undergoing significant transformations driven by technological advancements, regulatory changes, environmental considerations, and shifting market demands (Ahmed et al., 2014:240; Najafi, 2023:online). Higher education institutions must equip future quantity surveyors (QS) and construction managers (CM) with essential competencies to navigate this evolving landscape. Construction 4.0 represents the digital innovation emerging from the construction sector, leveraging advances in cyber-physical systems and digital technologies (Sawhney et al., 2020:3). C5.0, in contrast, focuses on reintegrating human elements into this digitised landscape, highlighting human-robot collaboration (Marinelli, 2023:1).

Within the above context, the Law of Diffusion of Innovation (LDI) provides a valuable framework for understanding the adoption of emerging technologies (Sinek, 2009:129). Rogers (1983:246) classifies individuals who adopt new ideas into five primary categories: innovators, early adopters, early majority, late majority, and laggards.

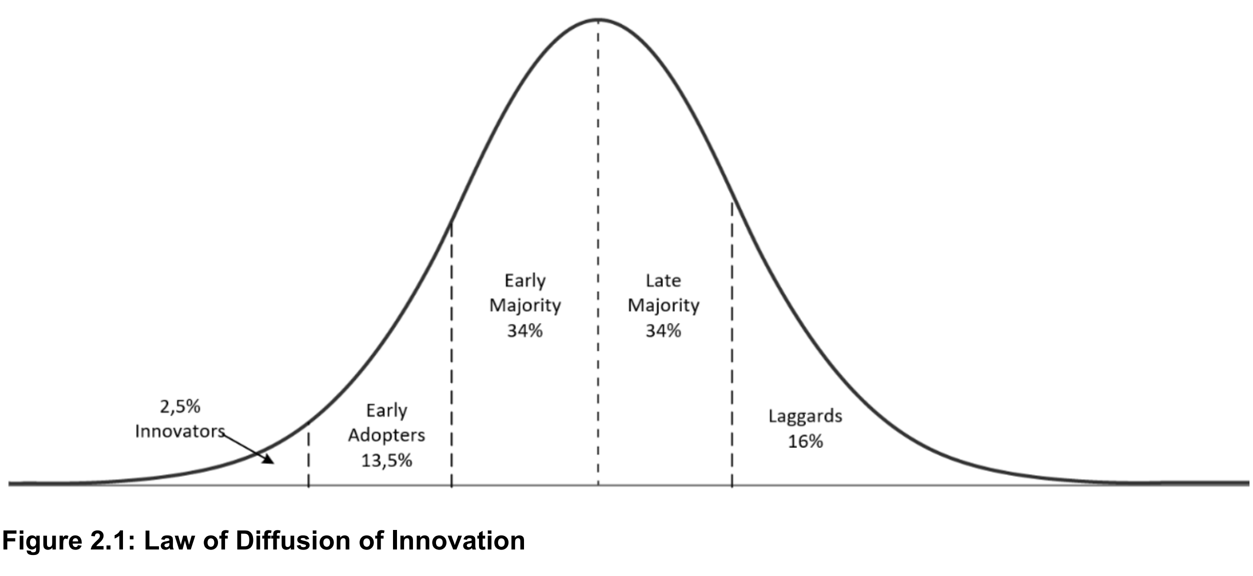

Figure 2.1: Law of Diffusion of Innovation

Source: Sinek (2009:129); Rogers (1983:246)

Figure 2.1 proved fundamental in understanding the inclination within any population towards innovation, which subsequently influences motivation and self-directed learning as a result ('why'). Rogers further highlights that innovation influences the adoption of inventions, adopters, marketing or communication efforts, time, and the prevailing social system (Rogers, 1983:0-11). Furthermore, the fragmented state of teaching, research and professional industries in the built environment poses a challenge within the context of the Fourth Industrial Revolution (4IR) or Industry 4.0 (I4.0) (Sawhney et al., 2020:5). In the initial investigation, Activity Theory was considered because of the methodical examination of the abilities of individuals and the social resources that are accessible to them, which influence a shared goal (Gedera & Williams, 2016:xi).

As referred to in Section 1.2, South Africa faces a significant skills gap compared to other nations due to many socio-economic factors, including infrastructural challenges and a high unemployment rate (Sutherland, 2020:233; Trading Economics, 2022:online). The COVID-19 pandemic has further amplified challenges in higher education, disproportionately affecting vulnerable students (Paterson, 2021). As the industry grapples with the implications of the Fourth Industrial Revolution (4IR), producing graduates with a balance of technical and soft skills becomes increasingly crucial.

With technology constantly changing and evolving, the fundamental focus of the CBE curriculum remains the established industry standards and guidelines which enable technological advancement. *Ultimately, the pilot study aimed to enhance understanding of the pedagogical requirements for realising Construction 4.0. and beyond within South African higher institutions, utilising the evaluation of specific student attributes through the lens of Activity Theory.*

2.2.1 The Scholarship of Teaching and Learning (SoTL) perspective

Higher Education Institutions (HEIs) in the construction sector face pressures from industry stakeholders and professional bodies to adapt to evolving demands (Perera et al., 2011:10). Much has been written about improving teaching practices within this new technological context. For instance, Wagner (2008:67) proposes seven basic requirements for scholars: critical thinking, collaboration and leadership, agility and adaptability, initiative and entrepreneurship, effective oral and written communication, accessing and analysing information, and curiosity and imagination. Saavedra and Opfer (2012:8-13) furthermore propose nine lessons for 21st-century learning to address pedagogy requirements: making it relevant, teaching through the disciplines, developing thinking skills, encouraging learning transfer, teaching students how to learn, addressing misunderstandings directly, treating teamwork like an outcome, exploiting technology to support learning, and fostering creativity.

Equally important is the importance of the professional attributes of academia, which act as the routes that feed the graduate attribute development of students, dubbed the ‘rhizomatic thinking’ of teaching (Dhunpath et al., 2021:126-129), highlighting the mentorship role that lecturers play in the students’ development. Some specific graduate attributes (GAs) proposed to produce employable graduates with adequate social skills include (UFS, 2019:10) academic competence, critical thinking, problem-solving, oral communication, written communication, community engagement, ethical reasoning, an entrepreneurial mindset and digital literacy (see Annexure 3.1 of Section 3). With the development of a pedagogical framework for curriculum, the ‘how’ is asked, while the ‘what’ forms the content (Hill et al., 2021). GAs are concerned about the relationship between the ‘what’ and the ‘how’, delving deeper into the students’ studies, from the generic content towards the profession-specific. Likewise, the focus moves from teacher-centred to more learning-focused as the tenure progresses (Barrie, 2007:452). Likewise, this shift in focus aligns with the University of the Free State's Vision 130, which emphasises a student-centred approach and the promotion of diverse, meaningful learning experiences (UFS, 2022:3).

2.2.2 Integrating Construction 4.0 and 5.0

The implications of 4IR are significant, yet understanding its benefits and challenges is challenging due to the rapid pace of technological innovation (Morrar et al., 2017). Hattingh (2017:21-23) aptly submits that it is vital for industry stakeholders to understand these technological shifts and ensure that relevant skill sets and other adaptive strategies are put in place to survive the industrial turbulence occasioned by the 4IR (Posillico et al., 2023:4169).

The South African CBE has a well-established pedagogical stance that is clearly stated and prescribed within their accreditation councils' accreditation guidelines for HEI programmes (SACQSP, 2015; SACPCMP, 2020). However, the epistemological contribution (Zou, 2008:26) seems to require rekindling with the South African CBE HEI mainly pragmatic approach, focusing on the prescribed knowledge, skills and competencies (SACQSP, 2015; SACPCMP, 2020). These requirements revolve around the standardisation of the Project Life Cycle (PLC) (Project Management Institute, 2016:20; SACPCMP, 2019:5), whereas C4.0 is the convergence of these core requirements to industrial production, cyber-physical systems and digital technologies (Sawhney et al., 2020:5). For instance, Begić and Galić (2021:2) highlight the main drivers of Construction 4.0 as Building Information Modelling (BIM), the Internet of Things (IoT) and Big Data (BD) predominantly within the design phases of the project life-cycle. Ultimately, C4.0 is the evolution of existing processes within the CBE (Sawhney et al., 2020:45), whereas C5.0 envisions keeping the agency of these developments within a human-centric harmonisation (Marinelli, 2023:1). However, the CBE approaches to these challenges are slow because of more complicated industry-interrelated processes, sub-processes, stakeholders, horizontal and vertical commerce, and discipline fragmentation, which limit knowledge sharing (Koc et al., 2020:464). Figure 2.2 illustrates the flow of information between industry, academia and various project phases.

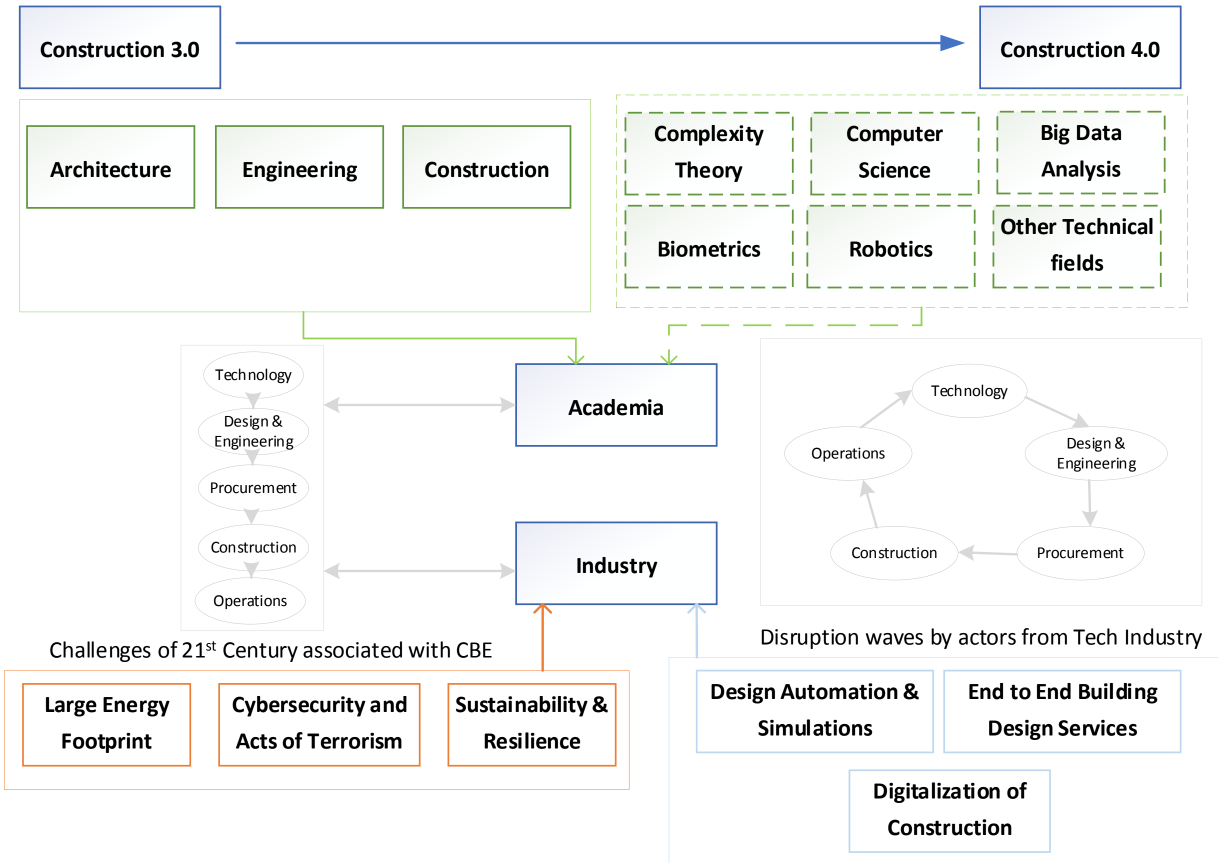

Figure 2.2: The flow of information between industry, academia and various project phases within the C4.0 context

Source: Koc et al. (2020:474).

From the above, it is concluded that understanding the significance of a profession's epistemology concerning the results of its pedagogical frameworks is essential. For instance, law schools may structure their teaching methods around "case dialogue". Simultaneously, pedagogies in the field of medicine may prioritise the significance of engaging in professional practice (Shulman, 2005:22). Transactional disciplines necessitate the exchange of ideas and communication between teachers, students and educators (Cousin, 2009:201-212).

The Fourth Industrial Revolution (4IR) presents opportunities and challenges for the construction industry. While C4.0 focuses on optimising construction practices through technology, C5.0 introduces the need for a human-centric approach, emphasising creativity, empathy, and social engagement. The industry must shift from traditional paradigms towards a holistic education approach encompassing technical proficiency and essential interpersonal skills.

2.2.3 Activity Theory framework

The umbrella term of Activity Theory (AT) is utilised as the primary guiding framework for the interpretation of the complexity of the CI that consists of multiple systems of which the accuracy of one system cannot ignore the other, with no single improvement that can be made to any element in a system that would create a net gain for the system (Orstavik et al., 2015:13-25). Section 6.7 summarises the term 'expansive learning', as shown in Figure 6.3. Within each of the main articles, appropriate synopses for consideration of the particular study were provided; thus, they are not expanded on here. The different layers of the AT became apparent through the journey of the pilot study and the subsequent main articles (see Part 2, Sections 3 to 5, Articles 1 to 3). However, Spinuzzi (2020:26) aptly highlights the following differences between the first, second and third generations of AT:

- 1GAT: Mediation, internalisation, proximal development.
- 2GAT: Activity system, activity structure (mediation of artefacts).
- 3GAT Activity networks, contradictions, rules (cultural-historical activity theory).

The 3GAT provides the framework from which Article 3's consideration of the expansion learning framework (Engeström, 2001:136) could be built. However, establishing the specific CHAT system's object and defining the artefacts under review proved fundamental in considering the multiple systems under review (see Article 2). The pilot study explored the relationship between students and lecturers within a specific departmental setting to assess the perceived systems' accuracy and definitions. According to Hattingh (2017:20-23), in South Africa, many qualifications neglect the skills needed in a rapidly changing work environment shaped by disruptive technologies, emphasising job-specific training rather than entrepreneurial skills. Equally, HEIs and the industry could improve their relationship with the industry (O'Neill et al., 2023:3), building on social scientific theories, such as Vygotsky's concepts of the effect of culture or the tools of intellectual adaptations and proximal development (Mcleod, 2014), to understand how novel thinking is influenced within the South African CBE. From this perspective, the framework for the CHAT systems is shown in Figure 2.3 below:

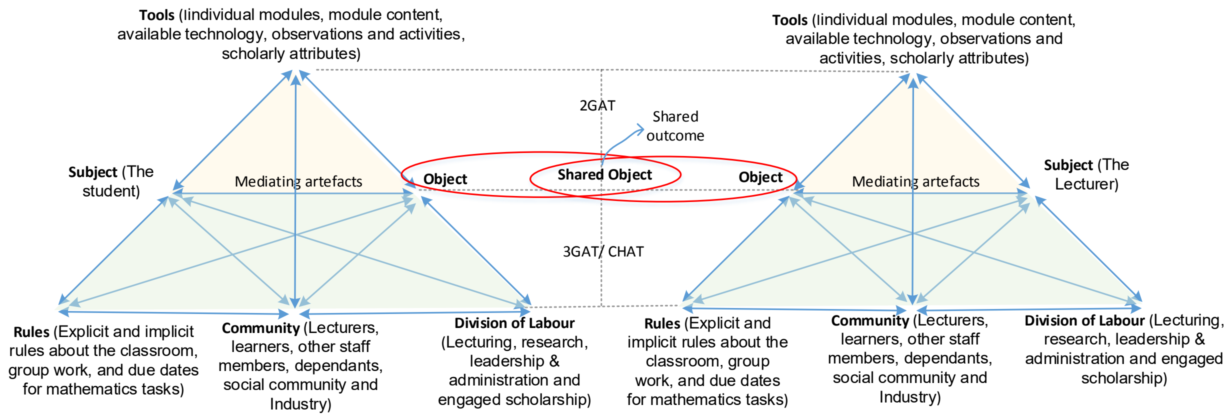

Figure 2.3: Human activity system structure interaction between SA CBE students and lecturers

Adapted from Engeström (2001:35); Fujioka (2014); Jones and Hashim (2014); Naidoo (2014)

By analysing the interactional dynamics between students, lecturers, and educational tools, AT offers insights into the learning environment essential for developing competencies aligned with C4.0 (Gedera & Williams, 2016). Figure 2.3 shows the interaction between two activity systems, indicating that CHAT is an appropriate framework for examining pedagogical practices within HEIs. It allows the evaluation of multiple systems, a prelude for expansive learning (Engeström, 2001:35), as utilised in Article 3 (Section 5). The complexities of the construction industry necessitate a robust theoretical underpinning that acknowledges multiple pathways to achieving educational outcomes.

2.3 PILOT STUDY: METHODOLOGY AND RESULTS

The applied methodology and the write-up of the pilot study informed the practical approach to presenting sequential data collection and interpretations, addressing the challenges posed by article formats and word limits. Creswell and Creswell (2018:40) emphasise the importance of consistent heading levels and structured presentation to enhance readability and coherence. Within the explanatory sequential mixed-method approach, it was found more practical in certain instances to omit intervening paragraphs in the data presentation sections, as the sequence had already been thoroughly explained in prior sections.

2.3.1 Research methodology

The pilot study employed an explanatory sequential mixed-method approach (Jacobs & Cornelius, 2022:111) to gather data from students and lecturers at a selected HEI in the South African CBE. The study aimed to assess the extent to which graduate attributes (GAs) prepare students for Construction 4.0 and subsequently support or consider C5.0 considerations. [From this baseline assessment, it was foreseen that practicalities would be identified in the subsequent investigations on the extended group of stakeholders, which would include registered QSs, CMs and CPMs, as highlighted in Section 1.7.1.]

The quantitative phase incorporated a structured survey (Naoum, 2007:103), administered to 80 students and 7 lecturers, yielding 42.5% and 100% response rates, respectively. Descriptive statistics were applied to analyse the data (Naoum, 2007:73).

The qualitative phase incorporated focus-group discussions with lecturers and students, respectively, to explore perceptions of curriculum relevance to C4.0 (Du Plooy-Cilliers et al., 2014:183). Thematic analysis (TA) was used to identify significant themes from the data (Maguire & Delahunt, 2017:3353).

2.3.2 Findings

In all three articles, the quantitative data are presented before the qualitative data, which are in line with the explanatory sequential mixed-method design Creswell and Creswell (2018:218). The subsequent quantitative and qualitative data of the pilot study are presented.

2.3.2.1 Quantitative results

The survey revealed that most students identified critical thinking and problem-solving as vital to their preparedness for C4.0. However, discrepancies emerged between student and lecturer perceptions regarding the importance of specific attributes, with students placing less emphasis on academic competence than lecturers. The data suggested that lecturers engage effectively with students on module content, particularly at the 2GAT level. However, understanding students' needs could enhance engagement and skill acquisition. HEIs in competency-based education could improve outcomes by supporting lecturers in evaluating students' progress and incorporating foundational material to improve the guidance of students in navigating complex curriculum demands. [This observation formed a fundamental aspect of the investigation in Article 1 (Section 3), where it was further tested across other HEIs and expanded to explore potential solutions, including whether it represents an issue that requires intervention.]

2.3.2.2 Qualitative results

Focus-group discussions highlighted the necessity for HEIs to cater to diverse student needs and adapt teaching methods that integrate C4.0 principles within traditional frameworks. Additionally, the use of 'tools', adherence to teaching guidelines, and recognition of GAs could foster increased student interest in C4.0 learning. [These insights also proved valuable for subsequent studies, emphasising the importance of interactions both within activity systems and between them, while underscoring the significance of observing the activity itself.]

2.4 DISCUSSION

The pilot study findings (see Sections 2.3.2.1 to 2.3.2.2) indicate a positive momentum towards integrating C4.0 attributes in South African construction education. However, a greater emphasis on soft skills and interpersonal competencies is required to prepare students comprehensively for the complexities of C5.0. The synchrony between the objectives of HEIs and the requirements of the construction industry appears to be a key area for development. Educators must embrace pedagogical strategies that prioritise technical knowledge and the social and creative competencies necessary for success in an evolving landscape. Even though South African construction undergraduate programmes may not focus heavily on C4.0 preparedness, generic GAs encourage the pedagogical development necessary for the field. The data aligned with existing literature [please refer to Appendix C (Pilot Study), Discussion Section)], suggesting that GAs provide a foundation for curriculum design that supports students' transition into adaptable graduates for C4.0 and the evolving C5.0 frameworks.

2.5 CONCLUSION AND RECOMMENDATIONS

To respond effectively to the demands of C4.0 and 5.0, South African HEIs must critically reassess their curricula. Integrating a balanced curriculum, fostering both technical and soft skills, is paramount for producing employable graduates [refer to Appendix C (Pilot Study), Concluding section)]. Future research should expand beyond this pilot study to encapsulate a broader range of institutions and stakeholders, enriching the understanding of pedagogical adaptations necessary for the South African CBE. The subsequent recommendations were made by understanding the following flowchart process.

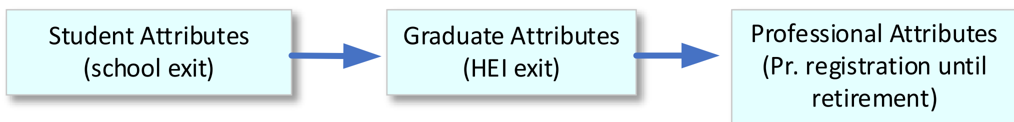

Figure 2.4: Understanding of the attribute acquisition during a QS, CM and CPM's professional career

- Curriculum Revisions: HEIs should develop curricula that fortify both technical skills and interpersonal attributes aligned with C4.0 and C5.0 requirements.
- Industry Collaboration: Establish partnerships with industry stakeholders to expose students to real-world applications.
- Continuous Research: Encourage ongoing research initiatives to refine pedagogical frameworks in response to technological advancements and workforce demands.

This chapter contributes to the dialogue on educational reform necessary to prepare the South African construction workforce for future challenges and opportunities [please refer to Appendix C (Pilot Study), Recommendation section)], potentially laying the groundwork for a more adaptive and integrated educational approach. Part 2, with special emphasis on Articles 1–3, includes the specific stakeholders' consultations as depicted in Section 1.

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PART 2

THREE MAIN RESEARCH ARTICLES

3
ARTICLE 1: FOSTERING GRADUATE ATTRIBUTES FOR JUSTICE IN SOUTH AFRICA'S CONSTRUCTION EDUCATION CURRICULUM AMID THE FOURTH AND FIFTH INDUSTRIAL REVOLUTIONS

Proposed Journal: *Journal of Construction*[3]

ABSTRACT

As the discourse around the Fifth Industrial Revolution (5IR) gains momentum, higher education institutions grapple with the implications of this paradigm shift while still adapting to the Fourth Industrial Revolution (4IR). Using South Africa as a reference point, this study examines Quantity Surveying (QS) and Construction Management (CM) programmes to bridge the gap between educational practices and the Graduate Attributes (GAs) needed for success in Construction 4.0 (C4.0) and the emerging Construction 5.0 (C5.0). This research utilises the Cultural Historical Activity Theory (CHAT) framework to explore how current curricula integrate C4.0 characteristics. Through an explanatory sequential approach, this study combines quantitative surveys and qualitative focus groups to assess students' perceptions and experiences across five accredited South African Higher Education Institutions (HEIs). The findings revealed an increasing student awareness of the value of industry-specific GAs, underscoring the need for an integrated educational framework that effectively integrates practical and theoretical components. Additionally, the research highlights the role of community engagement – both industry and peer participation – in enriching learning experiences, particularly in the evolving post-COVID-19 landscape. This study advocates a learning-centred curriculum design that fosters active involvement and practical application, ensuring that graduate education remains aligned with the dynamic demands of the C4.0 and C5.0 sectors.

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[3] https://journalofconstruction.com/

Keywords: Construction Education Transformation, Construction 4.0, Construction 5.0, Cultural Historical Activity Theory (CHAT), Curriculum Justice, Fourth Industrial Revolution (4IR), Graduate Attributes.

Notes: The Construction Industry (CI) and Construction Built Environment (CBE) terminology are used interchangeably, with CI primarily denoting the global viewpoint, while CBE pertains specifically to the South African context from a Quantity Surveying and Construction Management viewpoint.

3.1 INTRODUCTION

The swift advancement of technology (Nti et al., 2023), particularly within the context of the Fourth Industrial Revolution, has ignited significant discussions and research. A major concern in the Construction Built Environment (CBE) is the sector's ability and capacity to guide and apply technological developments and innovations effectively (Khuzwayo & Bernhardt, 2022; Koc et al., 2020). A study by McCord et al. (2023:19) highlights the need for construction education to improve preparing students for industry demands (e.g. by focusing on both technical, interpersonal skills and professional attributes such as attention to detail and time management). This study also suggests that shifting to outcomes-based learning goals in Construction Management and Quantity Surveying education that provides flexibility to implement innovative educational strategies (McCord et al., 2023:19). Aligning with the development of GAs as a focal point within student-centred teaching and learning (T&L) developments within the Fourth Industrial Revolution (4IR) (UFS, 2019:8-9), where adaptability and relevant skill sets are increasingly vital for future professionals. However, the South African socio-economic circumstances play a significant role. Many students rely on the National Student Financial Aid Scheme (NSFAS) to access higher education, but this funding is often insufficient due to increasing costs and limited resources (Mbaleki & Mbodila, 2023:21-23). Notwithstanding, the Construction Built Environment (CBE) itself has its own challenges, losing 106 00 jobs in the first quarter of 2024 within an economy showing a 59.7% unemployment rate for people aged 15 to 24 (South Africa, 2024).

Given these economic hardships, engaging students' motivations is crucial for promoting effective learning, particularly within disciplines such as QS and CM, where practical, hands-on experience is vital (Khuzwayo & Bernhardt, 2022:4). This is supported by Sparkling and Sengupta (2022:652-656), who illustrate that self-determination students can enhance student engagement by fostering autonomy, competence, and relatedness. This is particularly relevant in South Africa, where fostering student motivation through clear learning objectives and supportive teaching strategies to foster engaged students are essential for promoting learning (Fink, 2013:69, 70). As Sinek (2009:46) aptly says, "People do not buy what you do; they buy why you do it."

Additionally, C4.0 refers to the integration of digital technologies into construction processes, such as building information modelling (BIM), robotics, and the Internet of Things (IoT) (Building Transformations, 2023:online), which might not be at the top of some students' agenda. However, C4.0 can improve the construction industry's productivity, efficiency, and sustainability and create new job opportunities (Sawhney et al., 2020). Subsequently, critical attributes of C4.0 include real-time data, collaborative working, automation, prefabrication and modularisation, and sustainability (Statsenko et al., 2022:9-10). Therefore, one of the key responses of Higher Education Institutions (HEIs) to the Fourth Industrial Revolution (4IR) has been the strategic development and promotion of Graduate Attributes (GAs), dovetailing well with the human capital imperative (Mansour et al., 2023:1460). This strategic GAs readiness encompasses essential skills such as critical thinking, problem-solving, digital literacy, and adaptability to prepare students for the rapidly evolving demands of the modern workforce (Gleason, 2018:3; Griesel & Parker, 2009:1; Singaram et al., 2023:1-3). Consequently, C4.0 developments demonstrate that the Construction Industry (CI) is rapidly evolving (Aghimien et al., 2019:349-356). Thus, the necessity of this study is to explore how South African CBE students perceive the significance and relevance of attributes of Construction 4.0 (C4.0) and the emerging trend of emphasising the human factor in these advancements through [Construction 5.0 (C5.0)] (Marinelli, 2023:1).

When evaluating pedagogical frameworks for Quantity Surveying (QS) and Construction Management (CM) programmes, the Cultural-Historical Activity Theory (CHAT) framework offers valuable insights into how students engage with their learning environments and how they mediate artefacts to achieve specific learning outcomes (Spinuzzi, 2020:5). By analysing the mediation of learning tools within this context (Jones & Hashim, 2014:2), CHAT facilitates a deeper understanding of students' learning experiences related to the attributes of Construction 4.0 within the built environment. Furthermore, HEIs in South Africa’s CBE sector face pressures to align with competency-orientated industry standards set by accreditation bodies like the South African Council for the Quantity Surveying Profession (SACPQSP) and the South African Council for the Project and Construction Management Professions (SACPCMP). These bodies require an accredited degree at NQF level 7, followed by five years of relevant work experience for professional registration (SACPCMP, 2022:online; SACQSP, 2022:online). With only three years of study available, the pedagogy must ensure that graduates acquire the necessary technical skills and interpersonal abilities to meet industry demands (Pulitz, 2023:28-61). This alignment between education and professional practice enhances employability and prepares graduates for the job market and the pathway toward professional registration (Normand & Anderson, 2017).

Subsequently, this study employs an inductive approach (Creswell & Creswell, 2018:38), centring on students' first perceptions and experiences regarding GAs and the development of Construction 4.0 (C4.0) Attributes to inform C5.0 developments. It addresses the fundamental question: How do university QS and CM students perceive and experience the learning of GAs, and how do these perceptions assist in their preparation for C4.0 in establishing a human-centric foundation for the developments associated with C5.0? By evaluating and measuring students' perceptions and experiences, the study explores how HEIs in the CBE can address these challenges by integrating C4.0 and C5.0 attributes into CBE curricula, viewed through the lens of CHAT. The study employed an explanatory sequential mixed-method design (Creswell & Creswell, 2018:218) to address the gap in the development and placement of CBE C4.0 attributes. The study was limited to third- and fourth-year QS and CM students from five accredited HEIs in South Africa. It is assumed that by actively listening to the voices of relevant parties, such as students (Bitzer & Withering, 2020:14), we can align the development of Graduate Attributes with Construction 4.0 technologies better, while also incorporating the human-centred focus of Construction 5.0, fostering a balanced approach to education that values both technological proficiency and human well-being (Waks, 2015:9; Chiramba & Ndofirepi, 2023:64).

The literature review explores critical themes relevant to transitioning from C4.0 to C5.0 within the South African CBE education context. The section examines the advancements of C4.0 technologies, the evolving GAs necessary for industry alignment, and the emerging focus on the human-centric principles of C5.0. By linking these themes, the review aims to provide an understanding of the educational and industry-specific challenges and opportunities by first dissecting the advent of C5.0, before defining GAs and their role in these developments, before providing the necessary background of the cultural-historical activity theory (CHAT) used as the lens of interpreting the data within the study. This structured approach supports the study's focus on integrating graduate attributes within higher education curricula to meet the construction sector's dynamic demands and address this article's central research questions.

3.2 THE ADVENT OF CONSTRUCTION 5.0

The Fourth Industrial Revolution (4IR) and Industry 4.0 (I4) are important concepts driving technological advancements across many sectors, including construction. Industry 4.0 is characterised by cyber-physical systems (CPS), which blend the physical and virtual environments and accelerate the adoption of innovations like digitisation, automation, and human-machine interaction (Sawhney et al., 2020:3; Lu, 2017:1-10; Ślusarczyk, 2018:236).

Construction 4.0 (C4.0) signifies a transformative change in the construction sector through digital technologies like Building Information Modelling (BIM), Artificial Intelligence (AI), robotics, and the IoT (Ashworth & Higgs, 2023:20). These technologies promise increased efficiency, productivity, and sustainability improvements, departing from traditional construction methods (Sawhney et al., 2020:12). Nevertheless, the construction industry is frequently viewed as stagnant due to the slow adoption of innovative practices (Orstavik et al., 2015:48). While Construction 5.0 (C5.0) remains an evolving concept worldwide, it aims to overcome the limitations of Construction 4.0 (C4.0) by re-emphasising the human dimension. This human dimension includes promoting collaboration between humans and machines, enhancing well-being, and prioritising environmental responsibility (Marinelli, 2023:2). Most C4.0 technologies are primarily utilised in the preconstruction phase (digital phase), influenced by traditional practices and a scarcity of skilled professionals C4.0's value lies in its data intelligence, enhancing automation and digitisation, thus improving production efficiency during construction (Begić & Galić, 2021:16).

In South Africa, this shift underscores the need for HEIs to equip students with the underpinning technical skills essential for C4.0 (processes on which new technologies are based) and the adaptability, creativity, and ethical awareness necessary to meet the future demands of C5.0 (human-centric approach and socio-economic reality, within the QS & CM perspective). The groundwork established by C4.0 will act as a launchpad for C5.0's inclusive, human-centred approach, calling for curriculum alignment to reflect these evolving priorities.

3.3 GRADUATE ATTRIBUTES FROM A QS & CM PERSPECTIVE

With the foundation of C4.0 mentioned above, the springboard for C5.0's inclusive, human-centred approach underscores the need for curriculum alignment to integrate these developing priorities with particular emphasis on GA of QS and CM. Accreditation bodies in the QS and CM programmes emphasise a competency-based education, focusing mainly on knowledge, skills and competency (RICS, 2019:5). Generic Abilities (GAs) are, however, integral to the mediation of knowledge, skills, competencies, and attributes (KSCA) (Warier, 2014:19). Here, attributes encompass the attitudes and behaviours that higher education institutions (HEIs) endorse for their graduates (Barrie, 2004:262; Griesel & Parker, 2009:17-18). The primary goals of GAs are to enhance employability and to prepare students for lifelong learning and adaptability, which are essential components of a university degree (Anderson, 2017:4-18; Hazelkorn et al., 2018:6). This implies that the alignment between course content and GAs is required for students to gain the KSC needed for the future in C4.0, further implicating a grounded understanding of these terms. For instance, the World Economic Forum (WEF) identified eight essential ‘skill groups’ for the 2025 job market, categorised by their relative importance (WEF, 2020:36): problem-solving, self-management, working with people, and technology use, that encompass critical thinking, creativity, collaboration, adaptability, and the increasing significance of social skills. The WEF further emphasises integrating social and emotional learning (SEL) into educational technology products to cultivate these abilities and prepare students for future job market demands (WEF, 2016:5), indicating how skills can develop and influence attitudes and behaviours (GAs).

Notwithstanding these ‘skills’, Quantity Surveying and Construction Management degrees in South Africa, or a combination of both, provide pathways to professional registration and the job market (SACQSP, 2022:online; SACPCMP, 2020:39). While national diplomas and other routes exist (CBE, 2000), this study focuses on the main routes to professional registration. Upon completing an NQF7 level degree, graduates can register with their respective councils to acquire the experiential learning necessary for proficiency tests and professional certification (SACQSP, 2022:online; SACPCMP, 2020:39). This process typically requires mentorship by a professionally registered person in the applicable field to mentor a candidate through the Assessment of Professional Competence (APC) process (SACQSP, 2022:6-9). Developing graduates through HEIs is crucial in fostering the lifelong competencies required for the construction industry (SACPCMP, 2020:39), allowing for this mentorship period. However, the time frame to influence students’ professional trajectories during students’ studies effectively is limited. HEIs, furthermore, face diverse demands from the industry, academia, and regulating councils, creating tensions in balancing education and training (Perera et al., 2011). Clear and well-defined criteria from regulating councils are fundamental in facilitating this balance. For instance, the Royal Institute of Chartered Surveyors (RICS) policy for global accreditation processes outlines mandatory, core, and optional competencies linked to specific proficiency levels (RICS, 2019:5). These guidelines focus on core knowledge areas (SACQSP, 2014:2), skills and competency (SACPCMP, 2020:18; RICS, 2019:4-5; CIOB, 2018:4-5) that provide structure for HEIs to align their curricula with practical requirements and industry standards. Subsequently, the strategic development of graduate attributes to align with these criteria will ensure that graduates are equipped to meet the future needs of the workforce in the context of Construction 4.0.

3.4 GRADUATE ATTRIBUTES AS A START TOWARDS C4.0 ATTRIBUTES

The concept of GAs originated from concerns about student quality in South African Higher Education Institutions (HEIs) (Griesel & Parker, 2009:1; Butler-Adam, 2018:1) and has since evolved to address technological advancements and socio-economic inequalities, enhancing graduate employability (UFS, 2019:2-3). Essential GAs are underpinned by continuous learning, including technical ability, communication, intellectual capabilities for rapid conceptualisation and logical argumentation, applied workplace skills, and personal skills such as identity, teamwork, and cultural appreciation (Griesel & Parker, 2009:17-18; Dhunpath et al., 2021:127). GAs also underscore Professional Attributes (PAs) and are crucial for graduates' professional development (Dhunpath et al., 2021:140). Embedding GAs in curricula enhances reflective teaching and aligns education with employer needs (Mashiyi, 2015:186-195), while Barrie (2006:224; 2007:445) presents a model of cooperative education emphasising a shift from traditional teaching methods to a more integrated, learner-centred approach, focusing on the transmission, transaction, and transformation within education to improve alignment with graduate attribute acquisition. Considering this student-centred approach, many authors highlight key aspects in the advancement of teaching and learning practices that influenced the study, as summarised in Table 3.1:

Table 3.1: Key aspects in the advancement of teaching and learning

a)	Transitioning to University	Gibbs and Malcolm (2017:1-2) focus on the transition to university, emphasising identity, expectations, and the need for supportive structures to alleviate isolation fears.
b)	Emphasis on digital literacy	Jackson (2017:151) points out the emerging emphasis on digital literacy alongside traditional academic competencies, urging for clearer definitions and curriculum integration.
c)	Graduate adaptability and transferable skills	O'Donnell et al. (2017:35-36) also highlight the necessity of graduate adaptability in modern workplaces, advocating for refining transferable skills and attributes through experiences and meta-skills like self-awareness.
d)	Importance of personal, technical, and professional skills	Graduates require three main categories of proficiency: Personal Attributes, Technical Skills, and Professional Skills (McCord et al., 2023:12).
e)	Enhancing self-awareness and career management	O'Riordan and Morrison (2017:39) stress the importance of self-awareness for graduates' potential, recommending credit-bearing modules to enhance employability and career management.
f)	Resilience as a transformative attribute	Shimi and Manwaring (2017:73-74) discuss resilience as a transformative graduate attribute that is crucial across all aspects of student life and curriculum integration.
g)	Empathy and participatory roles	Normand and Kingsley (2017:1, 6 & 13) suggest empathy as a key graduate attribute, evolving from traditional client engagement to inclusive and participatory roles.
h)	Ethical engagement	Martin (2017:1, 12) explores ethical considerations in diverse HEI settings, promoting critical and creative engagement with ethical dilemmas.
i)	Defining "Graduateness"	Ramsay and Monk (2017:133-136) define "Graduateness" as encompassing essential skills, knowledge, and professional attributes required in the workplace.
j)	Reflexive thinking and collaborative practices	Manwaring (2017:186-187) emphasises the role of reflexivity in academia, advocating for the development of reflexive thinking and collaborative practices among lecturers to foster empowered and engaged learners.
k)	Real-world learning applications through work placements	Lay et al. (2008:1 & 6) discuss the real-world application of learning through work placements, highlighting the discrepancies between academic preparation and workplace realities.
l)	Backward design and constructive alignment	The concepts of backward design and constructive alignment are essential to the proposed learning-centred way of teaching and designing courses (Davis & Arend, 2013:xi).

With all of these complexities surrounding the advancement of teaching and learning practices through a student-centred approach, the following section investigates the potential of GAs to simplify the alignment of curricula for QS and CM programmes.

3.4.1 The justification for integrating GAs into curricula

Notwithstanding 3.4's introduction, integrating GAs into curricula is complex due to the diverse needs and expectations of the job market, HEIs, students, and communities. To provide context, Figure 3.1 was developed to summarise the factors contributing to the graduateness of QS and CM students within the study context that assist in summarising and understanding the criteria under investigation.

Maxwell and Armellini (2019:83) emphasise the significance of graduates as future ambassadors or “changemakers” within their professions. At the same time, Staunton et al. (2021) propose a three-phase implementation model for GAs: synthesising from practice, co-creating from research, and growing a community of practice, emphasising the link of HEIs with industry. Feedback, programme review, alignment with industry standards, and quality assurance are critical for successful GA integration (Staunton et al., 2021). According to Barrie (2007:440), there are four levels of GAs: Precursory (basic skills from high school), Complement (all-round skills), Translation (practical application of knowledge), and Enabling (intellectual and personal development). An effective curriculum design should align with programme objectives and clear goals, assessments, and feedback mechanisms, informed by central GAs for coherent programme and module mapping (Fink, 2013:69, 70). This approach ensures that educational content (‘what’) and pedagogy (‘how’) are effectively planned and aligned with industry requirements (Hill et al., 2021:54). A vital challenge in education is addressing the underlying reasons for learning, which is essential for student learning, the ‘why’ (Sinek, 2009) that aligns with self-determined learners (Sparkling & Sengupta, 2022:658). Fink (2013:5) mentions that students often lack self-direction and motivation due to the vague relevance of their studies. At the same time, Vygotsky’s concept of the zone of proximal development highlights the importance of scaffolding in pushing learners beyond their current capabilities (Stewart, 2021:18). GAs can assist in navigating university education by clarifying the purpose (goal) behind tasks and their contribution to students’ development. Lecturers can enhance learning outcomes by aligning teaching strategies with student goals, engaging materials, relevant technologies, and practical assessments (Davis & Arend, 2013:ix). This approach connects GAs with influential teaching philosophies, promoting skill and knowledge development across critical areas. Figure 3.1 provides a conceptual framework for these diverse contributors within the tenure of the undergraduate QS and CM student [T&L stands for teaching and learning, while some authors suggest learning and teaching (L&T) to illustrate the mindset change towards a learning-centred mindset (Angelo, 2021)]:

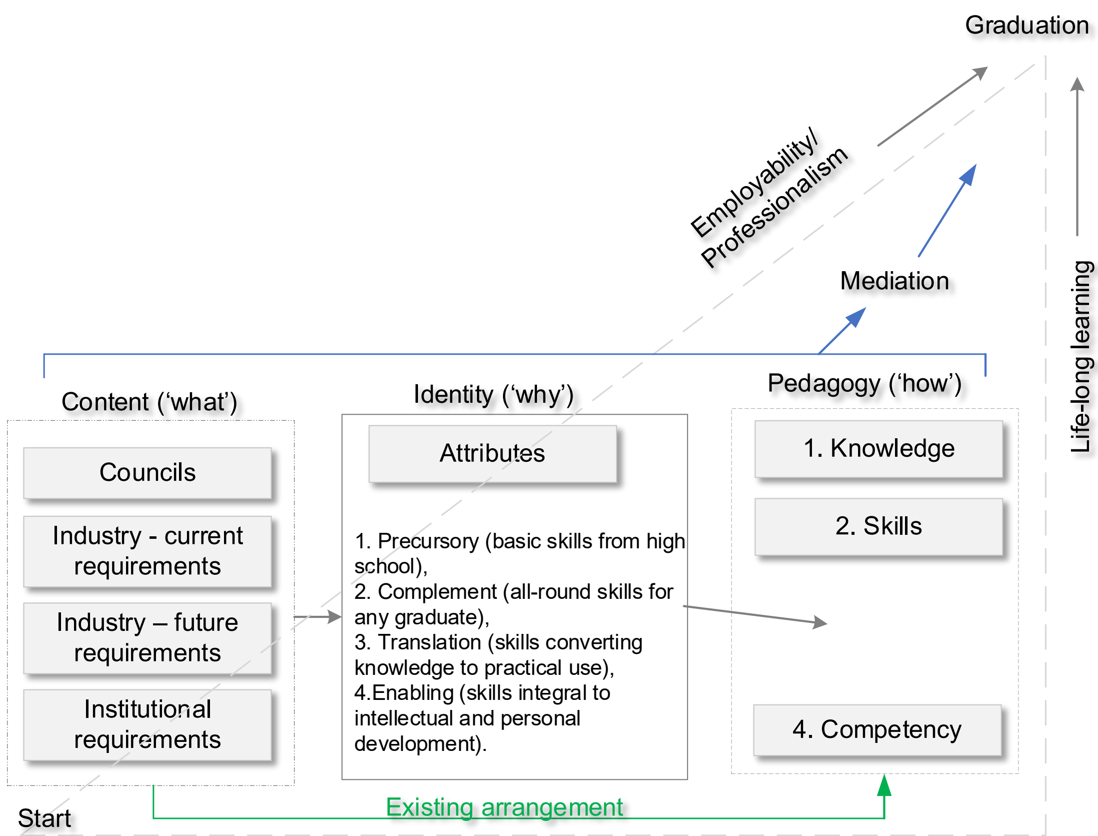

Figure 3.1: Existing QS & CM T&L vs proposed GAs L&T focus incorporation

Source: SACQSP (2014:2); SACPCMP (2020:18); RICS (2019:4-5); CIOB (2018:4-5); Warier (2014:19); Barrie (2007:440).

From Figure 3.1, it is seen that the integration of GAs within educational programmes, using principles like Constructive Alignment (CA), not only addresses student motivation ('why'), lecturer pedagogies ('how'), and industry demands ('what'), but also ensures a holistic and coherent approach to education. This alignment enhances students' ability to apply their knowledge and skills in professional contexts, making Activity Theory a suitable framework for examining and enhancing this educational synergy (Gedera & Williams, 2016; Garraway, 2021:228). This context provides the necessary background on which the CHAT may be applied.

3.5 APPLYING CULTURAL-HISTORICAL ACTIVITY THEORY (CHAT), BASED ON THE ACTIVITY THEORY (AT), TO CONSTRUCTION 4.0 EDUCATION

The Activity Theory (AT), originating from Soviet psychologists Vygotsky and Leont'ev – later expanded by Engeström – aids the comprehension of human activities as systemic interconnected and contextually socially situated processes in society (Jones & Hashim, 2014:2). Thus, AT (see also Figure 3.2) is particularly relevant in educational settings, such as QS and CM undergraduate programme, as it elucidates the interactions between individuals (e.g. students and/or educators), the tools they use (e.g. digital technologies, textbooks, etc.), and the community (e.g. educational institutions, the construction industry) within which learning occurs (Engeström, 2001; Spinuzzi, 2020:2). The AT has evolved through three generations, but only the 3rd generation is relevant for this study [i.e. 3GAT, also known as Cultural-Historical Activity Theory (CHAT)], that emphasises activity networks, contradictions, and rules (see Figure 3.2), which are applied in this research (Spinuzzi, 2020:3), by evaluating the existing artefacts' mediation to produce QS and CM graduates.

This study leverages the CHAT framework to explore the complex social dynamics of undergraduate CBE programmes (i.e. CM and QS). The interdisciplinary approach draws from organisational sociology and cultural psychology, highlighting the collaborative efforts of participants to effect change, making it suitable for studying educational complexities (Engeström, 2001). Furthermore, CHAT highlights networks of activity and pinpoints contradictions within organisational systems, focusing on symbolic artefacts like textbooks and software facilitating learning (Otrel-cass et al., 2016:40). Following an inductive line of reasoning (Creswell & Creswell, 2018:64), this study aims to establish the status quo of students' perspectives on existing pedagogical frameworks rather than testing proposed theories (Gedera & Williams, 2016:3). AT also helps to understand the existing status of curricula and the pathways taken to reach this point, contrasting with predicting future events (Hammond, 2023:personal interview). The literature review indicates that limited time is available for students during their undergraduate tenure to equip them with the necessary skills, knowledge, competencies and, ultimately, graduate attributes that translate into their professional development. Subsequently, the definition of artefacts, particularly the object (objective) of the programmes under review, is critical. The following categories of activities (see Figure 3.2) are assumed before continuing with the evaluation of the mediation of the artefacts:

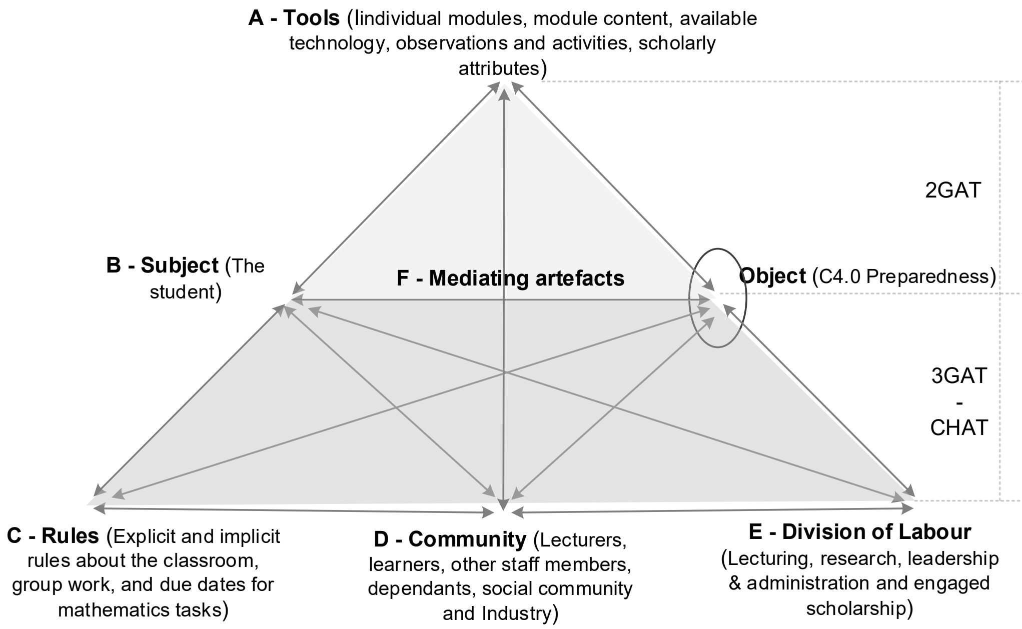

Figure 3.2: Human activity system structure

Sources: Adapted from: Engeström (2001:135); Jones and Hashim (2014:3 & 7); Crawford and Hasan (2006:6-8), Spinuzzi (2020)

As illustrated in Figure 3.2, CHAT in Construction Education enables educators to delineate the intricate interplay among students (subjects), subject matter (tools), and learning objectives (object). This study focuses on a single activity system (as demonstrated in Figure 3.2), avoiding the complexity of multi-system influences and their interaction (e.g. the construction industry or lecturers as subjects) (Otrel-cass et al., 2016:40, 57). This analysis seeks to uncover inconsistencies, such as discrepancies between current pedagogical methods and the proficiencies needed in the construction sector or between students’ existing knowledge and new capabilities necessary for C4.0. Addressing these contradictions can enhance the effectiveness and responsiveness of construction education programmes (Engeström, 2001; Spinuzzi, 2020), thereby positioning themselves more effectively to advance the C5.0 agenda. Investigating the mediation of artefacts (i.e. the relationship of the tools against the subject in meeting the object of the activity) helps identify possible improvements and contradictions to improve the specific objective (Brown, 2022:video). This approach seeks to identify tensions within the activity to enhance the application of graduate attributes (Gedera & Williams, 2016:1).

3.6 METHODOLOGY

An explanatory sequential mixed-methods design (Creswell & Creswell, 2018:218) was utilised to investigate students' perceptions and experiences of Graduate Attributes (GA) during their studies. This approach combines complementary research methodologies, epistemologies, and strategies to enhance the research investigation (Johnson & Christensen, 2014:53). The study utilised an initial purposeful sampling process by selecting the accredited HEIs, followed by a randomised population of these groups through focus-group discussions (Krueger & Casey, 2015:196). The identification of appropriate institutions offering a Bachelor's degree in Construction CM and QS was achieved through elimination. Twelve HEIs with variable accreditation statuses were considered (SACPCMP, 2023:online; SACQSP, 2023:online), where eight institutions were identified after the first round of elimination, of which five holds international accreditation (CIOB, 2024:online; RICS, 2024:online). Ethical clearance was obtained from five institutions to access students for research, with each HEI's department assisting with facilitating and communicating with student respondents. The quantitative and qualitative methodologies are briefly discussed below; however, because of the sequential method used, details of the number of participants are provided in the respective data analysis sections to allow for the continuity of the discussions.

The quantitative data collection followed the guidelines established by Johnson and Onwuegbuzie (2007:127), where a semi-structured survey [see Appendix D] was administered to students enrolled in five accredited CBE programmes. This approach facilitated access to the target population and boosted participation rates, as Wright (2005) emphasises. The semi-structured survey questionnaire sourced data from 102 students, representing approximately 3.92% of the estimated student population across the selected accredited institutions in South Africa, and it took place from April 2023 until July 2023. The quantitative data analysis utilised descriptive and inferential statistical techniques, as shown underneath the data analysis section (Section 3.7) (Pallant, 2020:94; Du Plooy-Cilliers et al., 2014:220) using IBM's SPSS Statistics software. Data are presented under three main headings: focusing on background interpretation of existing generic Graduate Attributes (GAs) (Section 3.7.1.1), the placement of C4.0 Attributes (Section 3.7.1.2) and the role of Activity Theory and the mediation of artefacts towards C4.0 preparedness (Section 3.7.1.3).

The qualitative data collection utilised focus-group discussions to capture diverse student perceptions and experiences through a semi-structured interview protocol (Krueger & Casey, 2015:374). The protocol [see Appendix D] encouraged in-depth discussions on themes identified from initial survey results, with the data collection taking place from August 2023 to September 2023. Thematic analysis methodology of focus-group transcripts was followed (Clarke & Braun, 2013:3-4), systematically familiarising, coding, searching for themes, reviewing, defining and naming the themes before relating them to GAs in CBE education with Construction 4.0 (C4.0) considering the CHAT. A combination of NVivo and ChatGPT-4.0 was utilised to assist in coding, organising, and interpreting the qualitative data, ensuring a comprehensive analysis of themes and patterns derived from participant responses. This section is presented under two headings: The theory and practical exposure (Section 3.7.2.1) and the students' understanding of Cultural Historical Activity Theory (CHAT) (Section 3.7.2.2).

Each data set is presented with a preliminary analysis before systematically triangulating the information to enhance study validity by combining quantitative surveys with qualitative focus groups (Denzin, 2017:27, 184 & 241). Reflexivity and transparency were maintained through reflection (Finlay, 2002:531), with ethical approval obtained from all participating institutions, adhering to the Belmont Report, Ethical Principles and Guidelines for the Protection of Human Subjects of Research (1979) principles. Informed consent, confidentiality, and the right to withdraw were emphasised to ensure the ethical treatment of all participants.

3.7 DATA ANALYSIS

3.7.1 Quantitative data

One hundred and six students participated in the survey, with 102 responses suitable for data analysis, with N-values ranging from 8 to 39 from each institution (exact population sizes are shown in Table 3.2). Respondents included third-year (final-year undergraduate) and fourth-year (Honours degree) students studying Quantity Surveying, Construction Management, or Construction Economics and Management degrees.

3.7.1.1 Background evaluation of students' interpretation of GAs and KSCA

Students were presented with nine prescribed GAs per the baseline [see Annexure 3.1] (UFS, 2019:10). Problem-solving and critical thinking were listed as the most conducive for Construction 4.0 preparedness, with Academic Competence and Community Engagement being the lowest. A high positivity mean among respondents was observed, ranging from 3.67 to 4.13 on a 5-point Likert scale [1: Not relevant at all & 5: Cannot go without (Vital)]. Over and above the above results, 58% of respondents indicated that more Attributes might be added to those presented, mainly career orientated. Correlating to the literature on continued competencies that are required from graduates (WEF, 2016:5). Through a ranking process, it could be established that skills (27%) and knowledge (27%) are the most important for new graduates in the workplace, while Attributes (24%) and Competencies (22%) were ranked as the least important for new graduates. The ranking process identified that the students perceive these capabilities as relatively equal in importance for new employers.

3.7.1.2 The placement of C4.0 attributes

Students' opinions towards C4.0 and GA were tested to form a picture of students' perceptions towards GAs and C4.0. Out of the 102 valid questionnaires submitted, all neutral selections were omitted to present a four-point Likert Scale (1: Disagree; 2: Somewhat disagree; 3: Somewhat agree & 4: Agree). The p-values between the HEI revealed that no significant differences could be identified between the sample groups, with values ranging between 0.47 and 0.90 (with the significance at $p < 0.05$) (Pallant, 2020:352-353). The combined means are shown in Figure 3.3 below:

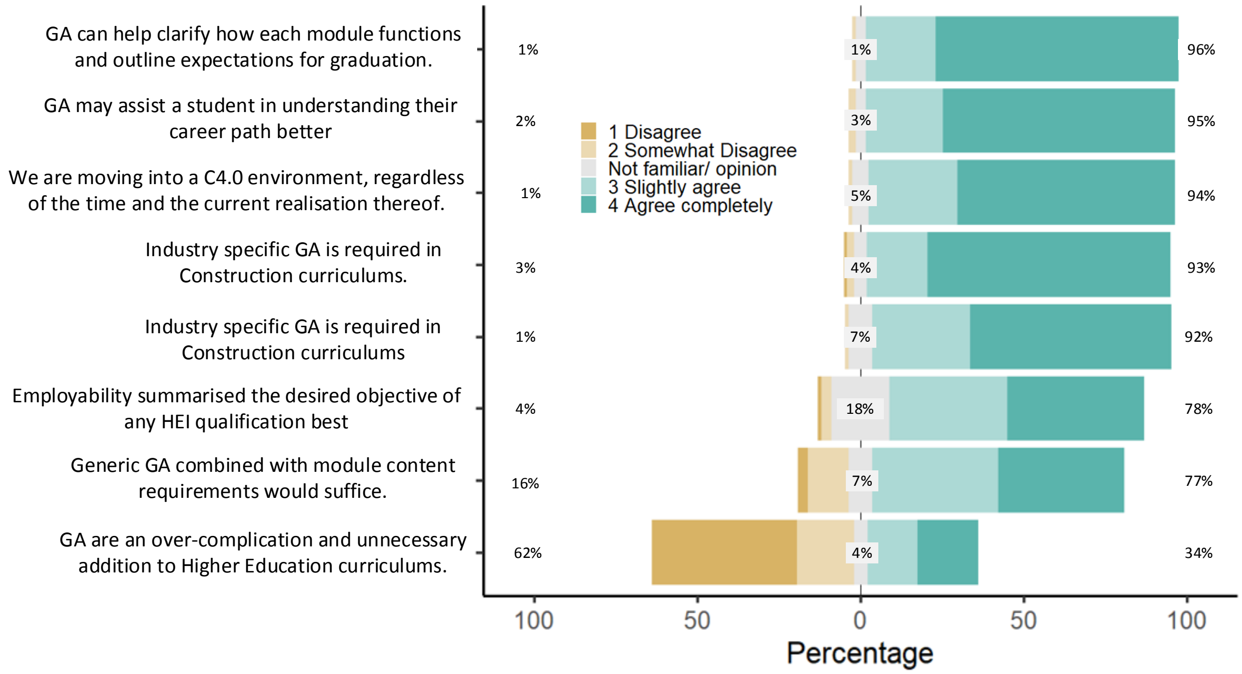

Figure 3.3: Placement of C4.0

Figure 3.3 shows that QS & CM students acknowledge the importance of Graduate Attributes (GAs) in preparing for Construction 4.0 (C4.0) education. Although students recognise that GAs introduce additional intricacy to curricula (the last two items within Figure 3.3), they highlight their potential regarding career paths and the consistency of modules (the first four items shown in Figure 3.3). There is a widespread agreement regarding the necessity of industry-specific GAs, demonstrating an understanding of the sector's shift towards digitalisation. The agreement implies that GAs play a crucial role in aligning educational outcomes with the requirements of the South African CBE, thus improving the chances of finding employment in an increasing C4.0 environment.

3.7.1.3 CHAT and C4.0 preparedness

Next, students were presented with a ranking process between the prescribed artefacts within the CHAT and the items mentioned above (see Figure 3.2). Students indicated that they experienced the subject and tools as the most important within the activity to prepare them for C4.0, with the lowest mean scores indicating a higher-ranked artefact (ranging from 1st to 6th), represented in Table 3.2.

Table 3.2: Ranking means of the activity of preparing students for C4.0 (ranging from 1 to 6)

Activity Theory artefacts	Combined Means N=102	HEI 1: N=39	HEI 2: N=10	HEI 3: N=8	HEI 4: N=19	HEI 5: N=26
F - Mediation of Artefacts	4.33	3.78	4.11	5.57	4.33	4.88
E - Division of Labour	3.94	4.22	3.67	4.00	3.59	3.84
D – Community	3.68	4.14	3.67	2.86	3.82	3.16
C – Rules	3.67	3.72	4.33	3.38	3.38	3.64
A - Tools	2.57	2.38	2.56	2.88	2.71	2.68
B – Subject	2.49	2.42	2.67	1.71	2.65	2.67

Based on the data in Table 3.2, the assessment of differences between HEIs on various artefacts was conducted using the Kruskal-Wallis test, given the non-normal distribution of data [If normality is not assumed or Bartlett's test fails, indicating non-parametric testing is required.] (Pallant, 2020:183-190). The results indicate no statistically significant differences between the groups across all measured artefacts, as reflected by p-values exceeding the conventional threshold of 0.05 (Pallant, 2020:252-353). This consistency in p-values suggests a uniform perception and experience of C4.0 attributes among students across the different HEIs. The power analysis (Cohen, 1988:71), however, shows varying levels of statistical power across artefacts, with values generally below the threshold of 80% in most cases (Lakens, 2013:2). The lower power indicates that while no significant differences were found, the study's sample size might limit the detection of smaller effects. Thus, while the findings suggest consistency, the possibility of undetected subtle differences should be acknowledged. This insight calls for caution in interpreting non-significant results as definitive proof of uniformity, highlighting the value of further research with larger samples to confirm these patterns.

Despite the lower power levels, the uniformity in responses underscores the generalisability of these findings, implying that C4.0 characteristics are similarly integrated across institutions. This alignment points to a cohesive approach in educational practices related to the development of GAs within the context of C4.0. The data further suggest that QS and CM students appreciate a balanced educational approach, where both tools and active personal involvement are valued as integral components of the learning experience.

These results indicate an appreciation for the structured processes within HEIs, which support students in navigating the mediation of artefacts essential for C4.0 readiness. This emphasis on mediation highlights practical, mediated learning experiences and signalling areas for potential pedagogical enhancement. The interplay of these artefacts within the HE settings, as shown in Figure 3.4, depicts a strong alignment with the 2GAT approach, with 3GAT (CHAT) indicating areas with moderate and lower levels of mediation, thus providing insights into the current state and areas for refinement in teaching approaches (expanded on below).

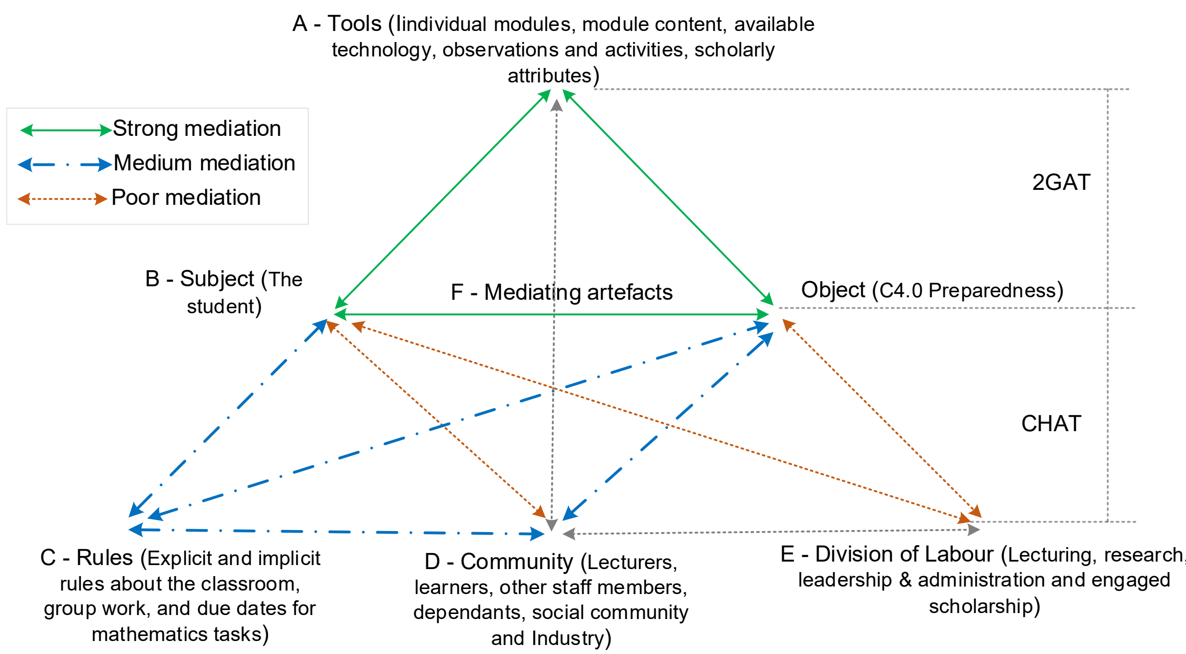

Figure 3.4: Illustration of the perceived mediation in achieving C4.0 preparedness

Figure 3.4 highlights the students' existing experiences towards a teaching-centred approach by emphasising the importance of tools and subject mediation in meeting the object of the activity while exposing the potential of deepening rules, community and personal development strategies towards division of labour. Figure 3.4 further assists in understanding the existing interaction between the artefacts within the activity system;

according to Fleer (2016:2), this historical understanding of existing systems allows for identifying potential improvements, which is investigated further in 3.7.2.

3.7.2 Qualitative data

Additional focus-group dialogues were conducted with learners to reveal underlying and implicit patterns to conduct thematic analysis (TA) (Maguire & Delahunt, 2017:3353). These focus-group discussions aimed to explore students' perceptions and experiences towards C4.0 and suggested GAs, which included six focus groups of the sampled HEIs, including 85 participants. Although the groups were slightly higher than the prescribed (between 6 and 20) amount in some cases (Du Plooy-Cilliers et al., 2014:183), it did allow for spontaneous interaction between participants. Two focus groups were third-year students about to complete their undergraduate degree, while four were honours students about to complete their Honours degrees.

The information obtained from these conversations was subsequently transcribed, coded, and classified for examination using the methodology outlined by Clarke and Braun (2013:3-4) above. Culminating into the themes highlighted under 3.7.2.1, while 3.7.2.2 shows the themes divided into categories guided by the CHAT.

3.7.2.1 Theory and practical exposure

The students' perceptions of practical experience and theoretical teaching were investigated through a series of questions [please see Appendix D] aimed at promoting discussions on the C4.0 framework, of the cyber-physical systems (CPS) and the relationship of the project life cycle (PLC) (Sawhney et al., 2020:14). The results correlated with Fink's (2013:69, 70) notion that students require justification of the material they are being taught and that it should be planned and linked to their recognition of how it links to their ultimate HE. Thus justifying the students' 'why' (as discussed in 3.4.1 and illustrated in Figure 3.1) and promoting self-determined learning (Sparkling & Sengupta, 2022:658). Table 3.3 illustrates students' diverse requirements and how they justify the material they use in making meaningful connections with curriculum content.

Table 3.3: Relationship between theoretical and practical

Descriptions	Frequency	Supporting Quotes
Site visit first – Physical training on processes and construction technology	7	(FG4/P3): "Visiting sites assisted me in reading and understanding drawings." (FG4/P4): "As a COVID student, I longed to get to go to the site."
The theoretical approach first, before embarking on on-site visits and construction technological exposure.	7	(FG2/P4): "We have our entire career still to learn from practical site". (FG2/P5): "It is important to know how to conduct yourself on a construction site before visiting a construction site."
A combined theoretical-practical approach	11	(FG5/P2): "Would appreciate it if the site and theory be combined, but in a focused manner." (FG5/P3): "Pictures and videos assist a lot if combined with theory, which is confirmed when actually seeing the process."
It does not matter whether theory or practical exposure is done first; it should be focused.	7	(FG3/P6): "Sometimes, when visiting sites, the progress does not allow for specific inspection of the theory currently being covered. Site exposure should be focused and planned to suit the work currently being covered in the classroom."

Table 3.3 highlights the dynamics in making theory and practices make sense to students [as highlighted in Table 3.1, particularly Gibbs and Malcolm (2017:1-2)]. From the qualitative inquiry findings, merely providing experiential learning as a tick box is not enough; instead, a focused alignment of and/or reflection on what was experienced can be related to the course content and the objective of the exercise.

3.7.2.2 The students' understanding of Activity Theory

In exploring the praxis of CHAT within QS and CM education, focus-group discussions provided a platform for students to reflect on how various CHAT artefacts support their journey toward Construction 4.0 readiness. The subsequent questions and discussions investigated the students' perceptions of the activities (artefacts) available to achieve the object (Gedera & Williams, 2016). These discussions aimed to establish the status quo of CBE HEI students in their current programme and how the transition from a teaching approach towards a learner approach may be facilitated (Barrie, 2007:452). Students were presented with Figure 3.2, from which they had to choose the most conducive artefact towards C4.0 preparedness with justification.

In Table 3.4, the data presented in 3.7.1 are explored further, with students again emphasising the prevalence of a 2GAT mediation of artefacts; however, most conversations highlighted the community's importance, particularly for the honours cohorts who experienced the COVID pandemic and the challenges it brought towards connecting into the CBE Community. Furthermore, the students internalised the artefact, highlighting their awareness of the role they could play towards the younger students and their orientation within their study tenure.

Table 3.4: Relationship between theoretical and practical

Descriptions	Frequency	Observations
A – Tools	12	Students highlighted the importance of tools, and the guidance provided. It is the first port of call.
B - Subject	1	Even though not frequently referred to, it emerged as a subjective theme by the students – highlighting how other artefacts influence their development. For instance, it highlights how they learn to develop and prioritise through tenure.
C – Rules	5	Some students highlighted how rules assist them in navigating what is expected from them.
D– Community	17	Community was specifically highlighted in the focus groups, and students indicated the importance of Community by highlighting the lack thereof in COVID, aligning themselves with piers, lecturers, and Industry. It highlighted how important "little" things, such as senior students assisting junior students with things they found challenging when they started, e.g. orientation on campus. It was also highlighted how the division of labour could detract from community engagement. The challenge of connecting with Industry was further highlighted as a major challenge, specifically for research and assignments, while students highlighted that they understand that Industry does not necessarily have the time to assist students.
E - Division of Labour	3	Some students highlighted that the division of labour boils down to their own management and that time management does become a challenge in certain sections of the year.
F - Mediation of Artefacts	2	Even though the mediation of these artefacts was not explicitly highlighted, the discussion did revolve around striking a balance between what is required and what is required for the world of work.

In Table 3.4, "community" emerged as a central theme (supporting the observation of Figure 3.4), particularly for those who felt isolated during the COVID-19 pandemic. For example, emphasising the importance of peer, faculty, and industry connections (FG4/P4): "… *for networking, especially within our context*" and (FG3/P2): "*Progress is not possible without other people giving you guidance.*" Additionally, tools were also noted as foundational, not just in practical application, but as guideposts for navigating academic and professional landscapes as confirmed by one student (FG3/P6): "... *Tools. Without it, you would not have had anything for the workplace."*

The 'Community' aspect was frequently discussed, underlining its role in learning and orienting students to both academic and Industry environments, illustrating how social dynamics within HEIs contribute significantly to student development. Students recognised that while they are at the heart of the learning process (the 'Subject'), their growth is highly influenced by the educational 'Tools', the 'Rules' governing their environment, the 'Community' they engage with, and the 'Division of Labour' they observe and partake in. One student highlighted (FG4/P5): "*I think the C – rules they're the most important ones because ... they can actually create tools that will help them in the prepare them for the Industrial Revolution.*"

The students' insights indicate a desire for educational experiences that balance theoretical knowledge with practical application. They articulated an understanding that while they must navigate 'Rules' and manage the 'Division of Labour' personally, these aspects are integral to the learning process and crucial in aligning their academic pursuits with the demands of the evolving construction industry.

In synthesising these insights, an enhanced focus on the 'Community' is advocated for, as it underpins the need for collaborative learning spaces where students can interact with peers and industry professionals – effectively 'rubbing shoulders' – to reinforce their career choices and professional trajectory. This highlights the importance of GAs within the KSCA relationship, as promoted by Warier (2014:19).

3.8 DISCUSSIONS

Utilising Figure 3.1 as a framework for unpacking the data presented in Section 3.7, this discussion section systematically discusses the quantitative and qualitative data before triangulating takes place (Denzin, 2017:7).

The quantitative data of QS and CM students highlighted their understanding of the knowledge, skills, competence and attribute (KSCA) relationship, highlighting the importance of problem-solving and critical thinking attributes for C4.0 preparedness (Section 3.7.1.1). They further indicate the potential of GAs in guiding them through this process and highlight that it might assist them in navigating the 'why' (motivating through justification) throughout their academic careers (Section 3.7.1.2). They emphasised the need to develop specific GAs and Construction 4.0 (C4.0) attributes to help justify and motivate their navigation through degree pathways, ultimately improving degree programmes. The value of comprehensive, artefact-mediated programmes that extend beyond traditional 2GAT to improve their readiness by preparing them to shift from a teaching-centred to a learner-centred educational model (Section 3.7.1.3) was shown. The data further revealed (as illustrated in Figure 3.3) that HEIs offering QS and CM undergraduate programmes face challenges transitioning from a primarily teaching-oriented approach to one emphasising learner autonomy and mentorship necessary for C5.0 (González-Pérez et al., 2023:12; Marinelli, 2023:14).

In the qualitative data inquiry findings, QS and CM students expressed a need for clarity and justification of what they are taught (Section 3.7.2.1). Focus-group discussions revealed diverse ways of making sense of the CBE and the content within programmes and how they would eventually apply it in Industry – starting with 'why' and then moving towards how and what is being taught may assist both lecturers and students in enhancing learning to be more career orientated. Focus group findings also underscore the importance of structured educational programmes that combine knowledge transmission with active, community-based learning, ensuring students are well-equipped for the CBE's future challenges and advancements (Section 3.7.2.2). The study's findings revealed that to thrive in the C4.0 era, HEIs must adopt a learner-centred approach that emphasises community engagement and practical tools, as illustrated in Table 3.4. These findings suggest the need for structured educational programmes that impart knowledge and actively involve students in learning through a supportive community network, thus preparing them for the challenges and innovations of Construction 4.0, as suggested by Koc et al. (2020:473).

Triangulation: Through the use of Figure 3.1 as a framework for the investigation, it was observed that the 'subject's' growth through the precursory, complementing, transitioning and enabling phases of the GAs framework (Barrie 2007:440) greatly enhances the depth of students' mediation of activities artefacts. Emphasising a self-determined focus on the "why", this figure highlights how these new arrangements could improve the alignment with C4.0 and C5.0 Graduate Attributes, supporting a forward-looking shift towards Construction 5.0 orientation. The application of Cultural Historical Activity Theory (CHAT) as a pedagogical and epistemological development lens reveals that these supportive structures are critical in mitigating isolation and enhancing student engagement with C4.0, corresponding to Table 3.1 [in particular Gibbs & Malcolm (2017:1-2)]. Additionally, Table 3.1 [in particular Jackson (2017:151) and O'Donnell et al. (2017)] stresses the importance of digital literacy and graduate adaptability, which aligns with the findings that problem-solving, critical thinking, and technical skills are pivotal for C4.0 preparedness and readiness. The study underscores McCord et al.'s. (2023:12) [Table 3.1 – d] assertion on the necessity of personal attributes and technical and professional skills, suggesting that a focused alignment of theoretical and practical exposure can significantly enhance students' competencies for and readiness in the modern workplace.

3.9 CONCLUSION AND RECOMMENDATIONS

This study highlights the importance of Graduate Attributes (GAs) in preparing students for the rapidly evolving demands of the South African Construction Built Environment (CBE) in the context of Construction 4.0 (C4.0) and the emerging paradigm of Construction 5.0 (C5.0). While South Africa still embraces C4.0, the industry is on the brink of a new era where integrating technology with human-centric values will reshape construction practices. C5.0 emphasises the importance of balancing technological advancement with sustainability, well-being, and human-machine collaboration, thus requiring a new skills set for future graduates.

Graduate Attributes, such as problem-solving, critical thinking, digital literacy, and adaptability, are essential for students to thrive in a C4.0 environment and lay the foundation for the transition to C5.0. The findings suggest that integrating these attributes into curricula is crucial for ensuring students are equipped to meet current and future industry demands. By fostering a learning environment that combines theoretical knowledge with practical experience and community engagement, HEIs can bridge the gap between academia and industry, preparing students for the challenges ahead.

Based on these findings, the following recommendations are proposed for here:

- Curriculum Integration: Incorporate C4.0 and C5.0 attributes into curricula, focusing on digital literacy, human-machine collaboration, and sustainability alongside traditional technical skills.

- Supportive Structures: Establish mentorship programmes, peer networks, and partnerships with industry to foster student engagement and help them navigate the transition from C4.0 to C5.0.
- Learning-Centred Approaches: Adopt learner-centred teaching methods that emphasise the relevance of GAs in both academic and professional contexts, ensuring students understand the 'why' behind their learning.
- Practical Experience: Through a mentorship mindset, strengthened work placements, site visits, and hands-on learning opportunities to bridge the gap between theoretical knowledge and real-world application, focusing on C4.0 technologies and C5.0 principles.
- Industry Collaboration: Develop more robust partnerships with industry to keep curricula aligned with emerging trends in C4.0 and C5.0, ensuring that graduates are equipped with the skills required for the future workforce.

In conclusion, HEIs must establish well-grounded Graduate Attributes (GAs) while allowing adaptability in their programmes to meet the construction industry's evolving demands towards C4.0 and C5.0 developments. Doing so will enhance student employability and contribute to the industry's sustainable development, fostering a generation of graduates' readiness for technological innovation and human-centred construction practices.

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ANNEXURE 3.1

Table 3.5: Nine proposed generic graduate attributes

Graduate Attribute	Definition
Academic competence	Academic competence refers to the knowledge, skills, and attitudes (including values) students develop through interacting with discipline-specific content. Critical to academic competence is lifelong learning, an all-purposeful learning activity undertaken on an ongoing basis to improve knowledge, skills, and competence. Lifelong learners are curious, take initiative, learn independently, transfer knowledge, and reflect on their learning.
Critical thinking	Critical thinking is a habit of mind that comprehensively explores issues, ideas, artefacts, and events before accepting or formulating an opinion or conclusion.
Problem-solving	Problem-solving is designing, evaluating, and implementing a strategy to answer an open- ended question or achieve a desired goal.
Oral communication	Oral communication is a prepared, purposeful presentation designed to increase knowledge, foster understanding, present findings or results, or promote change in the listeners' attitudes, values, beliefs, or behaviours.
Written communication	Written communication is the development and expression of ideas in writing. Written communication involves learning to work in many genres and styles. It can involve working with many writing technologies and mixing texts, data, and images. Written communication abilities develop through iterative experiences across the curriculum.
Community engagement	Community engagement is continuously negotiated collaborations and partnerships between the UFS and/or its members and the interest groups with which it interacts, aimed at building and exchanging the knowledge, skills, expertise and resources required to develop and sustain society.
Ethical Reasoning	Ethical reasoning is reasoning about right and wrong human conduct. It requires students to be able to assess their ethical values and the social context of problems, recognise ethical issues in various settings, think about how different ethical perspectives/concepts/frames of reference might be applied to ethical dilemmas, and consider the consequences of alternative actions. Students' ethical self-identity evolves as they practice ethical decision-making skills and learn how to describe and analyse positions on ethical issues.
Entrepreneurial Mindset	Entrepreneurial mindset is a set of attitudes, skills and behaviours that can be applied in all spheres of life. This mindset enables citizens to nurture their personal development, actively contribute to social development, enter the job market as an employee or self-employed, and start-up ventures that may have a cultural, social or commercial motive.
Digital Literacy	The ability of an individual to effectively and confidently use digital technologies to access, evaluate, create, and communicate information in various contexts is becoming increasingly important in today's technology-driven world. At the UFS, it is scaffolded across: • ICT Proficiency • Digital citizenship • Information, data and media literacy • Digital creation: problem-solving, creativity and innovation in a digital space

Source: UFS (2019:10)

4
ARTICLE 2: INTEGRATING GRADUATE ATTRIBUTES WITHIN A CONSTRUCTION 4.0 FRAMEWORK: INSIGHTS FROM SOUTH AFRICAN QUANTITY SURVEYING AND CONSTRUCTION MANAGEMENT EDUCATORS

Proposed Journal: *International Journal of Construction Education and Research*[4]

The construction industry is evolving rapidly with the advent of Construction 4.0, highlighting the adoption of advanced digital technologies, automation, and innovative practices. From a South African lecturer’s point of reference, this study employs Cultural Historical Activity Theory (CHAT) to examine how Quantity Surveying (QS) and Construction Management (CM) curricula can navigate the adaptations needed for the strategic readiness for preparing graduates for the dynamic demands of the Construction 4.0 work environment. The results underscored the collaboration required between Industry and academia, emphasising Higher Educational Institutions' (HEIs) responsibility for this collaboration as teaching and learning specialists. This collaboration lies in the strategic interaction of multiple artefacts, instead of merely addressing specific knowledge, skills, competencies, and attributes in isolation. Key themes emerged around the importance of graduate attributes, practical learning, industry engagement, and curriculum design. A proposed framework emphasises the integration of critical graduate attributes, hands-on industry exposure, and C4.0 technologies into the curriculum to bridge the gap between traditional educational models and industry expectations. Fostering adaptability, innovation, and lifelong learning among graduates, ensuring they are equipped to meet the challenges of the evolving construction landscape. This study’s contribution lies in a practical model for HEIs to enhance student readiness for future industry demands.

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[4] https://www.tandfonline.com/journals/uice20

Keywords: Activity Theory, Construction 4.0 (C4.0), Curriculum Development, Graduate Attributes (GA), Higher Education.

Notes: The Construction Industry (CI) and Construction Built Environment (CBE) terminology are used interchangeably, with CI primarily denoting the global viewpoint, while CBE pertains specifically to the South African context from a Quantity Surveying and Construction Management viewpoint.

4.1 INTRODUCTION

The counterpart of Industry 4.0 in the Construction Built Environment (CBE) is called Construction 4.0 (García de Soto et al., 2022:205). This concept opens the debate and research (Aghimien et al., 2022:1950) around how roles (i.e. Industry and higher education) will change due to Construction 4.0. Notwithstanding these developments, a pedagogy that supports learning experiences and outcomes requires a high degree of reflection, experience and motivation from lecturers (Sandri & Holdsworth, 2022:666).

"*No university education can prepare a graduate for all aspects of the industry …" is* a statement raised by a respondent during a study by Ahmed et al. (2014:242). Another study by O'Neill et al. (2023:1) further highlight several barriers to industry-driven change in Irish HEI Construction Management programmes, including excessive committees, lack of incentives for lecturers, differing views on programme success, extensive paperwork, overworked staff, and limited interdepartmental collaboration. Considering the socio-economic landscape in South Africa (SA), students have specific challenges regarding pre-university and on-campus finances and resources to support their studies (Chiramba & Ndofirepi, 2023). Academic departments within the SA CBE responsible for teaching Quantity Surveying (QS) and Construction Management (CM) and related combined programmes are challenged by diverse demands imposed by multiple stakeholders. These include, for instance, accreditation councils (Maritz & Siglé, 2016:17), HEI regulating bodies such as the South African Qualification Authority (SAQA) and the Council on Higher Education (CHE), and other organisations such as Higher Education South Africa (HESA) (Griesel & Parker, 2009:2; Hauptfleisch, 2024:79). In addition to meeting each institution’s general requirements (UFS, 2019:2), these departments also face industry pressures to remain relevant amidst the rise of C4.0 (Sawhney et al., 2020:17) and emerging discussions on Construction 5.0 (C5.0) (Marinelli, 2023:1; Najafi, 2023:online).

It has been observed that SA QS and CM HEIs also have the added obligation of catering to students entering the international job market, catering for diverse job markets such as the United States of America (USA), where the terms QS and CM are still relevant emergent (Saliger, 2019:online), with the professions mainly focusing on certifications that are not legally mandated (AACE, 2024:online; ASPE, 2024:online; CMAA, 2024:online). In SA, these credentials are mandated (Hauptfleisch, 2024:44). SA QS and CM structures share many similarities with professional pathways found in Commonwealth countries, particularly in how they structure HE and professional accreditation. Like in the UK and Australia (CIOB, 2018; RICS, 2024), South Africa’s CBE places a strong emphasis on acquiring higher education qualifications, followed by registration with a relevant accreditation body, which leads to eventual professional recognition after demonstrating the requisite skills, knowledge, and competencies (RICS, 2019:5). However, despite this structured pathway, not all SA graduates pursue professional registration, with multiple entry levels available for with a Bachelor’s degree at the National Qualifications Framework (NQF) level 7. These degrees typically span three years and carry 360 national credits (SACPCMP, 2020; SACQSP, 2022) – highlighting the need for South African HEIs to ensure that students are adequately equipped for their postgraduate careers within this limited time frame (Ekundayo et al., 2021:214; De Villiers, 2010:10).

This study proposes a framework for the interaction and integration of Construction 4.0 (C4.0) tools and processes into Quantity Surveying (QS) and Construction Management (CM) curricula to align higher education with the evolving needs of the construction industry (Saad, 2019; Ahmed et al., 2014:241). Combining quantitative and qualitative data explores the intersection of industry expectations, graduate attributes (GAs), and technological advancements, offering a pathway to bridge traditional education models with emerging industry demands (Hunt & Chalmers, 2021; WEF, 2015; 2016a; UFS, 2019:8). The framework leverages the Cultural Historical Activity Theory (CHAT) (Gedera

& Williams, 2016:20-21) to address how QS and CM students can acquire the necessary knowledge, skills, competencies, and adaptability for a digitised construction environment (Griesel & Parker, 2009:1; Koc et al., 2020:472 & 474).

CHAT provides a robust analytical lens to evaluate how technological tools and processes mediate learning and skills development within C4.0 contexts. It enables a structured examination of curriculum alignment – both horizontally across disciplines and vertically through progressive learning stages – through backward design principles (Barlow & Leed, 2011:4 & 5). The explanatory sequential approach adopted in this study (Creswell & Creswell, 2018:218) integrates these theoretical insights with empirical data to identify key contradictions and opportunities within current educational frameworks.

The resulting framework addresses curriculum design and provides actionable insights for HEIs, educators, and policymakers. By integrating GAs into curriculum planning and delivery, the study offers a practical roadmap for equipping students with the competencies (CIOB, 2018; RICS, 2019; SACPCMP, 2020; SACQSP, 2014) required to navigate the complexities of Construction 4.0, while fostering a learner-centred approach to meet both academic and industry expectations.

4.2 LITERATURE REVIEW PERSPECTIVES/DEBATES

With the transformative challenges highlighted above, the following review contextualises the intersection of GAs, curriculum design, and technological integration in Quantity Surveying (QS) and Construction Management (CM) programmes. Drawing on the Cultural Historical Activity Theory (CHAT) framework, it provides a structured analysis of mediating artefacts and systemic tensions in adapting curricula to align with C4.0 requirements. The discussion also highlights the importance of industry-academia collaboration, innovative teaching practices, and comprehensive frameworks that respond to global educational challenges. The literature is organised into the following key sections:

- CHAT Model Foundation: Examining the mediating artefacts in curriculum design for industry alignment.

- Teaching Practices: Addressing learner-centred approaches in South African HEIs to enhance adaptability.
- Construction 4.0 Frameworks: Exploring the integration of digital and human-centric technologies.
- Graduate Attributes: Identifying core competencies such as problem-solving, collaboration, and lifelong learning.

4.2.1 Cultural Historical Activity Theory (CHAT)

Cultural-Historical Activity Theory (CHAT) stems from the Social Development Theory pioneered by Vygotsky and further expanded by Leont'ev in the 1930s, providing a sociocultural psychology framework that bridges Sociocultural Theory and Activity Theory (Fleer, 2016:2). CHAT has evolved through three generations, with Engeström contributing significantly to its application in educational and organisational contexts (Jones & Hashim, 2014:2; Spinuzzi, 2020:2). While earlier iterations focused on mediation, internalisation, and proximal development, the third generation expands to encompass activity networks, contradictions, and rules, shifting the analytical lens from individual actions to broader systems (Gedera & Williams, 2016:vii; Spinuzzi, 2020:3).

CHAT is particularly relevant for investigating Construction 4.0 (C4.0) pedagogical developments due to its qualitative orientation and applicability to complex activity systems (Crawford & Hasan, 2006:16; Jones & Hashim, 2014:26). C4.0 introduces challenges such as integrating digital tools, adapting to industry transformations, and addressing skill gaps in graduates, making CHAT a valuable framework for identifying systemic contradictions that can inform teaching practices (Fleer, 2016:13-14). For the South African Construction Built Environment (CBE), these contradictions often lie within the object or motive of activities, particularly at the intersection of expansive and horizontal learning (Engeström, 2001).

This study adopts CHAT (3GAT) to analyse how Higher Education Institutions (HEIs) teaching Quantity Surveying (QS) and Construction Management (CM) programmes can mediate artefacts and align graduate attributes (GAs) with the demands of C4.0. CHAT provides a structured approach to evaluating activity systems, exposing tensions between curriculum design and Industry requirements and offering insights into transformative learning by providing a framework for the complexity of the activity under review. Figure 4.1 highlights baseline definitions of artefacts within this framework, emphasising their role in mediating the object of activities and addressing systemic contradictions (Gedera & Williams, 2016:vii & 38).

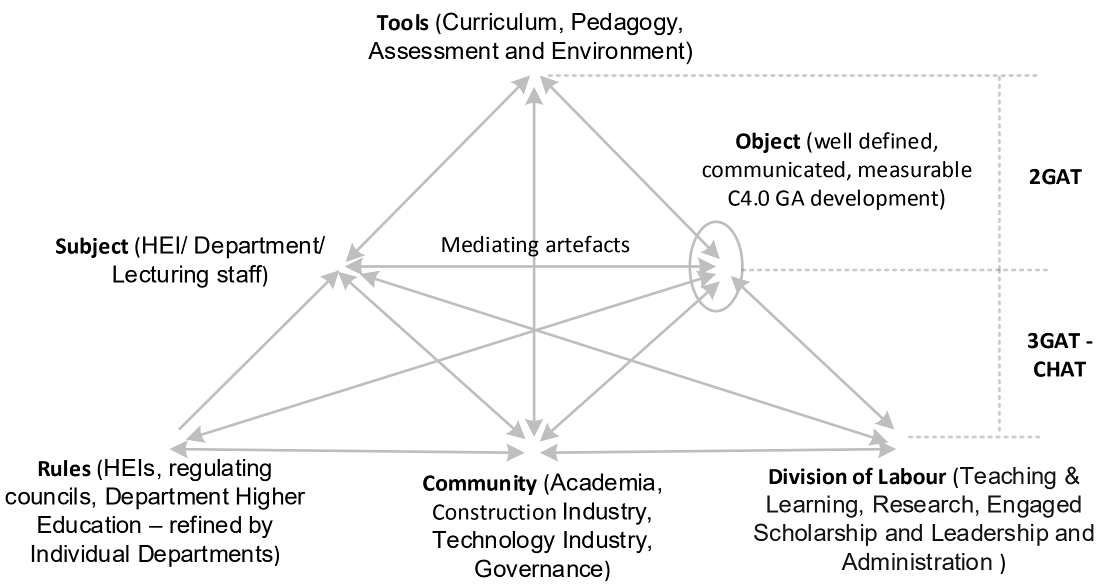

Figure 4.1: Proposed baseline definitions of artefacts within the CHAT

Sources: Adapted from: Engeström (2001:135); Jones and Hashim (2014:3 & 7); Crawford and Hasan (2006:6-8); Spinuzzi (2020)

Following the conceptualisation in Figure 4.1, this framework lays the foundation for the proposed model in Annexure 4.1, where it culminates in a systematic approach to curriculum design for C4.0. The proposed framework leverages CHAT to guide the integration of GAs, enabling HEIs to improve their understanding of their role in preparing graduates for the complexities of professional practice. By defining artefacts, understanding mediations, and addressing contradictions, this approach ensures curricula remain relevant and responsive to the evolving demands of the South African CBE.

4.2.2 Learning and teaching at the heart of the university

Learning is at the heart of any university, with research that can be categorised as learning for academics with 21st-century teaching focused on students' learning facilitation (UFS, 2019:3). Perry (1998, cited in Light & Calkins, 2009) highlights that intellectual and ethical development follows a pathway of students from dualism (which starts with a right and wrong approach with a certain amount of authorial acceptance); to realism discovered; up to commitment in relativism development – where a student accepts that making new commitments towards learning is an ongoing process. Generic attribute development can be seen as a starting point, with a teacher and teaching approach, which forms the basis, focusing on the learner and the learning approach (Barrie, 2006:224; 2007:445). When developing a curriculum's pedagogical framework, academics are confronted by the debate of teacher, student and learning-centred approaches to teaching (Angelo, 2021:34-35). It is thus essential to understand the theories available and how learning takes place to optimise effective teaching designs (Stewart, 2021:3), to assist willing and able students to achieve more than the expected learning outcomes (that would be possible on their own), through a learning-centred approach (Angelo, 2021:48). Information retrieval is typically more effective when associated with meaning (Stewart, 2021:8) aligning directly with the approach of starting with the 'why' but knowing the 'how' (Sinek, 2009:147-170). Developing broader skills for citizenship and future careers might be more conducive to teaching within the chosen discipline (Land, 2021:104). Subsequently, Angelo's (2021:48-49) seven C's to achieve proper alignment within a curriculum are considered for a practical consideration of the definition of the artefact of 'Rules' (Annexure 4.1 – Rules):

- Clarity: The clarity and transparency of the programme's learning outcomes,
- Coherency: How well a programme is vertically and horizontally aligned,
- Compelling: The subject focuses on questions, issues, or topics that interest stakeholders, staff, and students,
- Conceptual: The relevance and shelf-life of the programme's content,

- Challenging: The appropriate level of subject design, assessments, and gradings to convey the expected standard, e.g. through a taxonomy model such as Bloom's Taxonomy of Educational Objectives (Preville, n.d.:online),
- Consistency: The alignment with the programme's institutional values and other modules,
- Cost-effective: Return on investment for the programme.

Further improvement to the design of an effective curriculum is essential to ensure cohesion, constructive alignment and assurance of learning, which requires an active partnership with industry, community, students, and colleagues to foster meaningful engagement in the learning process (Hill et al., 2021:53). Critical thinking and problem-solving are listed at the top of the list of skills employers believe would increase considerably quickly, with self-management skills, such as active learning, resilience, stress tolerance, and flexibility, also emerging as essential skill requirements (Whiting, 2020). The SACQSP sets particular criteria for all accreditation QS programmes to adhere to (SACQSP, 2014). Similarly, the SACPCMP emphasises that, to prepare CM graduates for professional registration, the framework prescribes specific Graduate Attributes (GAs) that include the ability to obtain core industry knowledge and required discipline-specific skills, the development of specialisations, the integration of ethical responsibility, the further development of personal attributes expected from a registered professional, and the cultivation of outward-looking, professionally rich social values for managing projects effectively (SACPCMP, 2020) (Annexure 4.1 – Object).

To address the slow adoption of C4.0 concepts and technologies because of more complicated industry-interrelated processes, sub-processes, stakeholders, horizontal and vertical commerce, and discipline fragmentation, which limits knowledge sharing (Koc et al., 2020:464), the incorporating of Scholarship of Teaching and Learning (SoTL) practices are considered. As university teachers have diverse 'division of labour' needs Felten (2013) and Gelmon et al. (2012) were considered to define the lecturer's obligations as *teaching and learning, research, engaged scholarship, leadership, and administration.* Instead of loading more work and content onto curricula, smart and purposeful curriculum design is needed. By considering the overarching artefact of *division of labour*, the following decision criteria may assist in enhancing HE educators in closing the skills gap by improving the quality of education (WEF, 2015:8) (Annexure 4.1 – Division of labour) by:

- Finding creative solutions to fundamental challenges,
- Making education more available to a broader audience,
- Enabling more straightforward improvement of quality and best practices,
- Gaining insights into what students learn in real-time,
- Increase in teacher productivity.

In summary, the curriculum asks the following questions: what content should be included and how the content should be delivered and assessed (the pedagogy), according to Hill et al. (2021). The following section investigates the C4.0 framework within the South African CBE and its impact on teaching and learning (T&L).

4.2.3 Construction 4.0 and its nature within the CBE and T&L

The Fourth Industrial Revolution (4IR), characterised by the fusion of digital, physical, and biological technologies, has rapidly transformed industries, including the Construction Built Environment (CBE) (Schwab, 2016). The term ‘Industry 4.0’ emerged at the Hanover Fair in 2011, highlighting advancements in value chain organisation and virtual-to-physical manufacturing systems (Lu, 2017:1). This revolution, predicted to be more profound and rapid than its predecessors, introduces technologies such as Building Information Modelling (BIM), Big Data (BD), and the Internet of Things (IoT) into construction, collectively termed Construction 4.0 (C4.0) (Morrar et al., 2017:12; Sawhney et al., 2020). Caution towards the potential disconnect of the human element of technological developments has sparked discussions surrounding the term ‘Construction 5.0’ (C5.0) (Marinelli, 2023; Najafi, 2023), to which the relationship between C4.0 and teaching learning speaks directly to these discussions. C4.0 encompasses three key areas: smart construction sites, simulation and modelling, and digitisation and virtualisation (Koc et al., 2020:463). In South Africa, the uptake of these technologies is uneven due to infrastructural and socio-economic disparities (Sutherland, 2020:232). Achieving the potential of C4.0 requires a comprehensive digitalisation of industrial processes, with Cyber-Physical Systems (CPS) forming the backbone of this transformation (Begić & Galić, 2021:6-7). Interactions between industry, academia, and technological disruptors emphasise the need for a more integrated approach to innovation within CBE curricula (Koc et al., 2020:473; Larsen, 2015:113). Traditionally, innovation in construction responds to environmental changes and opportunities rather than formal strategies, necessitating flexibility alongside core principles (Loosemore, 2015:75-76). Beal and Bohlen's model, refined by Rogers (2003, cited in Sawhney et al., 2020) (Annexure 4.1 – Subject), outlines four stages of innovation adoption and is deemed crucial in the effective teaching and learning (T&L) practices for diverse socio-economical cohorts:

- Awareness: Learning about the innovation,
- Interest: Developing an interest in its details,
- Evaluation: Assessing its benefits and potential adoption, which may include *trial*,
- Adoption: Implementing the innovation after successful trials.

These diverse technological, demographic, and socio-economic disruptions are altering skill requirements, shortening the lifespan of existing skill sets, and necessitating a focus on critical thinking, problem-solving, and collaboration (WEF, 2016b:8). Incorporating education technologies can enhance instructional delivery, ongoing assessments, and learning outcomes, fostering essential skills beyond traditional academic learning (WEF, 2015:1, 2016a:4). The slow adoption of new technologies in construction is attributed to industry traditionalism, underscoring the importance of aligning curriculum content with industry needs (Begić & Galić, 2021:5), which emphasises the importance that GAs can play towards the dynamic evolving needs of KSC.

4.2.4 Graduate attributes within the CBE

As depicted in Figure 4.2, GAs do not work alone (Warier, 2014:19) and are defined by Barrie (2004:262) as

> the qualities, skills and understandings a university community agrees its students should develop during their time with the institution. These attributes

include but go beyond the disciplinary expertise or technical knowledge traditionally formed the core of most university courses.

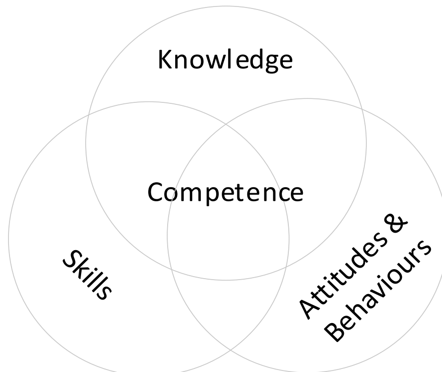

Figure 4.2: Knowledge vs Competence

Source: Warier (2014:19)

Additionally, as illustrated in Figure 4.2, Fieldman (2007, cited in Land, 2021:99) emphasises the importance of developing an awareness of global interdependencies, learning openness, and ambiguity tolerance. These attributes include cultural sensitivity, empathy, multiple perspectives, research skills, and resilience. Construction Management (CM) involves various roles, from Architectural Technicians to Site Managers, and includes disciplines like Building Control and BIM (CIOB, 2021:online). Accreditation ensures that academic programmes meet predefined standards, promoting competency and professional conduct among graduates (SACPCMP, 2020:14; SACQSP, 2015:2).

Employability and GA share a common objective, supported by academic, personal management, and teamwork skills (Seniuk et al., 2017:4). Despite GAs importance, lecturers often struggle to conceptualise and develop GAs within their modules due to work pressures and under-resourcing in higher education (Bitzer & Withering, 2020:17 & 26; O'Neill et al., 2023:75). A paper in the South African Teaching Advancement at University (TAU) Fellowship illustrates the relationship between GAs and Professional Attributes (PAs) (Dhunpath et al., 2021), emphasising that just as students need to acquire specific GAs, the lecturing staff must enrich their PAs (Dhunpath et al., 2021:126-129). For lecturers, learning takes place via research and practice, which inform their teaching (UFS, 2019:3). According to Saad (2019:2), for a curriculum to excel, it must fulfil the combined requirements of curriculum, pedagogy, assessments, and the environment (CPAE) (Annexure 4.1 – Tools & Signs):

- Curriculum: What will be taught?
- Pedagogy: How will it be delivered?
- Assessments: How can learning be measured?
- Environment: What are the required resources and student experiences?

With competency being supported by the necessary knowledge, skills and attributes (Warier, 2014:19), understanding different learning theories and their application can enhance teaching effectiveness (Stewart, 2021). However, it has been found that defining these terms with a shared ontology of knowledge, skills, competencies, and attributes (KSCA) is interpreted differently by different people (Warier, 2014:26; O'Neill et al., 2023; WEF, 2015a:4, 2016:2-3).

These foundational literacies, competencies, and character qualities are built through acquiring knowledge, skills, and attributes to enable competence maturity. It is concluded that the *mediation* of knowledge, skills, competency and attributes forms a crucial foundation for meditating artefacts with the CHAT (Annexure 4.1 – Mediation of Artefacts).

The comprehensive framework should align core curriculum content with industry requirements, using GAs as a bridge to meet these needs. As highlighted by Vygotsky's zone of proximal development, student capabilities require support and scaffolding to reach their potential (Stewart, 2021:18). Understanding the conceptions of how students develop generic graduate attributes suggested by Barrie (2006:224; 2007:445), from remedial non-curriculum interventions through disciplinary curriculum content, disciplinary curriculum process, course experiences, university experiences and moving from a process of teaching content, teaching processes, engagement up to a participatory involvement of student. By doing so, measurable platforms are created, such as *Bloom's Taxonomy of Educational Objectives* (Bloom's Taxonomy, 2001:online; Preville, n.d.:7). While Bloom's Taxonomy is more short-term and module-specific, GAs should be seen as representing the identity of HEI graduates (UFS, 2019:8). Thus, GAs' essential role is to prepare students to navigate the complexities of the CBE.

It is subsequently concluded that the pathway to professional registration built on GAs can be represented by Figure 4.3:

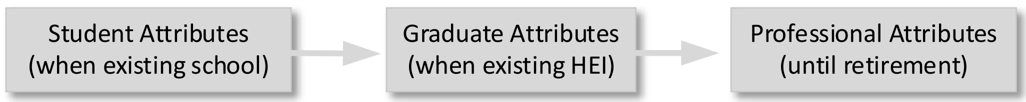

Figure 4.3: Assumed transition from student attributes to professional attributes

The transition from Graduate Attributes (GAs) to Professional Attributes (PAs), as illustrated in Figure 4.3, underscores the critical role of GAs in bridging the gap between academic preparation and professional readiness, setting the stage for a deeper exploration of how these attributes align with industry demands and curriculum frameworks in the CBE.

4.3 METHODOLOGY

Because of the emergent nature of C4.0 and GAs in South Africa within QS and CM programmes, an Explanatory Sequential mixed-method approach was adopted that provides for a deeper investigation of the topic by gathering both quantitative (phase 1) and qualitative (phase 2) data from (Creswell & Creswell, 2018:218). Triangulation takes place in the discussion section of the study (Creswell & Plano Clark, 2018:62). The accreditation bodies list eight accredited HEIs offering a bachelor's degree and higher (SACPCMP, 2023:online; SACQSP, 2023:online) of which five are internally accredited (CIOB, 2024; RICS, 2024). Through the purposeful sampling (a subset of non-probable sampling) procedure mentioned above (Du Plooy-Cilliers et al., 2014:142); seven institutions offering accredited programmes for Quantity Surveying and Construction Management (or a combination of the two) were approached, of which five allowed access to staff members via their ethical committees (including three internationally accredited HEIs).

Quantitative data: A semi-structured survey questionnaire (Naoum, 2007; Tashakkori & Teddlie, 2010:59) was utilised for the primary objective of establishing a baseline on which the focus group might be compared (Creswell & Creswell, 2018:5; Du Plooy-Cilliers et al., 2014:160; Kumar, 2014:181). A total of 29 survey questionnaires [please see Appendix E] were received from lecturers across the five accredited HEIs offering Construction Management and Quantity Surveying or related programmes (see lecturer respondent profile in Table 4.1).

Table 4.1: Respondent experience – survey

Experience	Industry Experience	Lecturing Experience	Professional statuses	
5 years or less	10	14	Professional (Pr) QS	5
6 – 10 years	7	5	Candidate (Can) QS	5
11 – 15 years	5	7	Pr Construction Project Managers	3
16 to 20 years	1	2	Can Construction Project Managers	2
21 to 25 years	2	1	Pr Construction Managers	3
Above 25 yrs of exp.	3	0	Can Construction Managers	1
			Other	8

Table 4.1 presents the number of respondents per category, and by using a conservative figure of 14 permanent lecturers per department, it was estimated that the sample of 29 represents approximately 34.8% of the population of lecturers involved in these South African accredited programmes.

Qualitative data: The quantitative data informed the subsequent qualitative analysis, with the second phase incorporating focus-group discussions and in-depth interviews with lecturers at five HEIs, where Quantity Surveying and Construction Management undergraduate programmes are taught (Tavory & Timmermans, 2014:80). The qualitative data were collected through two focus-group discussions and seven personal interviews. The 18 (16.1%) respondents that participated in the discussions included 13 lecturers, three senior lecturers and two professors, of which 13 were professionally registered. The enquiry delved deeper into the findings from the quantitative phase, providing more affluent, more prosperous, more detailed insights into the participants' attitudes, interpretations, behaviours and preferences towards Construction 4.0 and GAs (Strydom & Bezuidenhout, 2014:183). The enquiry focused on exploring specific Construction 4.0 attributes or generic GAs alongside associated knowledge, skills, and competencies (KSC); examining the linearity of pedagogical approaches pertaining to the project life cycle; assessing the influence of Construction 4.0 attributes on the curriculum; and investigating curriculum and pedagogical strategies to enhance students' self-directed learning ('why').

4.4 DATA ANALYSIS

The quantitative data were analysed using IBM's SPSS programme, which provides a foundational understanding of lecturers' perspectives on integrating graduate attributes (GAs) within the South African QS & CM curricula. Utilising simple descriptive statistics (Creswell & Creswell, 2018:173), this section presents the analysis of the data by focusing on the relationship between knowledge, skills, competencies, and attributes (KSCA) and the curriculum, pedagogy, assessments, and environment (CPAE). Additionally, it examines the perceived proximal development of KSCA over the academic tenure of students. A Cronbach's alpha (Coefficient alpha) analysis assisted in assessing the validity of the data and interpretation, with 0.7 taken as a lower threshold (Johnson & Christensen, 2014:170).

The qualitative data were first transcribed utilising OtterAI (2024:online) before being analysed through a reflexive thematic analysis (TA) as prescribed by Braun and Clarke (2022:5). The process of coding before searching for the themes (Maguire & Delahunt, 2017) utilised Ghat-GPT4o to identify potential codes and subsequent theme identification utilising NVivo. The topic summarises the discussions guided by the coding process and theme identification (Braun & Clarke, 2022:77), utilising an inductive TA (Braun & Clarke, 2022:9), as discussed further in 4.4.2.

Combining these methods allowed for a thorough exploration of the research questions, with the qualitative data helping to contextualise and explain the results. The data analysis included triangulation (Johnson & Christensen, 2014:307) and reflexibility (Johnson & Christensen, 2014:308) to improve study validity.

4.4.1 Quantitative data: lecturers' perspective

Utilising simple descriptive statistics (Creswell & Creswell, 2018:173-174), this section presents the analysis of this data, focusing on three data sets as depicted in 4.4.1.1 to 4.4.1.3 by first establishing the baseline of the lecturers' perception towards C4.0 and graduate attributes (GAs) before investigating the relationship between knowledge, skills, competencies, and attributes (KSCA) and the curriculum, pedagogy, assessments, and environment (CPAE). The last data set investigates the perceived proximal development of KSCA over the academic tenure of students.

4.4.1.1 The placement of C4.0 and GAs

A series of questions were presented to the respondents to establish the placement and relevance of C4.0 within QS and CM programmes, talking to the historicity of the CHAT framework (Engeström & Sannino, 2010:3). A series of questions were posed to respondents on a five-point Likert scale (1 – not relevant; 2 – somewhat relevant; 3 – relevant; 4 – essential [Vital]; 5 – Not familiar). An overall Cronbach Alpha score of 0.669 was seen in the data, indicating a moderate consistency (Johnson & Christensen, 2014:170), which is represented in the percentage breakdown below (see Figure 4.4).

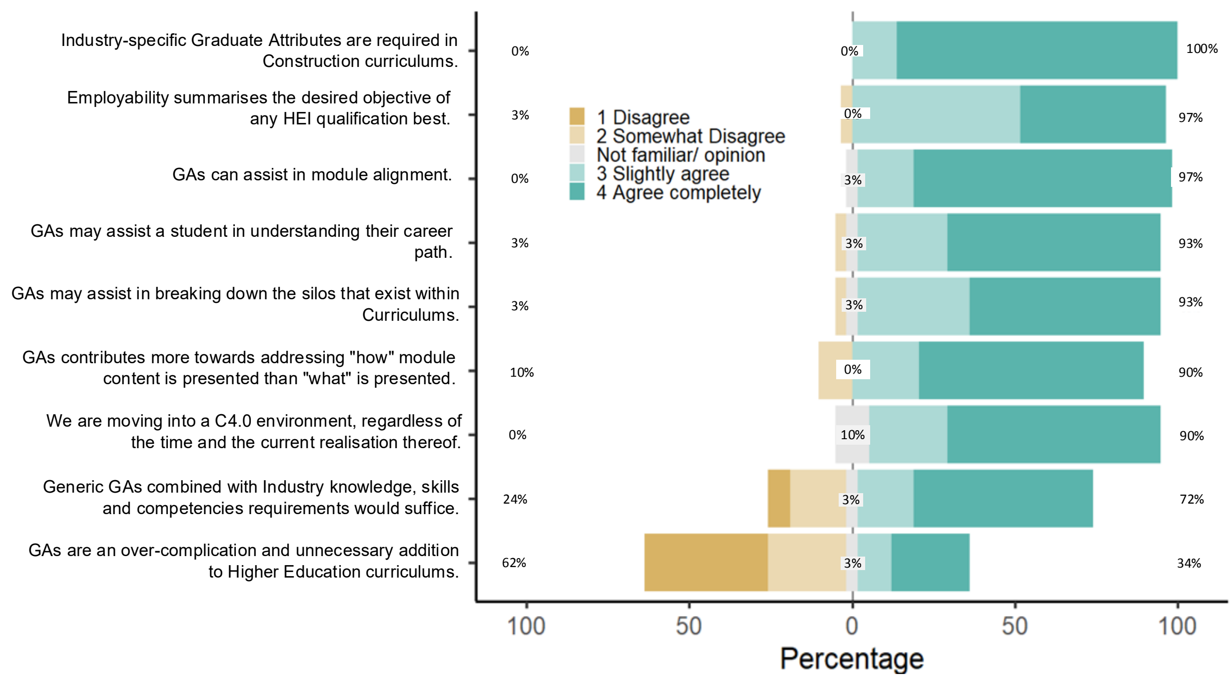

Figure 4.4: The placement of C4.0 Attributes

In Figure 4.4, HEI lecturers highlight the significant role of industry-specific Graduate Attributes (GA) in construction curriculums, with strong support for their necessity in aligning modules and enhancing employability. GAs are perceived as essential in shaping pedagogical approaches and assisting students in understanding career paths. There was some variation regarding the urgency of Construction 4.0 integration, but overall, GAs are not viewed as a major over-complication. The moderate reliability (Cronbach Alpha = 0.669) highlighted the diverse experiences and interpretations of C4.0 and C4.0 GAs processes in the future.

4.4.1.2 KSCA against CPAE (refer to Section 4.2.4)

The comparison of curriculum, pedagogy, assessments, and environment (CPAE) contributed to the acquisition of KSCA. The table summarises the mean scores for each aspect of the mean scores ranging from 1 (not relevant) up to 4 (essential [Vital]). The Cronbach Alpha score of 0.922 and the low standard deviations indicated consistency within the data:

Table 4.2: Observed KSCA and CPAE relationship (refer to Section 4.2.4)

KSCA Against CPAE	Curric./ Cont.	Pedag.	Assess.	Env.	St. dev.	
Knowledge (e.g. procurement processes, planning and control processes, etc.)	3.62	3.24	3.55	3.45	0.17	**Combined: N=29**
Skills (e.g. quantity take-offs, rate-buildups, etc.)	3.55	3.28	3.52	3.31	0.14	
Competencies (e.g. quality management, financial management, etc.)	3.32	3.19	3.14	3.32	0.09	
Graduate Attributes – as depicted above	3.48	3.36	3.41	3.25	0.10	
Construction 4.0 requirements	3.45	3.21	3.31	3.31	0.10	
Average	**3.48**	**3.26**	**3.39**	**3.33**		

In Table 4.2, the relationship between KSCA and CPAE reveals consistent alignment across curriculum content, pedagogy, assessments, and learning environments, with knowledge-related elements (Mean = 3.62) rated highest in content delivery. Skills and competencies also performed well across pedagogy and assessments, indicating strong support for practical application (Mean = 3.55 and 3.52). Graduate Attributes and

Construction 4.0 requirements showed balanced integration across all categories, emphasising their growing importance in construction education.

4.4.1.3 Proximal development of KSCA (refer to Section 4.2.4)

Table 4.3 presents the perceived development of KSCA across different academic years based on the mean scores ranging from 1 – not relevant to 4 – essential (Vital). The Cronbach alpha (0.901) and standard deviations indicated consistency within the data:

Table 4.3: Perceived proximal KSCA development during the students' tenure

Proximal Development of KSCA	Yr 1	Yr 2	Yr 3 (exit year 1)	Yr 4 (hon. exit yr 2)	St. Dev.	Combined: N=29
Knowledge (e.g. procurement processes, planning and control processes, etc.)	3.45	3.62	3.48	3.52	0.07	
Skills (e.g. quantity take-offs, rate-buildups, etc.)	3.38	3.50	3.72	3.69	0.16	
Competencies (e.g. quality management, financial management, etc.)	2.97	3.38	3.72	3.79	0.38	
Graduate Attributes – as depicted above	3.14	3.38	3.66	3.72	0.27	
Construction 4.0 requirements	3.07	3.21	3.62	3.71	0.31	
Average	**3.20**	**3.42**	**3.64**	**3.69**		

The data displayed in Table 4.3 show that existing practices align well with the expected progression (Barrie, 2007:445). However, knowledge and skills showed some inconstancy in growth, indicating that constructive alignment (Angelo, 2021; Hill et al., 2021) can assist in aligning these criteria. Notably, however, they had the lowest standard deviation – 0.07 and 0.16, respectively – indicating consistency in their understanding. However, competency, GA, and C4.0 requirements showed a higher standard deviation but had a good alignment towards proximal growth, indicating some indifference between respondents and some diversity of understanding and comprehension of how they align with the curricula.

The findings suggest that the current pedagogical frameworks are well grounded; they can become more effective by focusing on a backward design focusing on the HEI's graduate attributes and constructive alignment (Angelo, 2021; Hill et al., 2021) through understanding the movement from a teaching-focused (2GAT) to a learning-focused

(CHAT/3GAT) pedagogy (Spinuzzi, 2020:26; UFS, 2019:4). However, this suggests that more can be done through the *community* of learning in these alignments.

4.4.2 Analysing qualitative inquiry into lecturers' perspectives

The qualitative findings of this research are based on interviews and focus groups conducted with South African lecturers from various higher education institutions (HEIs), centred around the four key objectives listed in the methodology section. The thematic analysis revealed several key themes (as shown below) critical for the integration of Construction 4.0 attributes into the curriculum for Construction Management (CM) and Quantity Surveying (QS) programmes. These themes align with the broader literature on the need for graduate attributes, practical experience, technological adoption, and curriculum design in higher education, as justified below.

4.4.2.1 Key themes and frequencies

By coding the semantic themes (Maguire & Delahunt, 2017), 20 sub-themes (Annexure 4.2) could be identified and grouped into five main themes (Table 4.1). Each theme is defined and supported by direct quotes from the lecturers, illustrating their perspectives on the critical graduate attributes needed to enhance teaching and development in the QS and CM curricula:

Table 4.4: Summary of key themes and frequencies

Theme	Freq.	Definition and Relationship to the Research Question
Graduate Attributes and Industry Expectations	23	Participants emphasised integrating critical GAs like professionalism, adaptability, and problem-solving, ensuring students are equipped for the dynamic construction industry. Aligning education with industry needs prepares graduates to be adaptable, innovative, and collaborative.
Practical Learning and Industry Engagement	13	Participants highlighted the importance of early, hands-on learning and industry exposure to bridge the gap between theory and practice. This approach ensures that students are industry-ready and capable of applying their knowledge in real-world scenarios.
Adoption of Construction 4.0 and Digital Technologies	17	Integrating C4.0 technologies and digital tools to modernise education, enhance collaboration, and foster adaptability will prepare students to navigate and lead technological advancements in the construction industry.
Balanced Curriculum Design and Continuous Assessment	17	Participants stressed the need for a curriculum that balances theory with practical application and uses continuous assessment to improve learning outcomes. This approach ensures that students can apply theoretical concepts in real-world contexts.
Meeting Evolving Industry Challenges	16	Participants acknowledged the Industry's evolving needs and challenges in adopting new technologies, promoting innovation, and developing a holistic understanding of construction. Prepares students to meet future challenges and adapt to industry changes.

Graduate Attributes and Industry Needs: While the quantitative data illustrate the strong agreement among respondents regarding the necessity of embedding GAs in the curriculum, such as professionalism, adaptability, and problem-solving, it is further reinforced by qualitative findings. In Table 4.4, lecturers emphasised the value of GAs in preparing students for the complexities of the construction industry. One lecturer remarked (*L5*),

> *I give employers the students who ask the most questions and show initiative, not necessarily those with the highest marks.*

Another said (*L7*),

> *GA will greatly assist in breaking down the silos within and how students think about planning a project, considering other stakeholders, and how to interact with them.*

The discussions support the notion that GAs are essential for fostering the adaptability and critical thinking needed to thrive in a dynamic environment, echoing the importance of aligning education with industry needs, as highlighted in the quantitative data.

Practical Learning and Industry Engagement: The quantitative results show that practical learning and industry exposure are crucial for bridging the gap between theory and practice. Lecturers advocated early industry engagement through vocational work and site visits. For instance, one lecturer suggested (*L3*),

> *If I had my way, I would insist on four weeks of vocational work before students start their first year.*

Another added (*L8*),

> *I realised that the more practical example they get, either being on-site or getting somebody from the site to come and give them a presentation, which all assists in understanding drawings.*

The discussions underscore the necessity of Work-Integrated Learning (WIL), which is embedded in the model as a critical driver for developing industry-ready graduates. The interaction between practical learning and industry engagement ensures that students are equipped with theoretical knowledge and understand how to apply it in real-world scenarios.

Digital Transformation and Curriculum Evolution: Integrating Construction 4.0 technologies and digital tools was a recurring theme in the qualitative and quantitative findings. Lecturers noted that students had to be capable of adapting to rapidly changing technologies, stating (*L6*),

> *Technology disrupts what you've just taught them … they should be able to adapt and identify trends.*

This interaction between digital literacy and curriculum design within the model supports the ongoing modernisation of construction education. The qualitative feedback aligns with the quantitative emphasis on the need for curricula that foster digital adaptability, reinforcing the model's inclusion of Construction 4.0 as a critical area for future-proofing students.

Balanced Curriculum Design and Continuous Assessment: The quantitative analysis emphasises the need for a balanced curriculum that integrates theory and practical skills while employing continuous assessment to enhance learning outcomes. Lecturers echoed this sentiment in the qualitative data, highlighting the importance of assessments that measure knowledge and practical application. One lecturer observed (*L4*),

> *Students should have a sense of base knowledge of the subject matter but, more importantly, teach students how to continue learning and adapt to new knowledge, new technologies, and techniques for doing things.*

This interaction suggests that continuous assessment is a mechanism to assist in certain areas and allow students to consistently develop the skills necessary for industry success (*L10*),

> *You cannot pass a term without being able to apply what you have learned.*

Evolving Industry Challenges and Curriculum Responsiveness: Both the qualitative and quantitative data revealed that the construction industry faces significant resistance to adopting new technologies, which presents challenges for preparing students. One lecturer (*L9*) described the Industry as *"stuck in the dark ages",* while another emphasised (*L2*),

> *We need students who can engage with industry challenges and be innovative.*

This interaction highlights the importance of curriculum responsiveness to evolving industry needs, ensuring students are prepared for current demands and future disruptions.

4.5 DISCUSSION

Participants emphasised the importance of incorporating GAs, such as critical thinking, problem-solving, adaptability, and lifelong learning, into the curriculum, as suggested by the WEF (2015). However, they applied them very linearly towards the interaction of the CHAT, towards the tools and signs (individual modules – within silo), the subject (the student within the discussions), and the outcome (object), focusing more on the 2GAT interactions. The quantitative data indicated that while knowledge and skills development is well-supported, there is a need to enhance the environment (Angelo, 2021) to support the development of graduate attributes. These findings align with the broader literature that stresses the importance of embedding GAs into all aspects of the curriculum to prepare students for the complexities of the CBE (UFS, 2019). Focused practical experience and early industry exposure were highlighted as crucial for student development, corresponding to the SACPCMP's (2020) prescriptions. Lecturers noted that hands-on learning and site visits help students understand real-world applications of their theoretical knowledge. This approach is essential for bridging the gap between academic learning and industry requirements, ensuring graduates are well-prepared for professional practice. Integrating new technologies, including C4.0 tools, was identified as a significant development theme (Sawhney et al., 2020). Lecturers recognised the potential of these technologies to enhance the learning experience and better prepare students for modern construction practices. However, the slow adoption of these technologies due to the Industry's (South African) traditionalism was also noted, highlighting the need for curricula to be grounded when adopting technological advancements. Effective curriculum design and assessment methods are critical for balancing theoretical knowledge with practical skills (SACQSP, 2015). Continuous assessment was suggested in some cases to ensure ongoing student development and avoid delays in progress. The need for a structured curriculum that integrates theoretical and practical components was also emphasised. Two items that did not prominently present themselves within the data were the importance of the development of professional attributes (PA) as suggested by Dhunpath et al. (2021) and how to measure and align areas such as innovation within curricula (Sawhney et al., 2020).

The study's premise was to develop a model for the decision-making process of developing C4.0 Attributes within South African QS and CM programmes based on the CHAT. From the literature, the definitions of the artefacts could be made; however, the interaction between Industry and academia was somewhat unclear, with different possible connection points on the CHAT. During reflection on a latent theme [please refer to Annexure 4.1] – the silos that exist within departments and pedagogical practices – the interaction between *Tools and signs* and the *Subject* was ruled out because of the isolation it might cause within the activity system. The observed understanding of proximal development (Stewart, 2021:18) underscores this conclusion, which lecturers understood but struggled to measure and apply, corresponding with Barrie (2007). Thus, the interaction between points is suggested as the *Community*, enabling a more informed

Object that leads to more precise *Rules* for the *Subject* on the *Division of Labour* for improvement of the implementation of the "*Tools and signs*" and subsequent improved *Mediation of Artefacts* within the CHAT.

4.6 CONCLUSION AND RECOMMENDATIONS

In conclusion, enhanced mediation of the artefacts within the teaching-learning process is essential, achieved through effective constructive alignment and communication. The study highlights the critical role of Graduate Attributes (GA) in preparing QS and CM students for the Construction Built Environment (CBE). By integrating GA's into the curriculum, Higher Education Institutions (HEIs) can enhance the understanding of the knowledge, skills and competency relationship, thus enhancing the employability and adaptability of their graduates by stimulating more excellent mediation within CBE HEI departments and staff. The findings suggest that while the current curriculum, pedagogy, assessment and environment (CPAE) support the development of knowledge and skills, there are opportunities to improve the environment to support GAs, deepening competencies, while developing specific C4.0 Attributes. It emerged that the object of becoming C4.0 ready or compliant is not only a Graduate 'objective' but also a HEI object. Annexure 4.1 proposes a framework from which the interactions between academia and Industry align their 'objective' towards producing employable and life-long learners as agents within the CBE.

The recommendations for improving curriculum alignment with the demands of Construction 4.0 (C4.0) in Quantity Surveying (QS) and Construction Management (CM) education underscore the need for integrated and actionable strategies. Firstly, embedding specific C4.0 Graduate Attributes (GAs) across curricula is pivotal, focusing on developing critical thinking, problem-solving, and lifelong learning skills. Enhancing practical learning experiences through industry collaboration and hands-on opportunities further bridges theoretical knowledge with real-world applications. To ensure measurable progress, clear milestones for integrating C4.0 technologies should be established, guiding students' development systematically. Continuous assessment methods can monitor this progress, providing iterative feedback to support ongoing learning. The

Cultural Historical Activity Theory (CHAT) framework is highlighted as a valuable tool for aligning curriculum design with epistemological and pedagogical principles, promoting a structured approach to integrating GAs. Future research should refine these models, particularly in areas like expansive learning (EL) and multi-actor collaboration (Engeström, 2001), such as change laboratories (Garraway, 2021), to ensure adaptability to evolving industry demands. These recommendations aim to create a cohesive educational framework that prepares graduates for the challenges of a rapidly digitising construction sector, ensuring their employability and professional growth.

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ANNEXURE 4.1

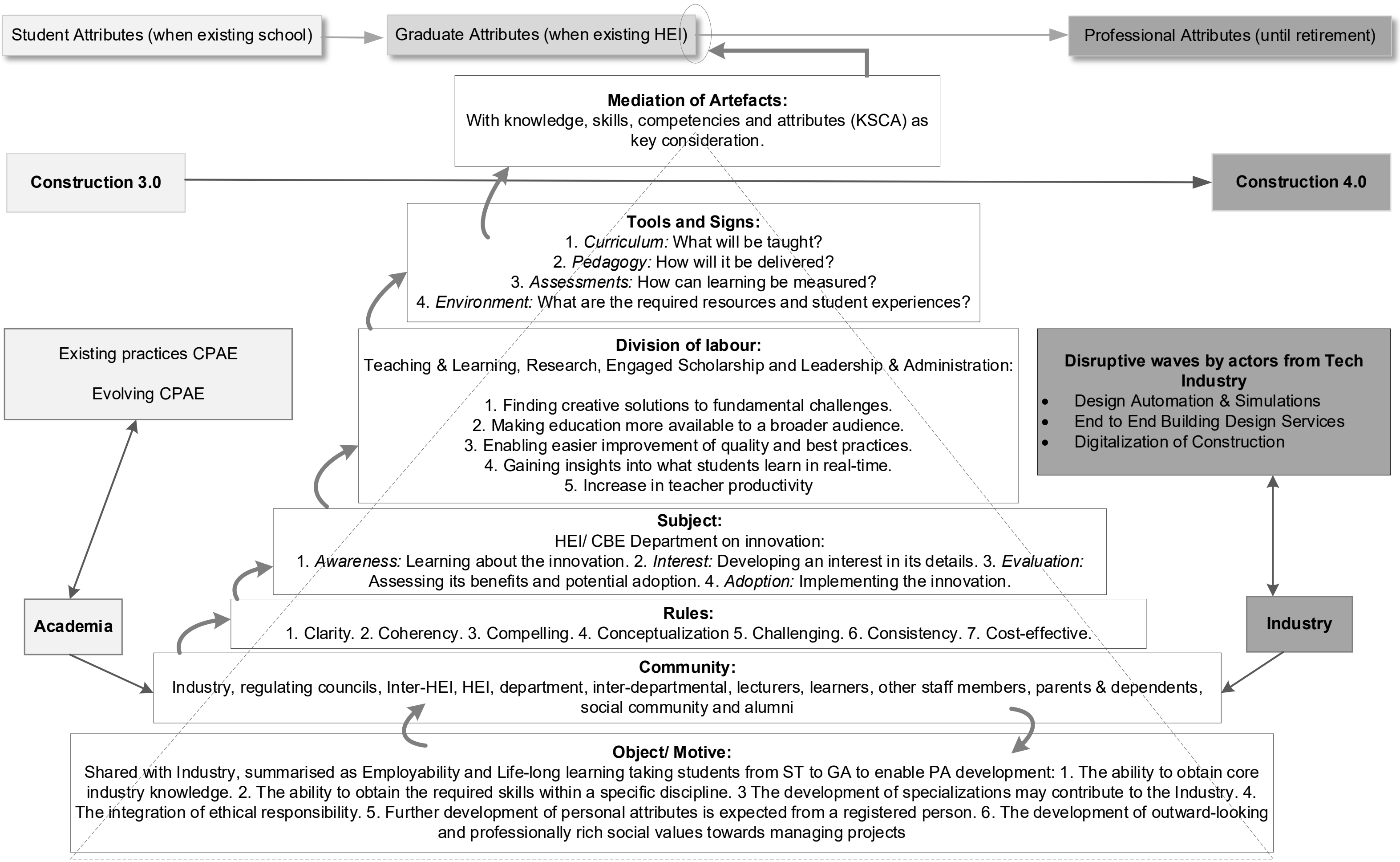

Figure 4.5: CHAT-based framework for integrating graduate attributes and C4.0 in South African CBE curriculum

Sources: Adopted from Engeström (2001); Felten (2013); Fujioka (2014); Gelmon et al. (2012; Griesel and Parker (2009); Hauptfleisch (2024); Jones and Hashim (2014); Maritz and Siglé (2016); Naidoo (2014); O'Neill et al. (2023); Saad (2019); SACPCMP (2020); Sawhney et al. (2020); UFS (2019); WEF (2015).

ANNEXURE 4.2

Table 4.5: Initial round of theme development

Theme	Sub-themes	Freq	Definition and Relationship to Study
Graduate Attributes and Industry Expectations	Professionalism and Soft Skills	14	Emphasises professionalism, adaptability, critical thinking, and lifelong learning, aligning with industry needs for employability and preparing graduates for Construction 4.0.
	Critical Thinking and Problem-Solving	5	It focuses on fostering problem-solving skills essential for the construction industry and ensuring that graduates are capable of critical thinking to meet industry challenges.
	Adaptability and Lifelong Learning	2	Highlights the importance of teaching students to adapt to new technologies and continuously learn, ensuring they remain relevant in a rapidly evolving construction industry.
Practical Skills and Industry Exposure	Early Industry Exposure	3	Emphasises early exposure to industry environments, helping students apply theoretical knowledge in real-world settings and develop practical competencies needed for success.
	Hands-on Learning	9	Underlines the importance of practical projects and site visits to bridge the gap between theory and practice, preparing students to handle industry demands.
	Industry Collaboration	1	It highlights collaboration between academia and industry to create work-ready graduates, align education with industry expectations, and enhance employability.
Technological Adoption and Digital Transformation	Integration of New Technologies	7	Focuses on incorporating new technologies and digital tools into the curriculum to enhance learning, preparing students for the digitalisation of the construction industry.
	Digital Tools and C4.0 Technologies	2	Explores the role of digital tools like BIM in shaping students' learning experiences, ensuring early exposure to technology prepares them for the industry's advancements.
	Sequential vs. Reverse Teaching Approach	5	Discusses whether to teach construction stages sequentially or in reverse, suggesting that reverse teaching helps students better understand the "why" behind processes, fostering adaptability and critical thinking.
Curriculum Design and Assessment Methods	Balanced Curriculum	6	Stresses the need for a curriculum that balances theory with practical skills, ensuring students are well-prepared for both academic and real-world challenges.
	Continuous Assessment	3	Emphasises continuous assessment to ensure student progress and knowledge retention, preventing gaps in learning and enhancing overall academic performance.
	Theoretical and Practical Integration	5	Highlights the importance of integrating theory with practical application, ensuring students can apply academic concepts effectively in professional contexts.
Industry Needs and Challenges	Evolving Industry Needs	5	Focuses on how the industry's changing needs should shape the curriculum, ensuring students are prepared for emerging technologies and methodologies in construction.
	Resistance to Change	7	Discusses the challenges of overcoming resistance to new technologies in construction, highlighting the need to prepare students to promote innovation and manage change effectively in their careers.
	Holistic Understanding of the Construction Process	4	Promotes a comprehensive understanding of the entire construction process, helping students see the interconnectedness of each phase and preparing them for real-world project management.

5
ARTICLE 3: GRADUATE ATTRIBUTES' CONTRIBUTION TO IMPROVED COLLABORATION WITHIN QUANTITY SURVEYING AND CONSTRUCTION MANAGEMENT CURRICULA IN THE 4IR ERA

Proposed Journal: *Acta Structilia*[5]

ABSTRACT

The Fourth Industrial Revolution (4IR) is transforming industries globally, including the construction sector, through Construction 4.0 (C4.0). The study investigates the critical role of Graduate Attributes (GAs) within the South African Construction Built Environment (CBE) in adapting to these advancements and the interaction between industry and academia. Adopting an explanatory sequential, mixed-method approach, the data were collected from 288 registered Quantity Surveyors (QSs), Construction Managers (CMs) and Construction Project Managers (CPMs), supplemented by qualitative insights from ten in-depth interviews. The findings reveal that GAs such as adaptability, critical thinking, and problem-solving are essential for navigating the technological and collaborative demands of C4.0. Despite the significant focus on knowledge and skills in current curricula, the study underscores the critical importance of attributes in fostering lifelong learning, resilience, and innovation. Using the Cultural Historical Activity Theory (CHAT) as an analytical lens, this research offers a framework to realign higher education curricula with industry needs, emphasising the interplay of knowledge, skills, competencies, and attributes. The study contributes to global discussions on aligning educational outcomes with industry requirements in the context of 4IR. It provides insights to recalibrate South African higher education curricula, ensuring graduate preparedness and enhancing the employability of future construction professionals.

Keywords: Construction 4.0, Curriculum Alignment, Graduate Attributes, Graduate Employability and Adaptability, South African Construction Built Environment, Activity Theory.

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[5] https://journals.ufs.ac.za/index.php/as/index

Note: The Construction Industry (CI) and Construction Built Environment (CBE) terminology are used interchangeably, with CI primarily denoting the global viewpoint, while CBE pertains specifically to the South African context. Construction Management (CM) and Construction Project Management (CPM) are combined as CM to assist with the flow of the discourse.

5.1 INTRODUCTION

The Fourth Industrial Revolution (4IR) is reshaping industries worldwide, including the construction sector, by adopting Construction 4.0 (C4.0). Collaboration between Higher Education Institutions (HEIs) and the Construction Industry (CI) is vital for equipping graduates with the skills needed for the rapidly evolving workplace (Aliu et al., 2023:474; McCord et al., 2023:13). In South Africa, this collaboration faces unique challenges due to political and socio-economical complexities, and institutional structures within HEIs (Garraway, 2020:1). While global trends emphasise aligning pedagogic standards to enhance employability, implementation in South Africa remains intricate (Ramnund-Mansingh & Reddy, 2021:206). This study explores how Graduate Attributes (GAs) can address these 4IR challenges in the South African Construction Built Environment (CBE) from a Quantity Surveying (QS) and Construction Management (CM) perspective, culminating in a proposed framework for interaction between industry, HEIs and students towards graduate employability and adaptability.

C4.0 introduces advanced technological systems, including cyber-physical systems (CPS), with Building Information Management (BIM) as a central component (Sawhney et al., 2020:14; Begić & Galić, 2021:17). However, BIM maturity and C4.0 adoption vary widely across South African construction firms, reflecting disparities in exposure and implementation (Orstavik et al., 2015:103; Venter et al., 2021:149). These inconsistencies challenge HEIs to produce graduates who are both employable and adaptable to technology-driven environments (O'Neill et al., 2023:1; UFS, 2019:2). In the process of innovation diffusion, Rogers (2003:68-218) outlines how knowledge acquisition leads to skills development, with attributes like openness to innovation determining the pace of application. It is concluded that competence represents the culmination of this process, reflecting sustained and effective use of innovation.

In construction higher education, the integration of knowledge, skills, competencies, and attributes (KSCA) is often explored, *though their definitions frequently overlap* (Aliu et al., 2023; 2024; Kaewsri & Tongthong, 2014; Vaz-Serra & Mitcheltree, 2021). QS and CM regulatory councils emphasise competencies as measurable outcomes achieved through prescribed knowledge and skills, often neglecting the attitudes and behaviours necessary for developing these competencies (CIOB, 2018; RICS, 2019; SACPCMP, 2020; SACQSP, 2014). GAs are defined as the integration of attitudes and behaviours that aim to prepare students to navigate the challenges of 4IR (Griesel & Parker, 2009; UFS, 2019:8). This aligns with the CI's growing demand for soft skills like adaptability communication, and ethical reasoning (Van Heerden et al., 2023:2). Additionally, Warier (2014:19) supports the existing structures from regulating councils by defining competence as a triad of knowledge, skills, and attributes, positioning attributes as critical to sustained competence.

Forming part of a larger study that includes the student and HEIs voices, this study examines the relationship between KSCA and the adoption of C4.0 technologies within the South African CBE, addressing the primary research question: What is the relationship between knowledge, skills, competencies, and attributes and its effect on the adoption of Construction 4.0 technologies among registered persons (i.e. QS & QM in the context of this research)? The study hypothesises that knowledge provides the theoretical foundation, skills enable practical application, competencies ensure effective task performance, and attributes foster lifelong learning and professional growth.

Through an explanatory sequential method, the research begins with quantitative data collection and analysis, followed by qualitative data to deepen the findings (Creswell & Creswell, 2018:218). Cultural Historical Activity Theory (CHAT) provides a triangulation lens for the study, emphasising expansive learning (EL) through interactions between multiple activity systems (Engeström, 2001:136). This approach highlights the resolution of systemic contradictions through innovative activities (Engeström & Sannino, 2010:1-20), highlighting critical focal points for further development.

By focusing on registered professionals with the South African Council for the Quantity Surveying Profession (SACQSP) and the South African Council for the Construction Management Professions (SACPCMP), the study aligns with the exit levels prescribed by the South African Qualifications Authority (SAQA) for NQF Level 7 (Bachelor's degree) and Level 8 (Honours degree) (SAQA, 2023:online; SACPCMP, 2022; SACQSP, 2014). This targeted scope provides insights into the South African CBE's collaborative discourse for C4.0 and C5.0 development.

5.2 LITERATURE REVIEW BASED ON THEORETICAL UNDERPINNINGS

The construction industry (CI) is challenged to align its workforce's competencies with rapidly evolving technological and professional demands. This necessitates critically examining how key constructs – technical knowledge, interpersonal skills, and adaptability – intersect within higher education curricula to prepare graduates for the realities of Construction 4.0 (C4.0) and beyond (Ahmed et al., 2014). Higher education institutions (HEIs) are pivotal in bridging this gap by embedding Graduate Attributes (GAs) that integrate technical expertise, emotional intelligence, and lifelong learning skills, which are increasingly valued by employers (Hill et al., 2016; Vaz-Serra & Mitcheltree, 2021). Curricular development involves collaboration among educators, students, and industry stakeholders to align pedagogy with professional qualifications (Garraway, 2020:239; Hill et al., 2021:54). This literature review investigates the interplay of these constructs, addressing the foundational question of how GAs can support the development of competencies needed for professional success in the CI while aligning with theoretical perspectives such as expansive learning (EL) within the activity theoretical framework.

Foundational to any construction curricula, knowledge within the CI spans technical areas such as materials, construction methods, scheduling, and site management, alongside regulatory and legal frameworks (McCord et al., 2023:6-10). Competencies combine these technical and managerial skills with soft skills like teamwork, critical thinking, and emotional intelligence, which are essential for managing stress and ensuring professional well-being (Sunindijo & Kamardeen, 2020). Employability in the built environment further depends on work-integrated learning and adapting to technological advancements (Aliu et al., 2023). Thus, Graduate Attributes (GAs) emerge as a key component in equipping students with these skills while fostering lifelong learning and adaptability (Anderson, 2017:4-18; Bitzer & Withering, 2020:4-18).

The role of GAs extends beyond discipline-specific skills to encompass attitudes and behaviours, aligning with the CI's increasing demand for qualities like adaptability, communication, and ethical reasoning (Van Heerden et al., 2023:2). Warier (2014:119) positions GAs as integral to competency, emphasising the interplay of knowledge, skills, and attributes as shown in Figure 5.1:

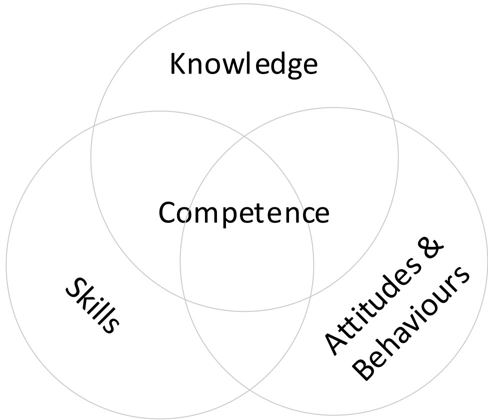

Figure 5.1: Graduate attributes integral to competence

Source: Warier (2014:19)

Within the South African context, regulatory councils such as the SACQSP and SACPCMP provide competency frameworks that prioritise knowledge and skills but often underemphasise behaviours and attitudes necessary for professional success (CIOB, 2018; RICS, 2019; SACPCMP, 2020; SACQSP, 2014). These guiding frameworks have become so foundational to the professional development of Quantity Surveyors (QS), Construction Managers (CM) and Construction Project Managers (CPM) (Hauptfleisch, 2024:24) that the transpiring changes of the 4IR/C4.0 (Lu, 2017:1-10; Sawhney et al., 2020:3) and the HEIs' emphasis on GAs consideration (Anderson, 2017:4-18) common ground should be clarified.

The literature review subsequently builds up to a theoretical framework used in the empirical study, as depicted in Figure 5.2. An EL perspective (as summarised in Section 5.2.3) is utilised as a lens for data triangulation. The literature review explores the Construction 4.0 framework and the role of diffusion of innovation before considering the role of GAs within the KSCA relationship and finally positioning EL within the activity theoretical framework.

5.2.1 Transformative shifts in the built environment: leveraging Construction 4.0 and innovation diffusion for enhanced efficiency, sustainability, and adaptability

The Fourth Industrial Revolution (4IR) has introduced transformative shifts across industries, including the construction sector. Construction 4.0 (C4.0) integrates advanced technologies such as automation, digitisation, and cyber-physical systems (CPS), enabling greater efficiency, sustainability, and adaptability in the built environment (Ślusarczyk, 2018:236; Lu, 2017:1-10). These advancements influence job roles and skill requirements, emphasising the need for HEIs to align curricula with industry expectations.

The concept of Physical-Digital-Physical Transformation (PDPT) aligns closely with traditional Project Life Cycles (PLC) in construction, bridging existing assets and new developments through digital design and physical implementation (Hauptfleisch, 2024:11; Sawhney et al., 2020:5). Technologies such as Building Information Management (BIM), robotics, and augmented reality (AR) exemplify the interplay between digital and physical tools within the C4.0 framework, as depicted by Sawhney et al., 2020:15 in Table 5.1:

Table 5.1: Digital and physical components of the C4.0 Framework

Digital:	Physical:
Building Information Management (BIM)	Robotics and Automation
Common Data Environment (CDE)	Sensors
Unmanned Aerial Systems (UAS)	Internet of Things (IoT)
Cloud-based Project Management	Workers with wearable sensors
Augmented Reality (AR) or Virtual Reality (VR)	Actuators
Artificial Intelligence (AI)	Additive manufacturing
Cybersecurity	Offsite Construction
Big Data and Analytics	Equipment with sensors
Blockchain	
Laser Scanners	

Source: Sawhney et al. (2020:15)

Adopting the technologies outlined in Table 5.1 presents several challenges, such as high initial investments, skill shortages, and resistance to change (Osunsanmi et al., 2020; Begić & Galić, 2021:7). Rogers' Law of Diffusion of Innovation (LoDI) theory (Rogers, 2003:170) offers a comprehensive framework to understand the adoption process, which unfolds through stages of knowledge, persuasion, decision, implementation, and confirmation. This framework is instrumental in aligning HEI curricula with the dynamic needs of industry, thereby ensuring that graduates are equipped to engage effectively with technological advancements. By comprehensively understanding the LoDI and the associated benefits and challenges of the C4.0 developments, a stronger sense of agency can be fostered and maintained within the context of CBE, as emphasised by Koc et al. (2020:472-474). Table 5.2 further elaborates on these benefits and challenges, as outlined by Begić and Galić (2021:7):

Table 5.2: Construction 4.0 main benefits vs main challenges

Benefits	Challenges
Adoption of the lifecycle-building approach.	High initial investments.
Reduction of waste and the improvement of efficiency.	Lack of skilled workforce and the need for enhanced work skills.
Horizontal, vertical, and longitudinal integration.	Deficiency of globally agreed standards for the Construction industry.
Cost and time reduction.	Data security, i.e. cybersecurity.
Improved safety performance.	Lack of knowledge about Construction 4.0.
Enhanced quality of buildings.	Resistance of the construction industry to change.
Improvement of the poor image of the construction industry.	

Source: Begić and Galić (2021:7)

It is evident that the adoption of Construction 4.0 (C4.0) is accompanied by inherent uncertainties regarding the speed and effectiveness of integrating these technologies into current practices. These uncertainties stem from factors such as the lack of a skilled workforce, the high initial investment required, and the need for globally agreed-upon standards (Osunsanmi et al., 2018:154). However, despite these challenges, the industry's ability to adapt – through collaboration between academia, industry, and emerging technology developers – will be crucial for overcoming these obstacles. As depicted in Figure 5.2, it is essential for the curricula of Higher Education Institutions (HEIs) to evolve to include the development and implementation of these new technologies as well as the practical skills and competencies necessary to address the specific challenges they present.

5.2.2 Conceptualising Graduate Attributes for South African CBE

Barrie (2004:262) defines GAs as

> the qualities, skills and understandings a university community agrees its students should develop during their time with the institution. These attributes include but go beyond the disciplinary expertise or technical knowledge traditionally formed the core of most university courses.

Thus, GAs are central in equipping students with the competencies required to adapt to C4.0 (Staunton et al., 2021). These attributes include adaptability, communication, ethical reasoning, and critical thinking – skills increasingly valued in the construction industry (Hill et al., 2016:155; Van Heerden et al., 2023:2).

Additionally, Figure 5.2 illustrates the integration of GAs within the KSCA framework, emphasising the balance between traditional professional standards and the emerging demands of C4.0. This framework facilitates a learner-centred approach, as suggested by the UFS (2019:4) and supported by Anderson (2017:6) when considering that GAs are defined as the community agreed-upon outcomes. GAs extend beyond technical knowledge and include qualities that may differ among students, influenced by their diverse backgrounds and learning methods (Bitzer & Withering, 2020:15). By introducing an additional layer to the vertical and horizontal alignment of the curriculum (Frake-Mistak et al., 2023:4 & 7), it becomes increasingly possible to plan effectively and evaluate towards the intended outcome (Barrie, 2007:457).

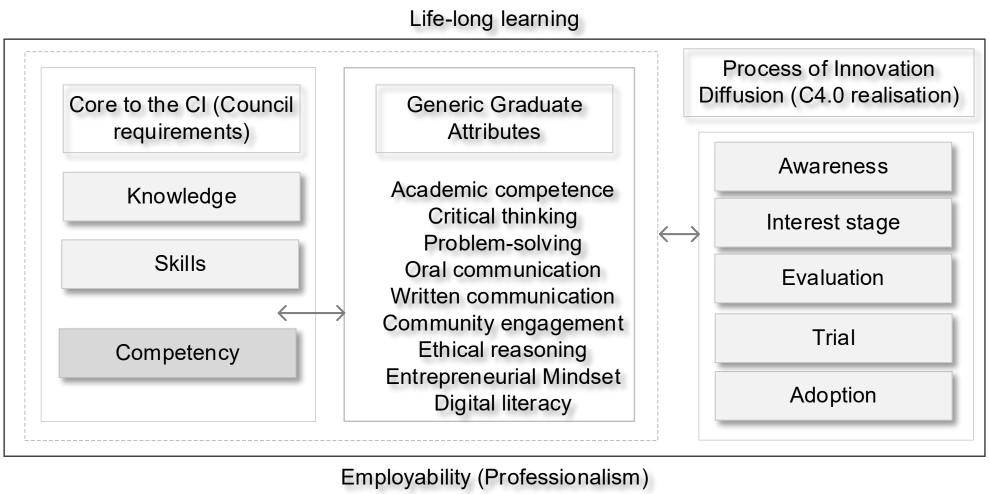

Figure 5.2: Conceptualisation of module content and GAs in the South African CBE

Source: Adapted from Griesel and Parker (2009); UFS (2019).

As illustrated in Figure 5.2, by aligning GAs with industry-prescribed knowledge, skills, and competencies and considering the LoDI, HEIs can improve students' preparedness for emerging technologies' practical and behavioural challenges. However, this interaction requires collaboration between the stakeholders, for which a framework of interaction is required. The next section considers expansive learning (EL) as a possible interaction framework.

5.2.3 Expansive Learning within the Activity Theoretical Framework

As mentioned above, the research is part of a more extensive study that uses the Cultural Historical Activity Theory (CHAT) framework to address the complexities involved when integrating GAs with C4.0 demands. CHAT provides a robust lens for analysing how individuals, tools, and communities interact within activity systems to address systemic contradictions and foster expansive learning (EL) (Engeström, 2001:137). This approach emphasises the transformation of activity systems through iterative cycles of questioning, modelling, and implementing new practices (Engeström & Sannino, 2010:8). CHAT's multi-voicedness (Engeström, 2001:138) allows for the inclusion of diverse perspectives, such as HEIs, CBE professionals, and technology developers, in curriculum design and professional development. EL subsequently considers multiple CHAT systems' interactions with each other, with Table 5.3 summarising EL's core questions and their application in the C4.0 context according to Engeström (2001):

Table 5.3: Modelling the new preliminary EL framework as a solution for the C4.0 application

Questions	Activity System Elements
Who learns?	Identify the subjects of the study (e.g. students, educators, industry professionals).
Why do they learn?	What contradictions are motivating the need for change? (e.g. Industry's need for Construction 4.0 skills vs. current graduate attributes).
What do they learn?	Analyse what practices are being developed (e.g. use of new construction technologies, collaborative problem-solving skills).
How do they learn?	Document the key actions in the expansive learning process, such as questioning old practices, modelling new solutions, and implementing changes.

Adapted from: Engeström (2001:138)

From a pragmatic view, however, when incorporating these definitions into the single CHAT system, as shown in Figure 5.3, the question of 'when' and 'where' was found lacking when multiple activity systems interact within the enquiry of the study. Additionally, the incorporation of the five W's of journalism: who, what, where, when and why (Georgia Institute of Technology, 2024:online) proved to be valuable considerations when considering the artefacts within the interaction of multiple systems (Sinek, 2009:61; Gedera & Williams, 2016:21-22; Engeström, 2015:63-64):

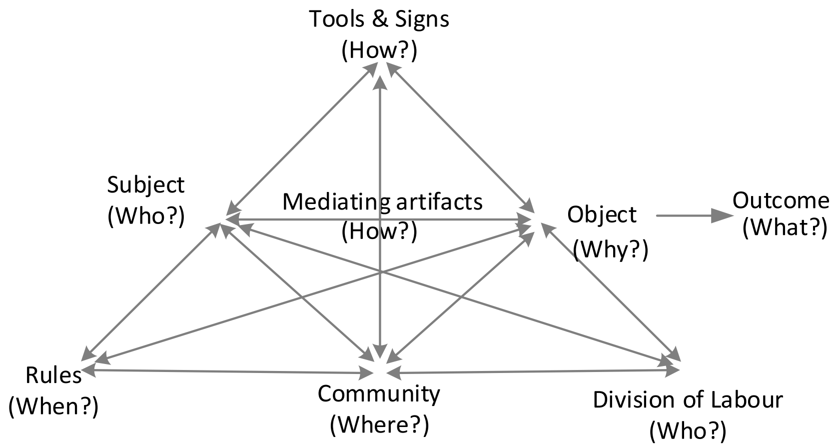

Figure 5.3: Assumed definition questions for defining artefacts within the CHAT system

Adapted: Georgia Institute of Technology (2024:online); Sine (2009:61); Gedera and Williams (2016:21-22); Engeström (2015:63-64).

Figure 5.3 shows the CHAT highlights the role of contradictions as catalysts for innovation, enabling HEIs to address gaps between traditional competency frameworks and the adaptive needs of C4.0. The expansive learning (EL) framework also emphasises the collaborative nature of learning, where students, educators, and industry stakeholders co-create solutions to emerging challenges.

In brief, Integrating Construction 4.0 technologies into the South African CBE necessitates rethinking HEI curricula, with GAs as a potential bridge between traditional competencies and the adaptability required for innovation. By leveraging frameworks such as CHAT and incorporating GAs into the KSCA relationship, HEIs can align their offerings with industry needs while fostering the lifelong learning and resilience required for professional success. Figure 5.2 and Figure 5.3 illustrate this integration's conceptual and practical underpinnings, providing a foundation for empirical research and future studies.

5.3 RESEARCH DESIGN AND METHODOLOGY

5.3.1 Research design

Focusing on the research question – what is the relationship of gratitude attributes between knowledge, skills, and competencies towards the effective adoption of Construction 4.0 technologies among professionals in the South African Construction Built Environment (CBE) – an explanatory sequential design was adopted for the study, involving a two-phase approach of collecting and analysing quantitative data first (phase 1), followed by qualitative data to elaborate on the findings for an in-depth interpretation of the respondents' understanding and interpretation of the proposed concepts (phase 2) (Creswell & Creswell, 2018:284; Johnson & Christensen, 2014:497).

Guided by Figure 5.2, the empirical study focused on the relationship between knowledge, skills, competencies, and attributes to highlight the perception of their relationship from a QS and CM perspective. The study forms part of a broader study. Subsequently, the target population for this study was limited to include the voices of registered persons from the SACQSP and SACPCMP. The following quantitative and qualitative data are considered separately in each section below before triangulating within the Discussion section (Creswell & Plano Clark, 2018:62).

5.3.2 Population, sample & response

With the explanatory sequential design, the quantitative enquiry utilised a simple random sampling method for the proposed population over one year (Daniels & Minot, 2020:10; Du Plooy-Cilliers et al., 2014:138; Kumar, 2014:303). The 2023 annual reports for the SACQSP and SACPCMP were considered for the quantitative data. The SACQSP had 4 454 registered professionals and candidates (SACQSP, 2023), while the SACPCMP had 1 699 professional and candidate Construction Managers (CM) and 1 679 Construction Project Managers registered (CPM) (SACPCMP, 2023), which were included in the target population. Of the 336 responses received, 288 were registered with the two Councils, equating to a representation of 3.68% representation of the total estimated 7 832 registered professionals and candidates as QS, CM and CPMs (SACPCMP, 2023:32; SACQSP, 2023:78). This decreased to 3.3% when the lowest usable population size of the responses is considered. Table 5.4 shows the summary of the background of the respondents, indicating years of experience, company size, qualification and professional affiliations:

Table 5.4: Respondent summary

Exp. (Years)	≤5	6-10	11-15	16-20	21-25	>25
%	30%	21%	18%	10%	6%	15%
Co. Size (Emp.)	1-10	11-20	21-30	31-40	41-50	>50
%	30%	11%	7%	3%	2%	47%
Degree (NQF)	None	UG (7)	Hons (8)	M (9)	PhD (10)	
%	6%	14%	55%	23%	3%	
Prof. Affil.	Pr QS	C QS	Pr CPM	C CPM	Pr CM	C CM
%	30%	35%	16%	12%	6%	1%

Notes: N=288; Exp. = Experience in years; Co. Size = Company size in number of employees; Degree = Highest degree achieved (NQF level in brackets); Prof. Affil. = Professional Affiliation.

The qualitative data collection was informed by the findings from phase one, using a non-probability method: a purposeful sampling technique aligned with the explanatory sequential mixed-methods design (Creswell & Creswell, 2018:287). Based on the survey questionnaire, the selected sampling of respondents (n = 10) was based on accessibility, knowledge, experience with the topic and representation of registration representation (Naoum, 2007:53). The ten respondents interviewed exhibited a broad range of experience from 6 to over 25 years in the field, with the majority having over 15 years of experience, indicating a well-experienced sample. Company sizes vary, with half of the respondents working in large organisations (above 50 employees) and the others in smaller firms (1–10 employees). Most respondents hold a BSc Honours degree in Quantity Surveying (QS), with some possessing additional qualifications, such as a PhD in Construction Management (CM) and two MBAs. Designations among the respondents include senior roles such as Directors, Senior Managers, and Consultants, with several individuals owning or directing their consultancies. Professional affiliations are diverse, including Pr QSs, Pr CPMs, and Pr CMs, reflecting a desired representation.

5.3.3 Data collection

For the quantitative data collection, a semi-structured survey questionnaire was circulated amongst professional and candidate QSs, CMs, and CPMs registered with the SACQSP and/ or SACPCMP. The survey questionnaires were administered from July 2023 up to April 2024. The semi-structured questionnaire formed part of a larger study, with this study focusing on three data sets from the survey. In general, the survey instrument focused on the background of respondents' professional profiles, their evaluation of key capabilities (KSCA) concerning their day-to-day tasks and C4.0, and their perceptions of the relevance of GAs to employability and future industry needs. These elements were explored through open-ended and structured Likert-scale questions to provide structured data and nuanced qualitative insights.

The subsequent qualitative enquiry included ten interviews conducted over two months for the qualitative data focusing on attitudes, behaviours, and preferences towards Construction 4.0 and students' attributes (Du Plooy-Cilliers et al., 2014; Naoum, 2007). Research objectives were conveyed verbally and in writing, along with written consent forms. The semi-structured interviews explored key themes, including the perceived importance of graduate attributes (GAs), graduates' preparedness for C4.0 and the alignment of academic curricula with industry needs. Participants were encouraged to share insights on gaps between higher education and practice and to suggest ways to enhance the employability of graduates. Data collection findings were reported anonymously using pseudonyms (Creswell & Creswell, 2018:257; McKinney, 2013:42), and verbatim transcripts were securely stored with the necessary password protection.

5.3.4 Data analysis

The quantitative data analysis employed descriptive and inferential statistics to interpret three datasets obtained from the semi-structured questionnaire (Pallant, 2020:94; Du Plooy-Cilliers et al., 2014:220):

1. Dataset 1:
   - Descriptive statistics examined respondents' baseline reliance on KSCA in their daily tasks.
   - Findings revealed the relative importance of each KSCA element, providing a foundational understanding of professional practices in QS and CM operations.
2. Dataset 2:
   - Spearman's Rank Order Correlation (henceforth referred to as Spearman's correlation – *rho*) and t-tests for regression coefficients were employed to analyse respondents' considerations when appointing new personnel based on KSCA relevance in the general context and C4.0's context. Given the non-linear nature of the data, Spearman's correlation (for non-parametric data) was applied to assess the monotonic relationship between the variables (Pallant, 2020:337).

- The significance was set at P <0.005 (Johnson & Christensen, 2014:578) while the Spearman's correlation with the following parameters was considered (Pallant, 2020:204): 0.1 < 0.3 – Low correlation; 0.3 < 0.5 – Medium correlation; 0.5 < 0.7 High correlation.

3. Dataset 3:
   - Descriptive statistics and t-tests analysed respondents' perceptions of attributes against core council requirements, innovation, and employability diffusion, as shown in Figure 5.2 and Table 5.6.
   - The p-value significance was set at 0.05 level P <0.005 (Johnson & Christensen, 2014:578).

For validity purposes, a Cronbach Alpha threshold exceeding 0.7 was utilised to measure the internal consistency data presented in the respective datasets (Johnson & Christensen, 2014:170).

Additionally, the subsequent qualitative data are presented and analysed through the process of transcription, coding, and theme identification before identifying the applicable semantic themes (Saldaña, 2009:92) and subsequent latent themes (Du Plooy-Cilliers et al., 2014:241) to be triangulated with the quantitative data (Creswell & Creswell, 2018:229). The data were analysed using a process of coding, categorising, identifying themes and interpreting themes (Saldaña, 2009:12). This thematic code frequency round is shown in Table 5.7 (Annexure 5.1) before the grouping of the main and subthemes in Table 5.8 (Annexure 5.1). Pseudonyms for the respondents included the use of the letter "R" with a number denoted next to it (Thus Respondent 1 = R1).

5.4 RESULTS

5.4.1 Quantitative results

5.4.1.1 Baseline of KSCA use

For datasets 2 and 3, the relationship between the registered persons' reliance on the KSCA to conduct their day-to-day tasks was considered. The respondents were asked to indicate the percentage they rely on to conduct their day-to-day work when considering KSCA, as illustrated in Figure 5.4.

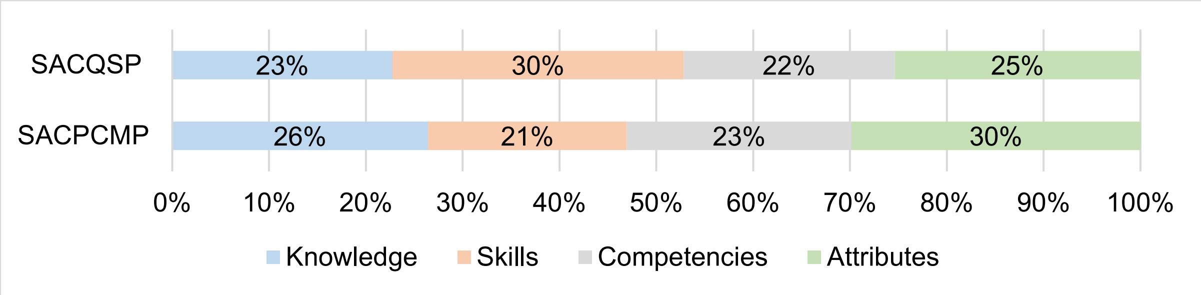

Figure 5.4: Registered persons' allocation of KSCA as elements used to conduct day-to-day tasks

Figure 5.4 illustrates the ranking of SACQSP and SACPCMP registered respondents on KSCA elements for their professional tasks. While SACPCMP respondents place slightly more emphasis on attributes (30%) and competencies (23%), SACQSP respondents prioritise skills (30%) and show a relatively balanced reliance across all categories. They highlighted nuanced differences in their professional focus, but they also highlighted the importance of all four elements.

5.4.1.2 Appointment considerations based on KSCA

Using Spearman's test (Pallant, 2020:129), this baseline was compared further against the a) general qualities respondents look for in potential candidates, b) against the C4.0 capabilities and lastly, both the c) general and the C4.0 capabilities were compared, as shown in Table 5.5. *The objective was to establish whether respondents look for the same qualities within candidates and those they use during their work, based on KSCA.* The first observation on the Cronbach alpha indicated that the data skills and attributes samples showed valid internal consistency if a factor of 0.7 is used (Johnson & Christensen, 2014:170). Thus, skills and attributes were further investigated, with the SACQSP group showing a medium to strong correlation towards skills and attributes. In contrast, the SACPCMP group only showed a medium to strong correlation towards attributes (Pallant, 2020:213).

Table 5.5: Reliability and correlation analysis of assessment categories across SACQSP and SACPCMP

Assessment Categories	Designation	Cronbach alpha	a) Own KSCA vs new appointee		b) Own KSCA vs new appointee on C4.0 KSCA		c) New appointee general KSCA vs C4.0 KSCA		Useable N
			Spearman's Correlation	Two-sided P	Spearman's Correlation	Two-sided P	Spearman's Correlation	Two-sided P	
Knowledge	SACQSP	0.67	0.469	*<0.001	0.322	*<0.001	0.490	*<0.001	181
	SACPCMP		0.245	0.027	0.303	0.007	0.445	*<0.001	78
Skills	SACQSP	0.74	0.416	*<0.001	0.427	*<0.001	0.587	*<0.001	180
	SACPCMP		0.288	0.009	0.223	0.042	0.475	*<0.001	81
Competencies	SACQSP	0.58	0.326	*<0.001	0.172	0.021	0.448	*<0.001	180
	SACPCMP		0.174	0.120	0.266	0.017	0.443	*<0.001	79
Attributes	SACQSP	0.74	0.506	*<0.001	0.440	*<0.001	0.604	*<0.001	181
	SACPCMP		0.441	*<0.001	0.351	0.001	0.563	*<0.001	77

*Significant P <0.005 — 0.1 < 0.3 - Low *rho* — 0.3 < 0.5 - Medium *rho* — 0.5 < 0.7 High *rho*

Note: *rho* = correlation value

The analysis suggests that SACQSP registered persons value attributes and skills, as indicated by the medium to strong correlations observed in the SACQSP group. This trend demonstrates a preference for candidates who strongly align with their professional KSCA with day-to-day tasks. The SACPCMP group's focus on attributes suggests that while technical competencies and knowledge are foundational, the ability to exhibit the right professional attributes remains critical when considering new appointees, especially within a C4.0 context. The data above highlight the importance of attributes during new candidates' appointments, particularly within a C4.0 context. The next section explores this observation further by investigating the proposed model of Figure 5.2.

5.4.1.3 What are employers looking for in potential CBE candidates?

Next, the C4.0 learning-centred approach framework approach is investigated by ranking the most important to the least important criteria when appointing a new employee, according to the respondents (refer to Figure 5.2 above). Simple descriptive statistics are used to interpret the results and p-values observed for statistically significant differences of 0.05, indicating that the difference is not strong enough to be statistically significant at a 0.05 level (Johnson & Christensen, 2014:578).

Table 5.6: Ranking of criteria for appointment of new graduates considering C4.0 developments

Criteria	Council	Rank	N	Mean	Std Deviation	Std Error Mean	Two-Sided P
A – Core to CBE (Council requirements)	SACQSP	1	185	2.17	1.335	0.098	0.051
	SACPCMP	1	84	1.85	1.207	0.132	
C – Graduate Attributes	SACQSP	2	186	2.32	1.196	0.088	0.59
	SACPCMP	2	76	2.41	1.073	0.123	
E - Employability (Professionalism)	SACQSP	3	186	3.08	1.219	0.089	0.747
	SACPCMP	3	78	3.13	1.21	0.137	
D – Diffusion of Innovation process (C4.0 realisation)	SACQSP	4	186	3.53	1.218	0.089	0.756
	SACPCMP	4	78	3.47	1.326	0.150	
B – Life-long learning	SACQSP	5	188	3.72	1.380	0.101	0.867
	SACPCMP	5	80	3.69	1.346	0.151	

Table 5.6 shows that *A – Core to CBE* (Council requirements) and *B – Graduate Attributes* have lower mean rankings, indicating respondents considered them more meaningful. *D – Life-long learning* and *D – Diffusion of Innovation* (C4.0 realisation) have higher mean rankings, indicating they are less important, with *E – Employability* (Professionalism) rated moderately important. The standard errors are relatively low across all criteria, suggesting that the respondents' rankings are fairly consistent and the means are reliable estimates of the true population means.

The contradiction observed against the CHAT highlights the fluidity of the object of employment with a lower correlation towards general and C4.0 requirements, hinting towards the respondent's uncertainty of what C4.0 attributes and competencies include, corresponding to the emergent nature of C4.0 within South Africa (Venter et al., 2021:149). It was further observed that when the Core KSC were grouped, these criteria were consistently ranked more critical than GAs, suggesting that the respondents deem these criteria more important when evaluating a new candidate, hence the interviews with the key respondents to investigate this further.

5.4.2 Qualitative results

5.4.2.1 Semantic results

Guided by the quantitative data, the qualitative data collection utilised a semi-structured interview protocol in Figure 5.2, investigating respondents' perceptions of GAs and the relationship between knowledge, skills, competencies, and attributes.

The following semantic themes could be identified (Saldaña, 2009:92) through the process highlighted in 5.3.4 (refer to Annexure 5.1), which are:

- Self-reliant candidates: Participants are seeking candidates who can quickly become self-reliant. Higher Education Institutions (HEIs) should see the efficiency of mentoring time (once in the workplace) as a significant contribution. As respondent 3 (*R3*) noted,

  Graduates should become 'grown-up' quicker.

- This sentiment was echoed by *R1*, who emphasised the need for candidates to

  hit the ground running.

- Adaptability and flexibility: The importance of adaptability and the ability (similar to theme 1) to grow in new environments were recurrent themes. Participants highlighted qualities such as analytical skills and people skills. For instance, *R4* mentioned,

  The ability to adapt and learn in new environments is crucial. Analytical and people skills are paramount in our industry.

  Another participant added,

  Graduates need to be flexible and capable of growing within diverse environments to meet industry demands (R5).

- Soft skills: Critical thinking, problem-solving, and communication were frequently cited as essential soft skills. *R5* emphasised,

  Critical thinking, problem-solving, and effective communication are essential soft skills our graduates must possess.

  R7 noted,

  In complex projects, the importance of soft skills such as teamwork and leadership cannot be overstated.

- Physical vs. Digital Literacy: The need for a balance between the need for physical knowledge and digital literacy was highlighted. *R9* pointed out,

  While digital skills are important, the foundation lies in physical knowledge, which cannot be overlooked.

  Conversely, *R10* commented on the growing importance of digital skills,

  With the integration of BIM and AI, digital literacy is becoming increasingly important.

- Integration of Technology: The need to integrate technology into the curriculum was emphasised. Participants stressed preparing students for the digital transformation in the construction industry. *R1* remarked,

  Students must be proficient in both the physical and digital aspects of construction to stay relevant.

5.4.2.2 Latent themes

The following latent themes emerged from the iterative thematic coding process (Du Plooy-Cilliers et al., 2014:241), with notable reference to the importance of soft skills as attributes:

- Competence results from practical experience, and if not obtained during their degree programme, candidates should have the necessary soft skills (e.g. attitude) to identify their shortcomings to obtain these competencies:

Practical experience and the ability to learn on the job are crucial for our industry (R10).

Confidence, personality, and the ability to grow and adapt are critical attributes we look for in candidates (R6).

- Understanding the business is essential, with graduates well-grounded in the core knowledge and skills while understanding that they still have to learn and grow within the organisation, which relates to becoming lifelong learners (UFS, 2019).

  Hands-on experience and continuous professional development are vital for career growth (R1).

  Technical knowledge, the ability to read plans, and understanding contracts are foundational for new hires (R4).

- A nuanced differentiation between QSs and CMs respondents could be observed. CM participants emphasised a more physical or process understanding, while QS participants emphasised the increased movement towards digitisation.

In summary, the analysis highlights the importance of a balanced approach to education that combines core technical knowledge with essential soft skills and digital literacy. Integrating graduate attributes into the curriculum is crucial for preparing students for the evolving demands of Construction 4.0. The importance of adaptability and analytical skills emphasised the significance of critical thinking and teamwork. Integrating physical and digital literacy is crucial in Construction 4.0. Employers seek solid foundational knowledge and adaptable, confident individuals who can thrive in dynamic environments. As one participant noted:

> *For instance, good communication and teamwork are vital in the construction industry … it is not necessarily the academically strong candidates that thrive in the industry. They should be able to bring all the diverse requirements together within the company. – R8.*

5.5 DISCUSSIONS & TRIANGULATION

Within the quantitative data, respondents showed the strongest correlation towards GA (Table 5.5), indicating that this criterion was the most universal of the KSCA criteria under consideration. However, respondents showed the groundedness of the KSC when grouped against GA (Table 5.6). The qualitative data supported this through the discussion on *self-reliant candidates, adaptability and flexibility, and soft skills*, which can be classified within GAs (Griesel & Parker, 2009:1). This proves vital in understanding the expansive learning considerations within the CHAT and forming a platform to explore the increased industry involvement in HEIs. With GAs and skills being the only criteria that showed a valid correlation between the groups, it indicated a good platform of uniformity for starting HEI and CBE integration within the KSCA symbioses of identifying the common object. These findings are consistent with previous studies that emphasise balancing technical skills with interpersonal competencies to meet industry demands (Aliu et al., 2023; Vaz-Serra & Mitcheltree, 2021); however, the diverse need of the professions pulls in multiple directions when considering KSC, which is further exacerbated by the emergent nature of C4.0. This highlights that integrating emerging C4.0 technologies and associated competencies emphasised by relevant GAs into their curricula requires grounding in some commonality, such as GAs. The importance of GA in preparing students for the evolving demands of C4.0 is evident, aligning with literature advocating for the inclusion of digital literacy, continuous learning, and innovation in construction education (McCord et al., 2023; Sawhney et al., 2020).

The thematic analysis revealed several key themes that highlight employers' expectations regarding graduate attributes in the CBE. First, participants emphasised the need for self-reliant candidates who can quickly adapt to the workplace, focusing on adaptability and flexibility to navigate diverse environments, corresponding with Bitzer and Withering (2020) and Staunton et al. (2021). Analytical and people skills were particularly valued, along with critical thinking, problem-solving, and communication, which were identified as essential soft skills. Additionally, the balance between physical knowledge and digital literacy was highlighted, reflecting the growing importance of digital tools like BIM and AI.

Integrating technology into the curriculum was deemed crucial for preparing students for Construction 4.0.

Latent themes further emphasised the importance of practical experience and the need for graduates to be lifelong learners who can continuously develop their skills within an organisation, as shown by Warier (2014:19). A nuanced difference emerged between Quantity Surveyors (QS) and Construction Managers (CM), with QS participants focusing on digitisation (aligning with the baseline results of 5.4.1.1), while CM participants highlighting the importance of physical and process understanding. Overall, the analysis underscores the need for a well-rounded education that integrates both technical knowledge and soft skills, preparing graduates for the dynamic and evolving demands of the construction industry. Employers seek adaptable, confident individuals with strong communication and teamwork skills, which are essential for success in the field.

The hypothesis stated *that knowledge provides the theoretical foundation, skills offer practical application, competencies ensure the ability to perform tasks effectively, and attributes foster continuous professional development.* Suppose the "Process of Innovation Diffusion" of awareness up to adoption is considered against the expansive learning matrix (see Figure 5.3). In that case, the main contradiction that emerged is that the QS & CM practitioners have limited influence on the GA except through the filter of HEIs and regulating councils and associations. With the emergent nature of C4.0 and the empirical data, it is concluded that all three parties are learning and that attitudes and behaviours culminate towards a strong sense of 'why' from which the 'how' and 'what' can flow, as suggested by (Sinek, 2009:61). Through this process, the existing contradictions, as depicted in Figure 5.5, underscored the importance of industry and HEIs to collaborate towards a shared object, as suggested by Aliu et al. (2023) and McCord et al. (2023), from which the CHAT framework within the multiple activity system could be built:

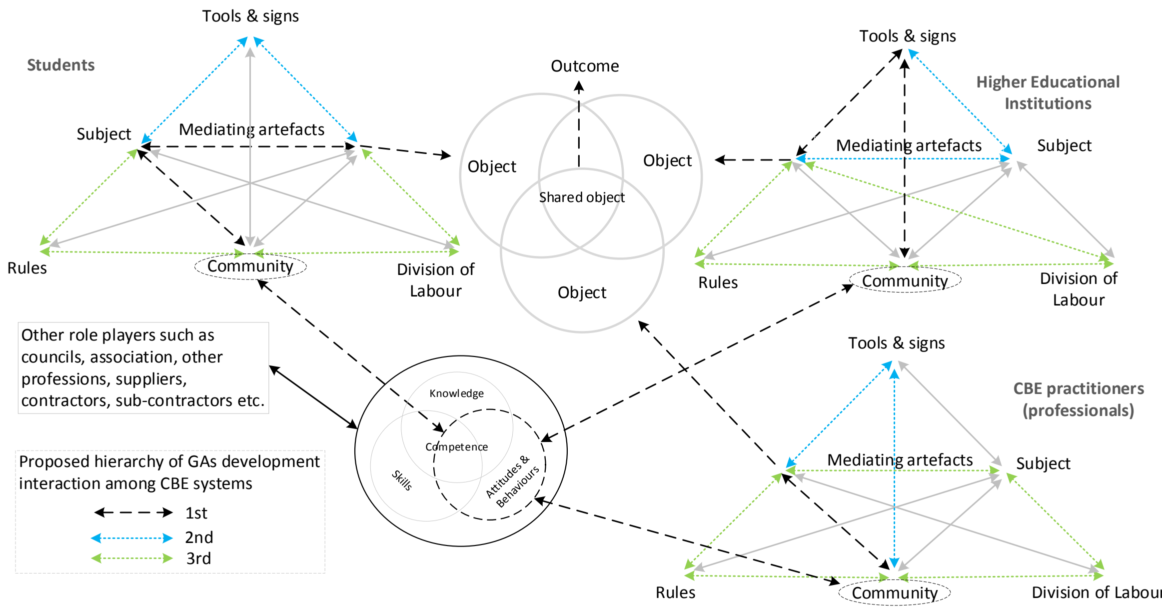

Figure 5.5: **Observed multiple C4.0 Attribute CHAT System**

Source: Adapted from Engeström (1987); Gedera and Williams (2016); Hauptfleisch (2024); Koc et al. (2020); Warier (2014)

The study was limited to GAs and registered QSs, CMs, and CPMs' perspectives on their interaction with the stakeholders, as depicted in Figure 5.5. It is suggested that knowledge, skills, and competencies should be evaluated in separate studies and would be conjecture if included in the following conclusions. It was subsequently observed that the community ('where') is the best common ground of interaction, where mediation within the activity systems can adequately access the subjects ('who') towards a shared object ('why') and outcome ('what') to address the developments within C4.0. This will lead to a more optimum mediation that includes rules ('when') and the division of labour ('who') and, thus, improves the agency of the CBE on the path to C4.0 realisation.

5.6 CONCLUSION & RECOMMENDATIONS

Based on the theoretical framework (Figure 5.2), the expansive learning framework provided a valuable lens (layer) for investigating C4.0 preparedness within the South African Construction Built Environment (CBE). This study highlights the pivotal role of Graduate Attributes (GAs) in equipping professionals with the competencies needed to navigate the demands of Construction 4.0 (C4.0). Through the CHAT framework, it is evident that integrating GAs into educational curricula is essential for fostering skills like adaptability and critical thinking – both crucial for success in a technologically evolving industry. The research underscores a strong alignment between professionals' skills and those sought in potential candidates, reinforcing the importance of innovative pedagogical approaches in South African HEIs. GAs are a critical foundation for vertical alignment in education, facilitating student progression, employability, and readiness for professional registration or postgraduate studies. This study contributes to the global discourse on aligning educational outcomes with industry needs, offering empirical evidence from the South African context and influencing HEIs, mentorship programmes, and industry practices.

This study was limited to the Quantity Surveying (QS), Construction Management (CM), and Construction Project Management (CPM) professions within South Africa, focusing exclusively on individuals registered with the SACQSP and SACPCMP. It examined the role of Graduate Attributes (GAs) within Construction 4.0 (C4.0) advancements as part of students' complex professional development. The scope is further narrowed to the application of GAs. Additionally, the study utilised Cultural Historical Activity Theory (CHAT) as a lens to triangulate empirical data, progressing only to the modelling phase within the expansive learning cycle for further investigation. Based on the findings, the following recommendations are proposed to which generic GAs present an exciting point of departure for collaboration in the development of specific C4.0 GAs:

- Curriculum Enhancement: HEIs should integrate digital literacy and C4.0 technologies into curricula, emphasising both technical skills and essential GAs like adaptability and critical thinking.
- Industry Collaboration: HEIs and industry stakeholders should collaborate to align curricula with evolving construction sector needs, offering real-world learning opportunities that bridge academic knowledge and practice.
- Continuous Professional Development: Industry bodies and professional councils should advocate ongoing professional development focused on emerging

technologies and the GAs required for effective performance in a C4.0-driven environment.

- Future Research: Further studies should investigate the long-term impact of incorporating GAs into construction education and explore effective pedagogical strategies for fostering these attributes. Specific attention should be given to the unique needs of the South African CBE and innovative approaches like change laboratories (Garraway, 2021) (that would enable further testing and implementation of the proposed framework).

The advocacy of technological advancements in the construction industry can be retained through the increase and deepening of innovative thinkers within the construction industry.

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ANNEXURE 5.1

Table 5.7: Thematic analysis code frequency table

Number	**Code**	**Frequency**	**Number**	**Code**	**Freq.**
1	BIM Projects	3	15	Personality Traits	7
2	Reading Plans	3	16	Technical Knowledge	7
3	Industry Lag	3	17	Balance Digital and Physical	7
4	Integration of Digital and Physical	4	18	Need for Digital Skills	7
5	Professional Demeanour	4	19	Analytical Skills	8
6	Psychometric Testing	4	20	Ability to Learn	8
7	Resistance to Change	4	21	Continuous Learning	8
8	Flexibility	5	22	Digital Literacy	9
9	Foundational Knowledge	5	23	Soft Skills	10
10	Confidence	5	24	Challenges and Adaptation	10
11	Adaptability	6	25	Core Knowledge	11
12	Technological Advancements	6	26	Construction 4.0	12
13	Client Interaction	6	27	Curriculum Development	13
14	Incorporation of Soft Skills	6	28	Industry Expectations	14
15	Personality Traits	7	29	Graduate Attributes	15

Table 5.8: Thematic grouping of main themes and sub-themes

Main Theme	Subtheme	Definition	Freq.
Graduate Attributes	Adaptability	The ability of graduates to adapt to new environments, technologies, and work situations.	8
	Lifelong Learning	The continuous pursuit of knowledge and skills development throughout one's career.	7
Digital Literacy	Basic Digital Skills	Proficiency in using standard digital tools and applications relevant to the construction industry.	6
	Advanced Digital Skills	Advanced skills in using industry-specific software and technologies, such as BIM and data analytics.	5
Professional Competence	Analytical Skills	The capacity to analyse complex situations and data effectively to make informed decisions.	4
	Problem-Solving	The ability to identify, analyse, and resolve issues efficiently and effectively.	5
Interpersonal Skills	Communication Skills	Proficiency in both oral and written communication within a professional context.	7
	Teamwork	The ability to work collaboratively with others from diverse backgrounds to achieve common goals.	6
Employability	Professionalism	Demonstrating professional behaviour and attitudes in the workplace.	4
Core Knowledge Areas	Technical Knowledge	Understanding fundamental principles and practices specific to the construction industry.	8

PART 3

EPILOGUE

6
EPILOGUE: CONCLUSION, RECOMMENDATIONS AND PROPOSED FRAMEWORK AS CONTRIBUTION TO KNOWLEDGE

6.1 INTRODUCTION

In conclusion, this doctoral study reflects on the cumulative insights drawn from the preceding articles, integrating theoretical and empirical findings to propose practical recommendations for graduate attribute development within Construction 4.0 contexts. The objective, as shown in Section 1.5 (Part 1) of this Epilogue, is to *integrate the literature and empirical research results, compile and substantiate learning, teaching and professional development directives for managing or implementing graduate attributes needed in the South African Construction Built Environment (CBE) that contribute to integrating knowledge and practice and determine why*. To address this objective, this chapter concludes the thesis by summarising the key findings of the three main articles and discussing their theoretical and professional contributions (see Section 6.4). This research aimed to explore the integration of Construction 4.0 (C4.0) attributes within South African Higher Education Institutions (HEIs), particularly within Quantity Surveying (QS) and Construction Management (CM) programmes and its influence on the preparation of graduates for the technological developments (see Section 6.2). By utilising Cultural Historical Activity Theory (CHAT) and exploring the roles of graduate attributes, this research sheds light on how the proper grounding and definitions of the key criteria within the CHAT system are crucial towards implementing Expansive Learning (EL) within South Africa's CBE HEIs (see Section 6.7). It further establishes what key role GAs play within the EL framework and how the interaction between multiple systems within HE within the CBE influences the focus of pedagogical delivery of QS and CM programmes in the Construction 4.0 (C4.0) era (see Section 6.3)

6.2 INTEGRATING FRAMEWORKS FOR UNDERSTANDING THIS DOCTORAL STUDY'S CONTRIBUTIONS

Notwithstanding general pressures from the Innovation Diffusion network (see Figure 5.2) existing within the CBE (Larsen, 2015:113), the implementation of institutional pressures, advocating Graduate Attributes (UFS, 2019) and observation of the socio-economic circumstances of students. It has been observed that many students experience the silo effect of curriculum design (Nisula & Pekkola, 2018:107), which leads to anxiety and less-than-optimal performance. GAs promise to assist with pedagogical approaches to make learning and teaching more relevant and fun for students while addressing developments within the industry (see Section 4.5). Revolutionary technologies characterise the 4IR, with the fusion of technologies which blurs the lines of digital, physical, and biological divides, transforming the existing structures of governance, business, and human interactions (Newman et al., 2021:573) (see Section 2.2.2); it is a disruptive innovation that will significantly impact industries and sectors worldwide (Schwab, 2016:7-8). From the Farmer report (Farmer, 2016:5), however, it is evident that the realisation of the Third Industrial Revolution (3IR) is still proving to be a challenge for the CI in the context of the United Kingdom (UK), and it is assumed to be similar in the South African CBE context. Posillico et al. (2023:4169) further highlight the lack of general cohesion within curriculum development in light of the above developments.

Building on these observations, the South African construction industry faces additional challenges in adapting to technological advancements and preparing graduates for an evolving workforce, particularly within the constraints of established frameworks and institutional practices (Rukande, 2019:online). With its entrenched practices, existing project life cycles (PLC), stakeholders, and, in general, complex existing processes, making impactful, innovative changes includes many silos within the CBE (Hauptfleisch, 2024:43-44; South Africa, 2019:2 & 5). Highlighting the need for a cautious and grounded approach to aligning students for this transition by keeping curriculums grounded and agile. With the complexity of the CBE that lies in the multitude of stakeholders (Hattingh, 2017:20-30) who depend on one another, the accuracy of one system cannot ignore the other, with no single improvement to any element in a system that would create a net gain for the system (Loosemore, 2015:67). In addition, in the endeavour to strike a balance between innovation and risk mitigation, Pareto optimality is a fundamental concept to bear in mind when investigating the gain of an industry as a whole (Orstavik et al., 2015:24).

To understand the nurseries of professional preparations to gain insights into teaching those cross-professions (Shulman, 2005:22), transactional disciplines' requirements of dialogue between students and educators (Cousin, 2009:201-212) had to be established. While information literacy instruction focuses more on the critical understanding of information than on skills acquisition (Hunt & Chalmers, 2021:90-91), identifying key concepts and threshold capability (Land, Meyer, & Flanagan, 2016:196) proves crucial for deep learning and developing critical thinking on the acquisition of the identified profession (Hunt & Chalmers, 2021:92). The Law of Diffusion of Innovation (Rogers, 1983:10-11) provides grounding within the diversity of innovation progress and uptake, which affect the entire population – thus, industry and higher education students – and depend mainly on the network to which the students are exposed to.

By considering the established routes of professional registration (Maritz & Siglé, 2016:7), the study focused on three distinct stakeholders highlighted in the study, namely HEIs, students and CBE practitioners (specifically Quantity Surveyors and Construction Managers). It was observed that technological disruptors are increasingly contributing to the CI's trajectory (Koc et al., 2020:473), which played a role in the conceptual and theoretical framework of the study.

6.2.1 Conceptual and theoretical framework

[As referred to in Section 1.4 of the Part 1]

By considering the three main stakeholders, the key outcomes of GAs of student-centred teaching (UFS, 2019:4), self-directed learning (Fink, 2013:5), and the golden circle, as proposed by Sinek (2009:41) [please also see Section 2.2], a dissertation by articles became apparent. Starting with the 'why', the three main articles centred around making learning relevant for students through course design and assessments (Hunt & Chalmers, 2021:90-91).

Figure 6.1 highlights the framework around which the study was developed, starting with the ‘why’, ‘how’ and ‘what’. This high-level approach allowed the study to take shape quickly, while the additional layers of understanding developed as the study progressed, with the Pilot Study proving vital in developing the necessary grounding.

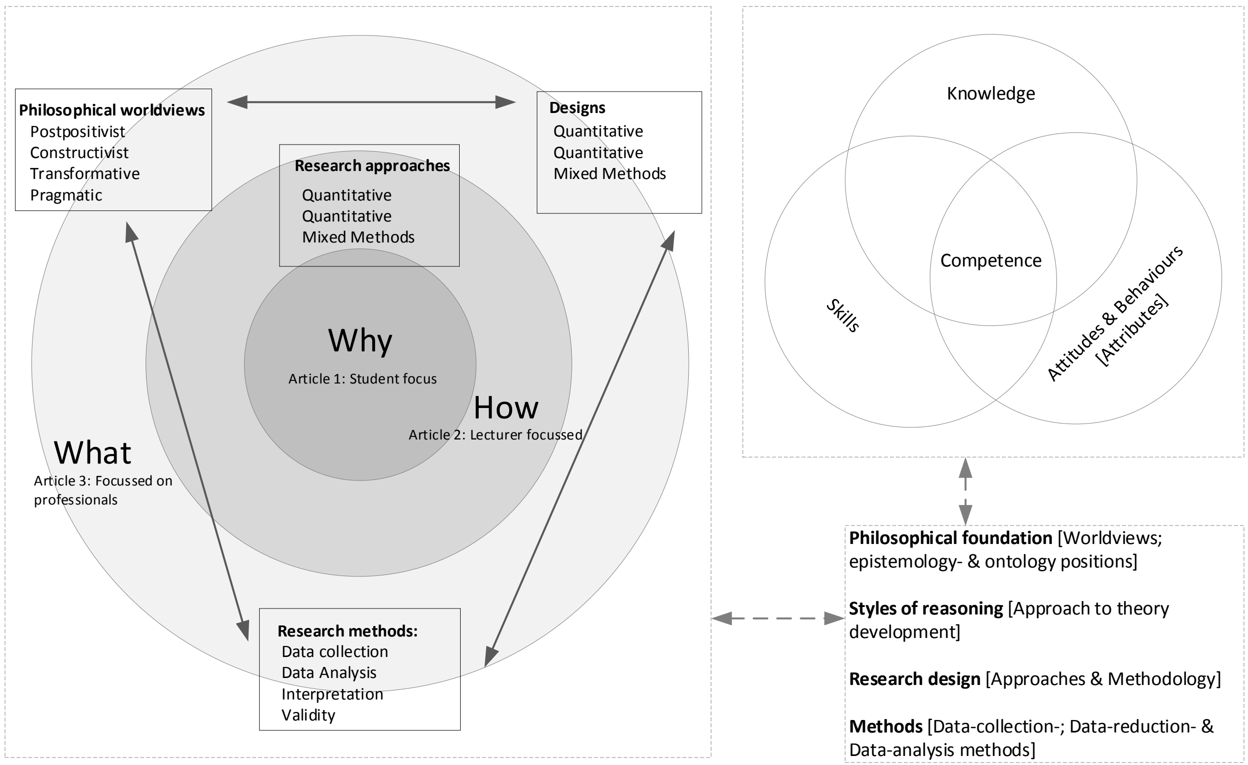

Figure 6.1: Conceptual framework for the study

Source: Amended, Creswell and Creswell (2018:5); Sinek (2009:173; Jacobs and Cornelius (2022:106); Warier (2014:19)

An epistemological position of objectivism was subsequently taken (Jacobs & Cornelius, 2022:110) based on the complexity of the CBE, which is plagued by immature project definitions and technical assessments, overemphasis on the lowest price, conservative clients, high contractors’ risk and complex contracts and dispute resolutions (WEF, 2016:16). A pragmatism world view considers real-world challenges and practice that is influenced by knowledge and action that leads to the epistemological stance (Creswell & Creswell, 2018:5-6; Jacobs & Cornelius, 2022:110). The three different styles of reasoning were adopted for each study is repeated below (Creswell & Plano Clark, 2018:12):

1. Article 1: Study focusing on students ('why') – inductive reasoning.
2. Article 2: Study focusing on HEIs or lecturers ('how') – abductive reasoning.
3. Article 3: Study focusing on the CBE or practitioners ('what') – deductive reasoning [The design logic of Article 3 aligns broadly with deductive reasoning, but it is important to note that the article did not aim to test a formal hypothesis, even though stated and linked to the research results. Instead, it confirmed conceptual patterns arising from the earlier parts of the study and acted as an additional lens into the development of the final integrated framework].

Initially, the study would have only included the three studies mentioned above; however, after conducting the pilot study as suggested by Creswell and Creswell (2018:158), it proved a significant contribution to the understanding of the underlying partners on which the research is based, by obtaining valuable insights into the evaluation of the proposed Activity Theoretical framework (AT) and its relevance towards the systematic investigation potential on the subjects' capabilities, social background and the impact of available resources on a common objective (Gedera & Williams, 2016:xi). The above parameters appear relevant to this study, as they define the South African CBE students' specific, systematic, and social construction using Activity Theory. Additionally, the AT incorporates the interaction between mediating artefacts (tools), the subject, applicable rules, the community, the division of labour (time), and the objective towards a specific outcome (Gedera & Williams, 2016:20-21). Forming the foundation of the study and gradually moving towards Expansive Learning (EL) (see Figure 6.2 & Figure 6.3), as suggested by Engeström (2001). EL involves **transforming an activity system** as it responds to **internal contradictions and develops new forms of activity** (Engeström, 2001:137), allowing for the consideration of the horizontal alignment of multiple activity systems (Engeström, 2015). With the development of the term 'Construction 5.0', new emphasis emerged on bringing back the human element (Marinelli, 2023:1) concerning the sustainability of C4.0 developments (Najafi, 2023:online), further supporting the importance of the investigation on GAs' role towards keeping agency of these technological advancements in the CBE (Koc et al., 2020:474).

6.2.2 Integrated framework for C4.0 GAs within the expansive learning

Building on the conceptual framework, the study progressively construed a comprehensive framework for expansive learning (EL) [please see Section 6.7]. It recognised that merely reacting to technological advancements within the Construction Industry (CI) was insufficient to address the dynamic changes these innovations introduce. Instead, a proactive and well-structured approach was needed to maintain alignment with existing practices in the CBE while safeguarding the agency of construction innovation. HEIs are positioned as the nexus between academia and industry, particularly in the study, which focuses on students, lecturers and registered QS and Construction Management professionals.

To advance this inquiry, the study employed the seven stages of EL as outlined by Engeström et al. (1999:384), emphasising the systematic examination of stakeholder perspectives to establish the current state of practice (also see Section 6.7). The foundational analysis informed the development of cohesive frameworks for decision-making processes and the artefact definitions within a unified CHAT system. Additionally, the proposed platform facilitated the exploration of a multi-system framework (Please see Figure 5.5), offering a robust basis for subsequent investigations into collaborative and innovative practices within the CBE.

Adopting CHAT as a lens, the study evaluated GAs through the interrelated articles:

1. Student Perspective (Article 1): Students' learning experiences were examined to identify gaps between existing teaching methods and the attributes required for C4.0. The findings emphasise transitioning from a teaching-centred to a learning-centred approach, enabling expansive learning, as depicted in Figure 3.4.
2. Lecturer Perspective (Article 2): This phase engaged educators to assess curriculum design and their role in fostering graduate attributes aligned with C4.0. The research identified the need for a systematic framework to deepen

pedagogical objectives and recommended collaboration between HEIs and industry.

3. Industry Perspective (Article 3): Insights from QS and CM practitioners highlighted the necessity for strategic academia-industry collaboration. The study proposed a communal interaction model, integrating feedback loops to mediate artefacts and strengthen curriculum relevance (Figure 5.5).

The overarching framework synthesised the insights from these stakeholder groups, progressing through the (Engeström et al., 1999:384) seven stages of expansive learning (Figure 6.3). This iterative approach ensured a balanced integration of theoretical knowledge and practical applications within HEIs, fostering graduate adaptability to technological advancements and societal needs.

The study culminated in proposed decision-making and collaborative frameworks that align educational practices with the demands of the CBE, emphasising the strategic role of HEIs in bridging academia and industry.

6.3 SYNOPSIS OF THE INTEGRATION OF THE INTERRELATED ARTICLES

As mentioned in 6.2, this thesis consisted of three key studies informed by the research objectives and questions outlined at the start of the study (Sections 1.5 & 1.6), with the main research question stated as: *Through the Activity Theory*[6] *perspective: How can the teaching, learning and development of South African Construction Built Environment graduate attributes be transformed to contribute to the world of work?* Using the AT perspective, the study aimed to determine the contribution GAs play in the transformation of QS and CM students' learning and development in HEIs. Furthermore, considering the three different stakeholders' perspectives, how these C4.0 and GAs might be managed or implemented best by HEIs to address the technological progress in the workforce.

[6] The term AT is specifically kept in contrast to CHAT because the term acts as an embrella term as explained in section 1.4.1 and further discussed in 6.4.1. The understanding of the AT also evolved throughout the student and culminated part of the reflective process as shown in section 6.4.1.

Because the **pilot study**[7] played a significant role in the development of the study, it is briefly discussed before dissecting the three main articles (see Appendix C and Chapter 2 for full details):

The pilot study explored the foundational integration of Construction 4.0 (C4.0) attributes within South African undergraduate programmes for Quantity Surveying (QS) and Construction Management (CM) students. Employing an Explanatory Sequential mixed-method (to be used in the main three articles) approach underpinned by Activity Theory (AT), the study combined quantitative data with qualitative insights from focus groups to assess how well C4.0 competencies are embedded in the curricula. This served the dual purpose of establishing the role of the evolution of the CHAT to the Expansive Learning (EL) principles (as explained in Section 1.4) and supporting the research gaps highlighted in Sections 1.2 and 1.3. In particular, the Pilot Study highlighted a significant gap between the current focus on technical skills and the need for soft skills, such as critical thinking and collaboration, which are essential for the emergent Construction 5.0 (C5.0) framework. The findings suggest that a more balanced curriculum is needed – one that integrates both technical skills and human-centric attributes, highlighting the need for a framework to guide curriculum reform, enabling South African Higher Education Institutions (HEIs) to improve the preparedness of graduates for leadership roles in an increasingly digitised and collaborative construction industry.

The implication of the above is that new technologies cannot merely be placed as a reactive module contribution, but should be planned to follow the logical "rule of diffusion of the innovation process", while addressing quality and excellence as defined by Hazelkorn et al. (2018:6) and subsequently paraphrased below,

> Educational quality encompasses teaching, learning, research, engagement, and institutional leadership, extending beyond internal matters to reflect higher education's capacity to meet societal needs – often associated with "excellence" – and considers factors such as

[7] The Pilot study one: Conference paper: ASOCSA (18th Built Environment Conference; 15–16 July 2024).

knowledge production, innovation, student learning outcomes in both declarative knowledge and soft skills, student performance, retention, graduation, employability, support for student success, training of diverse graduates at various educational levels, curriculum breadth and responsiveness to contemporary needs, pedagogical methods and support, and connections to societal practice and working life, including graduates' preparedness as citizens and lifelong learners.

The three main articles' primary outcomes are highlighted and expanded on below, highlighting the implication of informed and planned implementation of pedagogical practices grounded in well-researched and tested epistemological grounding. It was found that the definition of the relationship between knowledge, skills, competency, and attributes (KSCA) is a fundamental component to establish before embarking on further discussion on GAs. Subsequently, the definition per Section 5.5 states *that knowledge provides the theoretical foundation, skills offer practical application, competencies ensure the ability to perform tasks effectively, and attributes foster continuous professional development*. With this definition in mind, the systematic synopsis of each article is shown below:

6.3.1 Article 1 (Section 3)

The article was guided by the original objective and subsequent question (Sections 1.5 & 1.6), which is evaluated through the synopsis of Article 1. The original objective and subsequent question are thus presented first before the synopsis of Article 1.

- **Objectives:** Identify, evaluate and measure student experiences towards the most important South African Construction Built Environment graduate attributes through the CHAT perspective and provide a rationale for the existence of these graduate attributes.
- **Research Question:** How do university QS and CM students perceive and experience the learning of GAs, and how do these perceptions assist in the preparation towards C4.0 to form the human-centric foundation for C5.0 developments?

Synopsis of Article 1: The article is titled *Fostering Graduate Attributes for Justice in South Africa's Construction Education Curriculum Amid the Fourth and Fifth Industrial Revolutions.*

Proposed Journal: *Journal of Construction*[8]

This article delved into the perceptions and experiences of South African Quantity Surveying (QS) and Construction Management (CM) students regarding Construction 4.0 (C4.0) and GAs within their educational programmes. The findings indicate that while students are aware of the importance of C4.0 and graduate attributes – such as digital literacy, adaptability, problem-solving, and critical thinking – there is a growing need to integrate soft skills, particularly those associated with Construction 5.0 (C5.0), such as collaboration and emotional intelligence. It can be acknowledged that existing processes contribute to adequate preparation for the world of work; however, more can be done to deepen the impact of QS and CM programmes. In summary, they specifically highlight the following key items (as summarised in Section 3.8; please also refer to Figure 3.1 & Figure 3.4):

- Students saw GAs as essential for guiding their academic journey and believed developing specific GAs and C4.0 attributes would improve degree programmes (Sections 3.7.1.1 & 3.7.1.2), highlighting the value GAs have in their academic journey, particularly in justifying curriculum content and assisting in navigating their academic journey.
- Students emphasised the need for programmes to be presented beyond the second generation of AT (2GAT), a shift from a teaching-orientated approach to a learner-centred and mentor-driven model in HEIs (Section 3.7.1.2), highlighting potential further research on the value of the mentor-driven model.
- Students seek clarity in the content they are taught, starting with the 'why' to help both lecturers and students enhance career-focused learning (Section 3.7.2.1), providing justification and improvement towards understanding the objective of

[8] https://journalofconstruction.com/ – Currently under review (2025/05/12)

what they are taught (to use the teaching-centred term – please see the next bullet).

- Students stressed the need for HEIs to adopt learner-centred, community-engaged education (specifically towards industry) to prepare well-rounded graduates for the C4.0 era.

Implications for the Study, Participants, and the Field: The findings underscore the disconnect between classroom learning and real-world demands, reinforcing the need for curricula integrating theoretical knowledge with practical skills. For students, embedding GAs enhances self-directed learning and professional development. For educators and HEIs, the study emphasises the value of learner-centred strategies and the necessity of aligning curricula with industry requirements to foster holistic graduate readiness. In the broader field, these insights contribute to the discourse on curriculum justice and integrating C4.0 and C5.0 principles in education.

Evaluation of Objectives and Research Question: The study successfully met its objectives by identifying and evaluating students' perceptions of crucial GAs and their alignment with C4.0 readiness. By applying the CHAT perspective, the findings provided a clear rationale for the significance of these attributes in addressing the evolving demands of the construction industry. The research question was also addressed effectively by highlighting the gap between current educational practices and industry expectations, emphasising the need for a human-centric approach to preparing students for C5.0 advancements. These insights reinforce the importance of embedding GAs into curricula to bridge academic learning with professional preparedness.

Justification of the Journal Choice: Article 1 is proposed for submission to the *Journal of Construction*, which focuses on integrating education, technology, and industry practices within the Construction Built Environment (CBE). This aligns with the article’s exploration of graduate attributes (GAs) within the context of Construction 4.0 (C4.0) and Construction 5.0 (C5.0), emphasising learner-centred, industry-engaged approaches in higher education. The journal’s commitment to showcasing research that bridges theoretical learning with practical application complements the study's findings, highlighting the need for curricula that address technological and professional demands.

This article contributes to the journal's discourse on preparing graduates for dynamic, technology-driven environments by exploring curriculum justice and aligning higher education practices with industry requirements. The journal's readership, including educators, industry professionals, and policymakers, ensures the research reaches a relevant audience, fostering discussions about transforming construction education to meet the challenges of the Fourth and Fifth Industrial Revolutions.

6.3.2 Article 2 (Section 4)

The article was guided by the original objective and subsequent research question (Sections 1.5 & 1.6), revisited and evaluated at the end of the synopsis.

- **Objective of Article 2:** Through the CHAT perspective, evaluate how critical graduate attributes are for lecturers in the South African Construction Built Environment and its implications.
- **Research Question:** How do university lecturers perceive the importance of graduate attributes in the South African Construction Built Environment, and how can these attributes be adapted to meet the needs of Construction 4.0?

Synopsis of Article 2: The article is titled *Integrating Graduate Attributes within a Construction 4.0 Framework: Insights from South African Quantity Surveying and Construction Management Educators.*

Proposed Journal: *International Journal of Construction Education and Research*[9]

This article examined the perspectives of Quantity Surveying (QS) and Construction Management (CM) lecturers on embedding Construction 4.0 (C4.0) attributes into their curricula. By addressing the 'how', the study identified challenges in integrating GAs into traditional educational frameworks and proposed a framework for adapting Graduate Attributes (GAs) within QS and CM programmes to equip graduates with the knowledge,

[9] https://www.tandfonline.com/toc/uice20/current – Currently under review (2025/05/12)

skills, and competencies (KSC) necessary for C4.0 [please refer to Figure 4.5, Section 4, (Annexure 4.1)].

Key themes emerged around digital transformation, industry engagement, and curriculum design, emphasising the need for curricula that align with industry requirements and foster adaptability, innovation, and lifelong learning among graduates. Lecturers recognised the importance of GAs beyond technical skills, highlighting critical thinking, adaptability, and problem-solving as essential. However, gaps in practical learning and industry engagement were apparent. The findings suggest that a broader, community-enhanced approach within the CHAT framework is crucial instead of focusing solely on module-level enhancements. This systematic approach facilitates curriculum mediation, developing an expansive learning environment and preparing students for the rapidly evolving construction industry.

Evaluation of Objectives and Research Question: The study met its objectives effectively by evaluating lecturers' perspectives on the role of GAs and their adaptation for C4.0 readiness. Using the CHAT framework, the findings highlight the need for systemic curricular changes to align with technological and industry demands. The research question was addressed by proposing a structured framework emphasising community enhancement over isolated module improvements, thus enabling better mediation of curriculum artefacts. This approach ensures HEIs are equipped to meet the dynamic requirements of the construction industry under the C4.0 paradigm, ensuring that each QS & CM department understands the definition of their objective and the terms used within their pedagogy.

Implications for the Study, Participants, and the Field: The findings have significant implications for the study, participants, and the broader field of construction education. For the study, the proposed framework highlights how GAs can be integrated systematically into QS and CM curricula to bridge the gap between industry needs and educational practices. For participants, particularly lecturers, the findings emphasise the importance of fostering industry engagement and practical learning opportunities to prepare graduates better for C4.0 challenges. For the field, the study contributes to the discourse on curriculum innovation and pedagogy in construction education, providing a pathway for aligning curricula with the dynamic demands of the construction industry while fostering holistic graduate development.

Justification of the Journal Choice: *The International Journal of Construction Education and Research* is well-suited for this article due to its focus on education, training, and professional development within the construction sector. Many foundational articles for this PhD study were sourced from this journal (Appendix B), which underscores its relevance. By addressing the role of community-enhanced, industry-aligned curricula in advancing technological and pedagogical practices, this article contributes significantly to the global discourse on the integration of knowledge, skills, competencies, and attributes within the C4.0 framework.

6.3.3 Article 3 (Section 5)

The article was guided by the original objective and subsequent research question (Sections 1.5 & 1.6), which are revisited and evaluated within the synopsis.

- **Objective of Article 3:** The CHAT perspective evaluates the relevance of graduate attributes needed in the South African Construction Built Environment for the workforce and its implications.
- **Research Question of Article 3:** What is the relevance of graduate attributes in preparing South African Construction Built Environment professionals to address the needs of the evolving workforce in the context of Construction 4.0?

Synopsis of Article 3: The article is titled *Graduate Attributes' Contribution to Improved Collaboration within Quantity Surveying and Construction Management Curricula in the 4IR Era.*

Proposed Journal: *Journal Acta Structilia*[10]

This article investigated how expansive learning (EL) frameworks can recalibrate graduate attributes (GAs) to meet the evolving demands of the South African Construction

[10] https://journals.ufs.ac.za/index.php/as/index A ccepted (2025/02/02)

Built Environment (CBE) workforce within the context of Construction 4.0 (C4.0). The study focused on the interactions of multiple Cultural-Historical Activity Theory (CHAT) systems through the lens of EL, emphasising the importance of informed, collaborative decision-making when developing curriculum epistemologies.

Findings revealed that QS and CM professionals value a diverse set of knowledge, skills, and competencies, but place greater emphasis on attitudes and behaviours in new employees. While technical skills remain critical, *soft skills* such as adaptability, collaboration, and communication are pivotal for aligning graduate competencies with industry needs. The EL framework highlighted bridging contradictions within educational systems to foster lifelong learning and ongoing professional development among all stakeholders. This study proposed a critical framework for integrating technical and soft skills in construction graduates, aligning with both C4.0 and the human-centred approach of Construction 5.0 (C5.0).

The findings underscore the need for stronger collaboration between HEIs and industry professionals to develop curriculum designs that promote continuous professional development. GAs were identified as a common ground for fostering communal engagement within QS and CM professions, enabling deeper competency development and preparing graduates for the dynamic demands of the CBE.

Evaluation of Objectives and Research Question: The study successfully achieved its objectives by evaluating the relevance of GAs in preparing construction graduates for C4.0 challenges. Using EL frameworks provided a valuable lens for addressing systemic contradictions and fostering collaboration between multiple CHAT systems. The research question was addressed by proposing a practical framework (Figure 5.5: **Observed multiple C4.0 Attribute CHAT System** – Section 5.5) for recalibrating GAs to align with industry expectations, ensuring graduates are equipped with the technical and soft skills necessary for success in a rapidly evolving workforce.

Implications for the Study, Participants, and the Field: The findings significantly affect various stakeholders. For the study, the EL framework offers a robust foundation for recalibrating GAs, enabling HEIs to adapt curricula to industry-specific needs while fostering collaboration between educational and professional systems. For participants, including lecturers and industry professionals, the study emphasises the importance of continuous professional development and lifelong learning to remain competitive in the CBE. For the broader field, the proposed framework contributes to advancing curriculum design by integrating C4.0 and C5.0 principles, ultimately supporting the development of a workforce that is adaptable, innovative, and equipped to navigate technological advancements in the construction industry.

Justification of the Journal Choice: The journal *Acta Structilia* is well-suited for Article 3 due to its focus on professional development, construction management, and industry-relevant research within the South African CBE. Endorsed by the South African Council for the Quantity Surveying Profession (SACQSP) and aligned with the Royal Institution of Chartered Surveyors (RICS), the journal provides a platform for addressing issues of expansive learning in C4.0 and recalibrating GAs. This article aligns with the journal's goals by exploring how EL frameworks can bridge gaps between HEIs and industry, promoting well-rounded, industry-ready graduates prepared for both C4.0 and the human-centric approach of C5.0.

6.4 CONCLUSIONS

Graduate Attributes (GAs) serve as the academic grounding for the commonly referred to as 'soft skills', translating these practical layman concepts into a structured and measurable academic framework. By aligning attributes such as critical thinking, communication, and teamwork with disciplinary standards and educational outcomes, GAs provide a robust theoretical foundation that ensures these skills are recognised, systematically developed, and assessed within academic programmes. The research combined Cultural Historical Activity Theory (CHAT) and Expansive Learning (EL) principles to establish a robust theoretical framework, providing Higher Education Institutions (HEIs) with a pathway to align curriculum design with industry demands. By integrating Graduate Attributes (GAs), students are more prepared to meet the evolving challenges of the Construction Built Environment (CBE). At the same time, lecturers and industry professionals gain actionable insights to improve teaching practices and support continuous professional development. Additionally, the study contributes to the broader discourse on curriculum reform in the CBE by presenting a holistic framework that balances technical skills with human-centric elements to equip graduates for a rapidly changing industry landscape.

This study made several contributions to the field of higher education in the Construction Built Environment (CBE), with three key summaries highlighted below, followed by an expansion on each in Sections 6.4.1 and 6.4.2:

Integration of Cultural Historical Activity Theory (CHAT) in Construction Education: This research demonstrated how Activity Theory could evaluate and enhance educational practices in the CBE effectively, particularly concerning Construction 4.0 and the development of C5.0 frameworks.

Bridging the Gap between Industry and Academia: The study highlighted the disparity between the skills taught in higher education and the skills demanded by the construction industry, emphasising the need for curricula that balance technical competencies with soft skills.

Focus on Graduate Attributes: The findings revealed that graduate attributes, such as critical thinking, adaptability, and collaboration, are crucial for preparing students for the challenges of Construction 4.0 (C4.0). This study contributes to the discourse on how these attributes can be effectively integrated into HEI curricula by focusing on a learner-centred approach in contrast to a teaching approach. Acknowledging that GAs are inconjunct with knowledge, skills, and competencies provides an additional layer to improve and deepen the outcome of graduates entering the workforce (see Figure 3.1 in Section 3).

The theoretical and professional contributions are discussed below through the conceptual and theoretical framework highlighted in Section 6.2.1, particularly Figure 6.1.

6.4.1 Theoretical contribution

This research contributes to the body of knowledge in the following ways, bringing together four minds of thought in the process, namely Expansive Learning (Engeström et al., 1999), Graduate Attributes (Barrie, 2007; Gleason, 2018; Griesel & Parker, 2009; Singaram et al., 2023), the Construction 4.0 framework (and the more emerging C5.0 framework) (Begić & Galić, 2021; Marinelli, 2023:2; Sawhney et al., 2020) and the theory of Diffusion of Innovation Rogers (1983). The process emphasises collaborative problem-solving and the transformation of social practices, making it highly relevant to the modern demands of Construction 4.0 and 5.0. For perspective, a summary of the evolution of the Expansive Learning theory is shown in Figure 6.2 below.

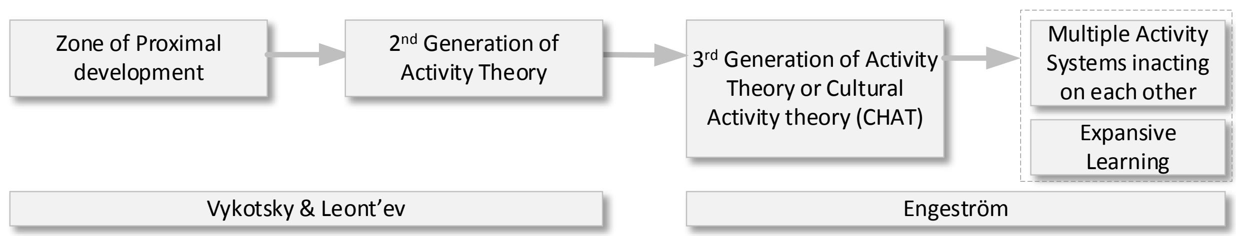

Figure 6.2: Simplified Evolution of Activity Theory

Adapted: Engeström (2001:134–137)

Integration of Cultural Historical Activity Theory (CHAT) in Curriculum Design ('why'): By applying CHAT to assess educational programmes, this research provides a framework for evaluating the mediation of learning tools and processes within QS and CM programmes. The use of CHAT highlights contradictions within the current system and enables the development of expansive learning models that support students in acquiring both technical and soft skills.

Expansive Learning in Construction Education ('how'): The thesis contributes to the literature on expansive learning by showing how it can be applied within construction education to foster continuous professional development and lifelong learning (refer to Section 1.7 for the search engines used). The expansive learning process addresses contradictions within activity systems and is particularly relevant for preparing graduates to adapt to emerging technologies and evolving industry practices. In Article 3 specifically, it was found that the incorporation of the five Ws of journalism, who, what, where, when and why (Georgia Institute of Technology, 2024:online), could enhance the definition of the artefacts, in particular of coming from a pragmatic worldview. It also poses the potential of addressing more practical application questions, particularly regarding the ‘when’ and ‘where’, which are not currently in the framework.

Graduate Attributes as Mediators (‘what’): The findings from all three studies emphasise the importance of graduate attributes (GAs) as mediators between knowledge, skills, and competencies (KSCA). This thesis adds to the theoretical discourse by proposing that GAs serve as critical enablers of Construction 4.0 and 5.0 readiness. These attributes, such as adaptability, critical thinking, and collaboration, are crucial for developing a workforce capable of navigating the technological and human-centred demands of the industry. Through the study, the understanding of GAs could also be confirmed by Warier (2014), who places GAs as a critical building block towards competency acquisition. GAs are fundamental in the mediation of knowledge and skills to acquire and implement competencies, which the CBE seeks (please see Figure 6.1 above – venn diagram).

6.4.2 Professional contribution

As a Programme Director involved in curriculum planning and pedagogy within QS and CM programmes, the findings of this research have several practical implications:

Collaboration with Industry (‘why’): The findings stress the need for closer collaboration between HEIs and the construction industry to ensure students gain relevant, hands-on experience. As a programme director, I believe these insights are valuable for fostering partnerships with industry professionals, creating internship opportunities, and embedding industry-led projects into the curriculum.

Curriculum Reform (‘how’): This research identifies specific areas where curriculum reform is necessary to improve educational alignment between HE outcomes and industry needs. The emphasis on integrating both technical and soft skills, as outlined in the framework proposed in Article 2, offers a clear path for curriculum development that meets the evolving demands of Construction 4.0 and 5.0.

Pedagogical Innovation ('what'): The research also highlights the importance of adopting innovative teaching methodologies, such as expansive learning, that promote active student engagement and critical thinking. These approaches will enhance the learning experience and ensure students are better prepared for Construction 4.0 (C4.0) and the development of Construction 5.0 (C5.0).

6.5 RECOMMENDATIONS

Based on the findings of this research, several recommendations can be made for HEIs and stakeholders in the South African Built Environment:

Curriculum Reform: HEIs should consider reforming their curricula to emphasise soft skills alongside technical competencies. By explicitly distinguishing the scaffolding between knowledge, skills, competencies and attributes in producing lifelong learners will prepare students for the dynamics of Construction 4.0 and Construction 5.0 developments. However, this broad statement is accompanied by the recommendation that expansive learning should be utilised in this reform:

Incorporation of Expansive Learning: While the current focus on competency outcomes – guided by regulating councils – successfully produces capable graduates, integrating expansive learning into pedagogical practices can elevate the impact within the CBE. A more impactful pedagogical approach can be developed through expansive learning (see Section 6.7 for more details) by asking who, why, what and how learning takes.

Industry Collaboration: Strengthening partnerships between HEIs and the construction industry is essential to ensure that the education provided aligns with industry needs. Articles 2 and 3, particular, assist with this alignment, where HEIs are best poised to direct the collaboration by first understanding and defining the CHAT system(s) (Article 2 - Figure 5.4) and focusing on the attributes as a connection point with the multiple system approach (as explained in the EL approach). This could include collaborative projects, internships, and guest lectures from industry professionals.

Lifelong Learning and Continuous Professional Development: In an era of rapid technological advancements, lifelong learning is essential. Higher Education Institutions (HEIs) play a crucial role in nurturing a culture of continuous learning, offering opportunities for both students and lecturing staff to research and expand their skill sets and attributes. For lecturers, this commitment to growth involves embracing the Scholarship of Teaching and Learning (SoTL) principles and aligning with the professional standards set by regulating bodies, integrating these principles into teaching practices. Through this approach, HEIs empower students to become self-directed learners who appreciate the interconnectedness of knowledge, skills, competencies and attributes (KSCA) and understand how to apply them professionally.

6.6 LIMITATIONS OF THE STUDY

While the study provides valuable insights into integrating C4.0 attribute development processes within the South African HEIs, several limitations may be acknowledged.

Firstly, the study focused on a select group of HEIs and professional stakeholders within South Africa's CBE. This selection was primarily based on institutions offering QS and CM programmes, which limits generalising the findings to other regions or institutions not included in the sample. Additionally, the evolving nature of C5.0 presents challenges, as this framework is still in its early stages of development. Therefore, the full implications of its integration into educational curricula remain speculative, and further longitudinal research is needed.

The research was conducted within five HEIs located in Bloemfontein, Gqeberha, Cape Town, and Johannesburg, assessing student and lecturer perspectives through quantitative and qualitative data collection. While this provided a valuable cross-section of insights, the geographic limitation means that perspectives from other South African regions, which may face different socio-economic and educational challenges, were not captured.

Moreover, the data were collected in a structured timeframe, targeting the second semester of 2023. While this minimised disruptions from assessment workloads for staff and students, it also restricted the study’s ability to observe potential changes in perspectives over a more extended period, such as across different academic years or varying institutional changes due to the integration of Construction 4.0 technologies.

The sampling method, which relied on anonymous surveys and voluntary participation in focus groups, may also present inherent limitations. The reliance on self-reported data means there could be a degree of bias in the responses, as participants may have had differing interpretations of the questions based on their own experiences and expectations within the CBE.

Finally, although the study endeavoured to balance student and lecturer perspectives, the focus on specific graduate attributes could have been more in-depth. Each proposed graduate attribute or a specific component of Construction 4.0 could justify its detailed study, as the breadth of this research may not have allowed for a nuanced exploration of each attribute’s long-term implications.

Despite these limitations, the study lays a solid foundation for further research into the role of Construction 4.0 and 5.0 attributes within the South African CBE. Future studies may benefit from expanding the scope to include more institutions, longitudinal data collection, and in-depth analysis of individual attributes and their long-term impacts on industry readiness.

6.7 FRAMEWORK FOR EXPANSIVE LEARNING TOWARDS C4.0 ATTRIBUTE DEVELOPMENTS WITHIN THE CBE HEIs

Future research could expand this study's scope by including a broader range of institutions and stakeholders, particularly in other regions of South Africa. Five HEI institutions teaching QS and CM programmes participated in Articles 1 and 2 (106 students and 29 lecturers), while 336 respondents participated in Article 3. The respective articles provide a particular breakdown (Sections 3 to 5). The study could have taken a much more focused approach towards each proposed Graduate Attribute, which justifies a study on its own. Similarly, many components listed under Section 6.4.1 could form studies independently; however, the study endeavoured to provide a platform from which these studies might spread. Instead of proposing multiple different directions that these studies can take, it is proposed that Expansive Learning be expanded on as a potential future field within the CBE HEIs and innovation, providing multiple opportunities:

Activity theory is based on five principles. It views 1. collective artifact-mediated, object-oriented systems as the primary unit of analysis; 2. highlights the multi-voicedness of diverse perspectives within these systems; 3. emphasises the historical development of activities (it highlights that these systems usually take a long time to develop); 4. recognises contradictions as drivers of change; and 5. allows for expansive transformations through cycles of collective adaptation and innovation (Engeström, 2001:136-137). Whereas EL fundamentally asks the who, why, what and how learning takes place within a specific system (CHAT) as a unit of analysis, multi-voicedness, history, contradictions and expansive cycles (Engeström, 2001:138). Going through seven cycles of expansion: 1. questioning (need state); 2. historical analysis and actual-empirical analysis; 3. modelling the solution; 4. examining and testing the new model; 5. implementing the new model; 6. reflecting on the process and consolidating; and 7. generating the new practice (Engeström et al., 1999:384). This study only started scratching the surface of this cycle, progressing up to level three as depicted in blue in Figure 6.3 below:

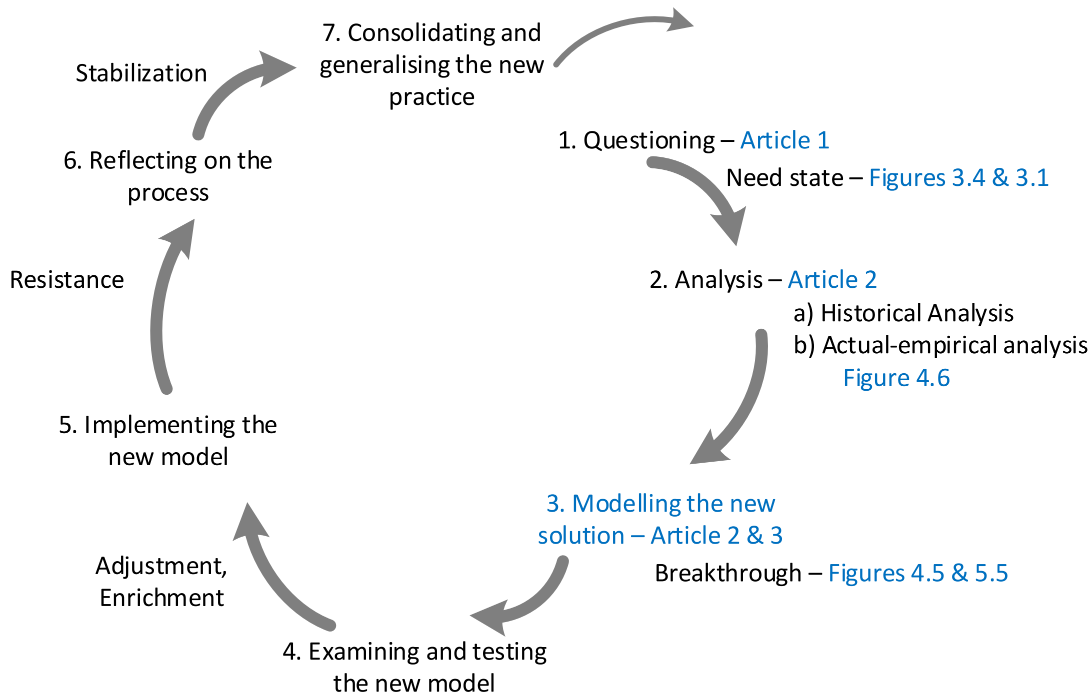

Figure 6.3: Sequence of learning actions in an expansive learning cycle

Source: Engeström et al. (1999:384); Engeström and Sannino (2010:8)

Figure 6.3 shows that further study is required, with much potential, as highlighted in the following section (Section 6.8).

6.8 SUGGESTIONS FOR FUTURE RESEARCH

Ideally suited for further investigation into the expansive learning (EL) investigation, change laboratories (CL), as described by Engeström and Sannino (2010:15-16), provide a framework for supporting transformative learning and innovation in educational and organised contexts, highlighted by Posillico et al. (2023). Garraway (2021) supports this methodology, reiterating its roots in CHAT and confirming the platform, highlighting contradictions within the organisational systems and facilitating transformative learning and innovation. Future research could apply this methodology to investigate further how EL can support HEIs in evolving towards more real-world practices (Newman et al., 2021), innovative and learner-centred practices within the context of C4.0. The approach has been applied in various settings, including the African context, where it has been used to tackle complex societal challenges, such as sustainable practices and climate change (Winberg et al., 2023). CLs are particularly valuable in environments undergoing rapid change, as they help participants reimagine their practices and foster collective agency to initiate meaningful reforms (Botha, 2017). By supporting bottom-up educational reforms and engaging diverse perspectives (Garraway et al., 2023), CLs hold promise for further investigation in addressing the evolving needs of CBE HEIs.

6.9 CLOSING REMARKS

This thesis has explored the role of graduate attributes in preparing students for the demands of Construction 4.0 and 5.0. The study identified key areas for improved alignment between higher education curricula and industry needs through the lens of Cultural Historical Activity Theory (CHAT) and expansive learning (EL). By emphasising a balanced integration of technical and soft skills, fostering industry collaboration, and promoting lifelong learning, South African HEIs can prepare their graduates better for the evolving challenges of the construction industry.

This research has demonstrated that while South African HEIs are progressing in integrating Construction 4.0 attributes into their curricula, there is still a considerable gap between current educational practices and the skills required by the construction industry. Bridging this gap requires a concerted effort from both academia and industry. The proposed framework offers a pathway for achieving this alignment by focusing on graduate attributes, practical industry engagement, and a balance between technical and soft skills.

Moreover, as the construction industry evolves toward a more human-centric approach under Construction 5.0, the role of HEIs becomes even more critical. By preparing students to navigate the complexities of both digital and human collaboration, educational programmes can ensure that graduates are technically proficient and capable of leading innovation in the construction industry.

In practical terms, the study aimed to provide a practical starting point for anyone seeking to understand how to prepare construction graduates for an uncertain future. These suggestions provide a clear starting point. It translates complex stakeholder dynamics and graduate expectations into actionable educational and institutional strategies. The proposed frameworks are not rigid models but guides for aligning curriculum outcomes with Construction 4.0 realities while preparing the ground for human-centric Construction 5.0 developments. Its value lies in helping HEIs institutions in their curriculum planning considerations to develop industry decision makers to drive cohesion within the construction industry and keep the agency within the profession.

6.10 PERSONAL REFLECTION

As I reflect on the journey of completing this research, I recognise the significance of my role as a researcher and a programme director. This dual role has given me a unique perspective on the challenges faced by HEIs in aligning their curricula with industry demands. My involvement in curriculum planning and accreditation processes allowed me to apply the findings of this research in real-time, offering practical insights into how pedagogical strategies can be adapted to meet the needs of both students and industry professionals.

The process of conducting this research has also deepened my understanding of the critical role that graduate attributes play in shaping the future workforce. As we move into the era of Construction 5.0, the balance between technology and humanity will become increasingly important. This research has contributed to my professional development and equipped me with the tools to lead meaningful change within the higher education landscape. I sincerely hope that the study's contribution might also assist others grappling with the same challenges. Looking ahead, I am committed to leveraging these findings to foster innovation and collaboration in higher education, ultimately contributing to a more equitable and transformative academic environment.

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PART 4

SUPPORTING APPENDICES

APPENDIX A1 – ETHICS: ORIGINAL APPROVAL UFS-HSD2022/0241/22

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS UV

GENERAL/HUMAN RESEARCH ETHICS COMMITTEE (GHREC)

14-Jun-2022

Dear Mr Hendri Du Plessis

Application Approved

Research Project Title:
The evaluation of Construction 4.0 attributes of South African Construction Build Environment students using Activity Theory

Ethical Clearance number:
UFS-HSD2022/0241/22

We are pleased to inform you that your application for ethical clearance has been approved. Your ethical clearance is valid for twelve (12) months from the date of issue. We request that any changes that may take place during the course of your study/research project be submitted to the ethics office to ensure ethical transparency. furthermore, you are requested to submit the final report of your study/research project to the ethics office. Should you require more time to complete this research, please apply for an extension. Thank you for submitting your proposal for ethical clearance; we wish you the best of luck and success with your research.

Yours sincerely

Dr Adri Du Plessis
Chairperson: General/Human Research Ethics Committee

Dr Adri du Plessis
Digitally signed by Dr Adri du Plessis
Date: 2022.06.14 18:22:15 +02'00'

205 Nelson Mandela Drive
Park West
Bloemfontein 9301
South Africa

P.O. Box 339
Bloemfontein 9300
Tel: +27 (0)51 401 9337
duplessisA@ufs.ac.za
www.ufs.ac.za

APPENDIX A2 – GATE KEEPER'S LETTER - FS-HSD2022/0241/22

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS UV

Office of the Vice-Rector: Research and Internationalisation
Kantoor van die Viserektor: Navorsing en Internasionalisering

07-Jun-2022

Dear Mr Hendri Du Plessis

<u>UFS AUTHORITIES APPROVAL</u>

Research Project Title:
The evaluation of Construction 4.0 attributes of South African Construction Build Environment students using Activity Theory

This letter serves as confirmation that your request to collect data from students and/or staff members at the University of the Free State for your research project has been approved **provided that you also have ethical clearance for the research from the ethics committee at the University of the Free State**.

Please make sure that you also obtain your ethics clearance letter containing your reference number from the ethics committee after you have received this letter before you conduct your research.

Kind Regards

PROF RC WITTHUHN
VICE-RECTOR: RESEARCH & INTERNATIONALISATION
CHAIR: SENATE RESEARCH ETHICS COMMITTEE

205 Nelson Mandela Drive/Rylaan
Park West/Parkwes
Bloemfontein 9301
South Africa/Suid-Afrika

P.O. Box / Posbus 339
Bloemfontein 9300
South Africa / Suid-Afrika
T:+27(0)51 401 2116
F:+27(0)51 401 3752
WitthuhnRC@ufs.ac.za
www.ufs.ac.za

APPENDIX A3 – EXTENSION LETTER - FS-HSD2022/0241/22

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS UV

GENERAL/HUMAN RESEARCH ETHICS COMMITTEE (GHREC)

22-Mar-2023

Dear Mr Hendri HB Du Plessis

Amendment Approved

Research Project Title:
The evaluation of Construction 4.0 attributes of South African Construction Built Environment graduates: an Activity Theory perspective

Ethical Clearance number:
UFS-HSD2022/0241/22

We are pleased to inform you that your amendment application for ethical clearance has been approved. Your ethical clearance is valid for twelve (12) months from the date of issue. you are requested to submit the final report of your study/research project to the ethics office. Should you require more time to complete this research, please apply for an extension. Thank you for notifying the ethics committee of the changes/amendments that have been made to your study; we wish you the best of luck and success with your research.

Yours sincerely

Dr Adri Du Plessis
Chairperson: General/Human Research Ethics Committee

Adri Du Plessis

Digitally signed by Adri Du Plessis
Date: 2023.03.22 13:38:08 +02'00'

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APPENDIX A4 – UNIVERSITY OF JOHANNESBURG

02 February 2023

Henri Du Plessis
University of the Free State (UFS)

Dear Henri Du Plessis

PERMISSION TO CONDUCT RESEARCH AT THE UNIVERSITY OF JOHANNESBURG

The request for the project titled *The evaluation of Construction 4.0 attributes of South African Construction Build Environment graduates: An Activity Theory perspective* refers. Permission is granted to conduct this study at the University of Johannesburg (UJ).

Please note that the granting of permission does not make it mandatory for UJ students and/or staff to participate in the study. As the researcher/applicant, you will need to engage with potential participants to obtain their consent to participate in the study.

Should you require assistance in distributing the survey to UJ students and/or staff, kindly send a brief description of your study together with the link to where participants can access the survey to tdewet@uj.ac.za, copying hemalij@uj.ac.za and rloots@uj.ac.za.

Sincerely

Dr Ndivhuwo Luruli
Executive Director: Research and Innovation
Email: nmluruli@uj.ac.za

APPENDIX A5 – CENTRAL UNIVERSITY OF TECHNOLOGY

Central University of Technology, Free State

INSTITUTIONAL PLANNING AND QUALITY ENHANCEMENT

H DU PLESSIS

PERMISSION FOR HENDRI DU PLESSIS TO CONDUCT HIS RESEARCH AT CUT ENTITLED "THE EVALUATION OF CONSTRUCTION 4.0 ATTRIBUTES OF SOUTH AFRICAN CONSTRUCTION BUILD ENVIRONMENT GRADUATES: AN ACTIVITY THEORY PERSPECTIVE".

Dear Mr. Du Plessis

This is to confirm that you have been granted permission to conduct research at the Central University of Technology for your research project entitled "The evaluation of construction 4.0 attributes of south African construction build environment graduates: an activity theory perspective."

The conditions of the conditional permission are:

- The research will not interrupt any of the official activities at The Central University of Technology;
- You will supply us with the copy of your report;
- The cost of all related activities will be covered by yourself;
- Recruitment of participants is the sole responsibility of yourself;
- Voluntary nature of the potential participants decision to consent to participate should be strictly observed;
- You should not disclose a potential participant's decision to participate or otherwise to any other party;
- Permission does not compel, in any sense, participation of staff members or students in your research.

Senior Director: Institutional Planning and Quality Enhancement

Mr. I Mokhele

10/05/2023

APPENDIX A6 – NELSON MANDELA UNIVERSITY

NELSON MANDELA

UNIVERSITY

PO Box 77000, Nelson Mandela University, Port Elizabeth, 6031, South Africa mandela.ac.za

Chairperson: Research Ethics Committee (Human)
Tel: +27 (0)41 504 3624
Dalray.Gradidge@mandela.ac.za

NHREC registration nr: REC-042508-025

Ref: [H23-ENG-BQS-EAP-002] / Approval: 27 March 2023 – 27 March 2024

27 March 2023

Dear Prof Crafford

THE EVALUATION OF CONSTRUCTION 4.0 ATTRIBUTES OF SOUTH AFRICAN CONSTRUCTION BUILD ENVIRONMENT GRADUATES: AN ACTIVITY THEORY PERSPECTIVE

PRP: Prof G Crafford
PI: Mr H du Plessis

Your application for ethics approval to conduct research at Nelson Mandela University has been considered by the REC-H on the basis that the study has been duly vetted and approved by the University of the Free State, Research Ethics Committee.

Kindly use the following ethics reference number **H23-ENG-BQS-EAP-002** together with your University's ethics clearance number in any correspondence with gatekeepers and participants at the University. Ethics clearance is valid for one year.

Please inform the REC-H, of any changes that may arise during the execution of the study, particularly to the methodology.

It must be noted that the Nelson Mandela University assumes that the Research Ethics Committee responsible for providing the original ethics approval/clearance has undertaken both ethics and scientific review of the protocol according to the National Health Research Ethics Committee (2015) Guidelines, and assumes primary responsibility for oversight with regard to any ethical issues that may arise in the course of the study. The Nelson Mandela University would also wish to be provided with an executive summary of the findings from the research.

We wish you well with the project.

Yours sincerely

Dr D Gradidge
Chairperson: Research Ethics Committee (Human)

cc: Department of Research Development

APPENDIX A7 – UNIVERSITY OF CAPE TOWN

CENTRE FOR HIGHER EDUCATION DEVELOPMENT
UNIVERSITY OF CAPE TOWN

Huri ǂoaxa (Hoerikwaggo) Building,
North Lane, Upper Campus
Private Bag #3 Rondebosch 7701
Telephone: (021) 650-5730

14 April 2023

Henri du Plessis
Department Quantity Surveying and Construction Management
University of the Free State

Dear Mr H. B du Plessis

The evaluation of Construction 4.0 attributes of South African Construction Build Environment graduates: an Activity Theory perspective

The Research Ethics Committee of the Centre for Higher Education Development has reviewed the documentation you submitted in respect of the above proposed research study.

I am pleased to confirm that the REC has approved the study to proceed on the terms specified in your submissions to the committee. Should the research focus and process change in any substantive way, you are requested to make a new submission to the Committee. Please note that ethics clearance is granted for ONE calendar year from the date of approval. You will need to re-apply for ethical clearance if your study extends beyond this period.

Please note that researchers who wish to access UCT students for research purposes must also apply to the Executive Director, Department of Student Affairs (DSA) using the DSA100 form and those wishing to access UCT staff for research purposes must apply to the Executive Director of Human Resources.

We wish you all the best with the research.

Yours sincerely

Rughubar Reddy

Sheena Rughubar-Reddy

Chair, CHED Research Ethics Committee
(on behalf of the Committee)

Reference: CHED2023_4_ Du Plessis

	RESEARCH ACCESS TO STUDENTS	**DSA100**

NOTES

1. This form must be **FULLY** completed by all applicants who want to access UCT students for the purpose of research or surveys.
2. Return the fully completed **(a) DSA 100 application form by email, in the same word format, together with your: (b) research proposal inclusive of your survey, (c) copy of your ethics approval letter / proof (d) informed consent letter** to: Nadierah.Pienaar@uct.ac.za. You application will be attended to by the Executive Director, Department of Student Affairs (DSA), UCT.
3. The turnaround time for a reply is **approximately 10 working days.**
4. NB: It is the responsibility of the researcher/s to apply for and to obtain **ethics approval and to comply with amendments that may be requested; as well as to obtain** approval to access UCT staff and/or UCT students, from the following, at UCT, respectively:
   (a) **Ethics**: Chairperson, Faculty Research Ethics Committee' (FREC) for ethics approval, (b) **Staff access:** Executive Director: HR for approval to access UCT staff, and (c) **Student access:** Executive Director: Student Affairs for approval to access UCT students.
5. **Note:** UCT Senate Research Protocols requires compliance to the above, **even if prior approval has been obtained from any other institution/agency. UCT's research protocol requirements applies to *all* persons, institutions and agencies from UCT and external to UCT who want to conduct research on human subjects for academic, marketing or service related reasons at UCT.**
6. **Should approval be granted to access UCT students for this research study, such approval is effective for a period of one year from the date of approval (as stated in Section D of this form), and the approval expires automatically on the last day.**
7. **The approving authority reserves the right to revoke an approval based on reasonable grounds and/or new information.**

SECTION A: RESEARCH APPLICANT/S DETAILS

Position	Staff / Student No	Title and Full Name	Contact Details (Email & Cell / Land line)
A.1 Student Number			
A.2 Academic / PASS Staff No.	2005108812	Mr Hendri du Plessis	duplessishb@ufs.ac.za/ 073 177 8963/ 051 401 9824
A.3 Visitor/ Researcher ID No.			
A.4 University at which a student or employee	University of the Free State	Address if *not* UCT: Building 79 – QS Building, UFS; 205 Nelson Mandela Dr, Park West, Bloemfontein, 9301	
A.5 Faculty & Department/School	Natural and Agricultural Sciences – Department Quantity Surveying and Construction Management / UCT CHED		
A.6 APPLICANTS DETAILS if different from above	Title and Name	Tel.	Email

SECTION B: RESEARCHER/S SUPERVISOR/S DETAILS

Position	Title and Name	Tel.	Email
B.1 Supervisor	Dr Somarie Holtzhausen	051 401 2048	HoltzhSM@ufs.ac.za
B.2 Co-Supervisor/s			

SECTION C: APPLICANT'S RESEARCH STUDY FIELD AND APPROVAL STATUS

C.1 Degree – if applicable	Doctor of Philosophy with specialisation in Higher Education Studies
C.2 Research Project Title	The evaluation of Construction 4.0 attributes of South African Construction Build Environment graduates: an Activity Theory perspective
C.3 Research Proposal	Attached: Yes ☒ No ☐
C.4 Target population	UCT BSc Construction Studies - students
C.5 Lead Researcher details	If different from applicant:
C6. Will use research assistant/s	Yes ☐ No ☒ If yes- provide a list of names, contact details :
C.7 Research Methodology and Informed consent	Research methodology: Quantitative via questionnaire and qualitative via focus group interviews. Informed consent: Yes, advised to participants for questionnaire and interviews
C.8 Ethics clearance status from UCT's Faculty Ethics in Research Committee /Chair (EIRC)	Approved by the UCT EIRC: Yes ☒ With amendments: Yes ☐ No ☒ (a) Attach copy of your UCT ethics approval. Attached: Yes ☒ No ☐ (b) State date / Ref. No / Faculty of your UCT ethics approval: 14/04/2023 Ref. / Faculty: CHED2023_4_Du Plessis – UCT, 22/03/2023 Ref. / Faculty: UFS-HSD2022/0241 – UFS

SECTION D: APPLICANT/S APPROVAL STATUS FOR ACCESS TO STUDENTS FOR RESEARCH PURPOSE
(To be completed by the ED, DSA or NOMINEE)

D.1 APPROVAL STATUS	Approved / With Terms / Not (i) Approved ~~(ii) With terms~~ ~~(iii) Not approved~~	* Conditional approval with terms a) Access to students for this research study must only be undertaken after written ethics approval has been obtained. *b)* In event any ethics conditions are attached, these must be complied with before access to students.	Applicant/s Ref. No.: 2005108812 / Mr Hendri du Plessis	
D.2 PREPARED BY:	Designation Personal Assistant	Name *Nadierah Pienaar*	Signature Pienaar	Date of Approval 28/06/2023
D.3 APPROVED BY:	Designation Executive Director / Nominee Department of Student Affairs	Name *Mr Pura Mgolombane*	Signature	Date of Approval *28/06/2023*

HR194a	ACCESS TO UCT STAFF FOR RESEARCH PURPOSES (Fulfilment of a Degree)	UNIVERSITY OF CAPE TOWN IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

NOTES

- Forms must be downloaded from the UCT Administrative Forms website: http://forms.uct.ac.za/forms.htm .
- This form must be completed by applicants who are requesting to access UCT staff for the purpose of research for the fulfilment of a degree.
- A copy of the research proposal as well as the Ethics Committee approval must be attached.
- It is the **responsibility of the researcher/s to apply for ethical clearance** from the relevant Faculty's Research in Ethics Committee (RIEC).
- If you are requesting staff information, you are required to complete the HR Information Request Form (HR190) and submit it together with all the required documentation. **Please note that the invite to participate in research will only be distributed once per application.**
- The turnaround time for a reply is **approximately 10 working days unless specified as urgent.**
- Please submit your application including the completed application form and all the above documentation directly to Zoe Cosmopoulos via email (zoe.cosmopoulos@uct.ac.za) for the attention of the Director: Analytics, Risk, System, Payroll & Admin. Please do not submit these to the Director directly.

SECTION A: APPLICANT DETAILS

Title	Mr	Name	Hendri
Telephone number	073 177 8953	Email address	duplessishb@ufs.ac.za
Student number	N/A	Staff number	N/A
Visiting researcher ID / passport number	8305095071085		
University or institution at which employed or a registered student	University of the Free State		
Faculty or department in which you are registered or work	Natural and Agricultural Sciences – Department Quantity Surveying and Construction Managemen		

SECTION B: SUPERVISOR DETAILS

	Title and name	Telephone number	Email address
Supervisor	Dr Somarie Holtzhausen	051 401 2046	HoltzhSM@ufs.ac.za
Co-Supervisor	N/A		

SECTION C: APPLICANT'S FIELD OF STUDY / TITLE OF RESEARCH PROJECT / STUDY

Degree	Doctor of Philosophy with specialisation in Higher Education Studies	
Research project or title	The evaluation of Construction 4.0 attributes of South African Construction Build Environment graduates: an Activity Theory perspective	
Research proposal attached	☒ Yes	☐ No
Target population	BSc Construction Studies - lecturers	
Number of UCT staff required	8	
Research method	☒ Interviews	☒ Questionnaire
Amount of time required for the above	15min for questionaire and 1 hour for Focus Group discussion	
Lead Researcher details	Mr Hendri du Plessis	

SECTION D: FOR OFFICE USE (Approval status to be completed by the Executive Director, Human Resources or Nominee)

UCT Proof of ethical clearance status attached	☑ Yes	☐ No	
Proof of ethical clearance status from the University/Institution, if registered outside of UCT	☑ Yes	☐ No	☐ Not Applicable

Support or approval			Role	Signature	Date
Supported?	☑ Yes	☐ No	Zoe Cosmopoulos (Specialist: HR Analytics)	Zoe Cosmopoulos	07/06/2023
Approved?	☑ Yes	☐ No	Naeema Brey (Director: Analytics, Risk, System, Payroll & Admin)	NBrey	07/06/2023

APPENDIX B – TABLE OF PRELIMINARY INVESTIGATIONS

Table B: Initial investigation of research on Attributes within the CI

Article Title	Key Focus	Conclusion	Comment towards research GAP
Understanding the Key Master of Construction Project Management **Graduate Competencies** Required to Meet Industry Needs in Australia (Vaz-Serra & Mitcheltree, 2021)	Identifies the competencies most valued by the Australian construction industry for MCPM graduates.	Interpersonal skills, resilience, and emotional intelligence are prioritised over technical knowledge. Continuous development and adaptability are critical for graduates.	While investigating competencies, strong outcomes towards GAs were found.
Empirical Investigation of Discipline-Specific Skills Required for the Employability of Built Environment Graduates (Aliu et al., 2023)	Examines the specific skills necessary for employability in the built environment sector.	Industry-specific technical skills combined with interpersonal competencies are crucial for employability. The study recommends targeted educational strategies to develop these skills in graduates.	GAs such as adaptability and collaboration are not explicitly addressed despite their relevance, emphasising a gap in embedding them into construction education.
	Proposes a model for developing employability skills in built environment graduates.	A balanced approach integrating technical expertise with soft skills is essential for graduate success in the construction industry. The model emphasises adaptability and continuous learning.	The framework touches on soft skills but does not emphasise the broader integration of GAs like critical thinking and problem-solving as core attributes in curricula.
Construction Education Needs Derived from Industry Evaluations of Students and Academic Research Publications (McCord et al., 2023)	Evaluates the educational needs in construction based on industry feedback and academic research.	Continuous curriculum improvement is necessary to meet the evolving demands of the construction industry. The study highlights the need for collaboration between industry and academia.	Industry needs are reflected, but GAs, which are necessary for developing holistic professionals, are under-represented, pointing to a gap in curriculum development.
Favourable Female Attributes in Relation to Career Challenges of Women Engineers in the Thai Construction Industry (Kaewsri & Tongthong, 2014)	Explores the challenges faced by women engineers in the Thai construction industry and the attributes that help them succeed.	Resilience, adaptability, and strong communication skills are vital for women to overcome gender-related challenges in the industry.	Attributes like resilience and communication are present but not directly integrated into broader curricula through GAs, showing a gap in formal educational structures.
Key Attributes and Skills for Curriculum Improvement for Undergraduate Construction Management Programmes (Ahmed et al., 2014)	Identifies key skills and attributes needed in undergraduate construction management programmes to meet industry demands.	Emphasises the importance of integrating technical, managerial, and personal skills in construction management curricula. Continuous curriculum evaluation and alignment with industry expectations are necessary.	Graduate Attributes remain peripheral in curriculum discussions, although they play a crucial role in future-proofing the workforce.
Psychological Challenges Confronting	Investigates the psychological challenges faced by	Graduate students in construction face significant psychological stress,	Psychological well-being is addressed, but there is limited focus on embedding

Article Title	Key Focus	Conclusion	Comment towards research GAP
Graduate Construction Students in Australia (Sunindijo & Kamardeen, 2020)	graduate students in construction programmes in Australia.	emphasising the need for support systems within educational institutions to help them manage stress and maintain well-being.	GAs like emotional intelligence, which are critical for holistic student development.
Factors Inhibiting Higher Education Institutions from Addressing Industry Needs in Construction Education (O’Neill et al., 2023)	Identifies the barriers that higher education institutions face in aligning their programmes with industry needs.	Challenges include outdated curricula, lack of industry-academia collaboration, and insufficient resources. Addressing these barriers is essential for producing industry-ready graduates.	While technical updates are suggested, the absence of an explicit focus on GAs in curriculum reform underscores a gap in addressing future competency needs.
Ranking Construction Programmes: The Academic Debate Begins (Badger & Smith, 2006)	Discusses the need for ranking construction programmes to benchmark and evaluate performance against world-class metrics.	Identifies the need for interdisciplinary collaboration, world-class faculty, and continuous programme improvement to meet industry demands.	It highlights the absence of graduate attributes (GAs) in formal programme rankings and educational frameworks, pointing to a gap in recognising the holistic development of students in construction programmes.

APPENDIX C – PILOT STUDY

BRIDGING CONSTRUCTION 4.0 AND 5.0: STRATEGIC ATTRIBUTES FOR TRANSFORMING SOUTH AFRICAN UNDERGRADUATE BUILT ENVIRONMENT PROGRAMMES THROUGH ACTIVITY THEORY

Conference Paper: 18th Built Environment Conference – Association of Schools of Construction of Southern Africa (ASOCSA)[11]

ABSTRACT

This paper examines Construction 4.0 (C4.0) attributes within South African Construction Built Environment (CBE) undergraduate programmes, aiming to bridge these attributes to the emergent Construction 5.0 (C5.0) framework, which advocates a collaborative and people-centred industry. Employing an Explanatory Sequential mixed-method approach underpinned by Activity Theory, this study combines quantitative data analysed through descriptive statistics with qualitative insights from focus-group discussions to map the integration of C4.0 attributes in educational pedagogy. The research uncovers that while C4.0 competencies are heavily emphasised within the curricula, there is a crucial intersection with C5.0 ideals, where soft skills such as problem-solving and critical thinking are vital for nurturing a collaborative and adaptive workforce. The qualitative analysis indicates a need for educational programmes to evolve, highlighting the role of generic graduate attributes in fostering a human-centric approach to technological education. The findings advocate a curriculum that equally emphasises technical skills and developing soft skills that align with C5.0 principles, preparing students for technological efficiency, leadership and collaborative roles in the construction industry. This paper contributes to the ongoing discourse on educational adaptation in the face of

[11]The Pilot study one: 3rd prize at the recent ASOCSA (18th Built Environment Conference; 15–16 July 2024)

industry evolution, providing a framework for integrating C4.0 technical skills with C5.0's people-centred approach.

Keywords: Activity Theory, Construction 4.0, Construction 5.0, Graduate Attributes, South African Construction Education.

Notes: The terms Construction Industry (CI) and Construction Built Environment (CBE) are used interchangeably, with CI primarily denoting the global viewpoint, while CBE pertains specifically to the South African context. The paper primarily examines Construction 4.0 and argues that it is a valuable foundation for advancing Construction 5.0 outcomes when combined with Graduate Attributes.

INTRODUCTION

Just as the construction industry is indeed dynamic and constantly evolving, driven by increasing complexities such as technological advancements, changes in regulations, environmental considerations, and shifting market or work demands (Ahmed et al., 2014:240; Najafi, 2023:online). Higher education is imperative in ensuring that future construction managers are equipped with the necessary attributes to perform work efficiently and effectively in this environment.

Similarly, Construction 4.0 is an evolving term that refers to digital innovation within the construction industry that stems from industrial production, cyber-physical systems and digital computing technologies (Sawhney et al., 2020). Construction 5.0 builds upon this, aiming to reintroduce the human element into these digitised environments, stressing the importance of human-robot collaboration (Marinelli, 2023:1). Due to the construction industry's reputation for being slow to respond and adapt to change, including innovative technologies and methods, the process of innovation diffusion is more intricate than initially perceived (Orstavik et al., 2015:3-11). The construction industry (CI) continues to be intricate, involving numerous stakeholders (O'Neill et al., 2023:1). Innovation primarily arises through a process of emergence involving multiple pathways and occurring at various levels. The industry’s predicament becomes apparent when one considers the complex process of creating new products for various clients. This involves forming temporary teams, utilising multiple procurement and production methods, and dealing with significant risks (Orstavik et al., 2015:3-11). The fragmented state of teaching, research and professional industries in the built environment poses a challenge in the context of the Fourth Industrial Revolution (4IR) or Industry 4.0 (I4.0) (Sawhney et al., 2020:5).

The Law of Diffusion of Innovation is a significant factor. Rogers (1983:246) classifies individuals who adopt new ideas into five primary categories: innovators, early adopters, early majority, late majority, and laggards(Sinek, 2009:129). Rogers posits that innovation influences the adoption of inventions, adopters, marketing or communication efforts, time, and the prevailing social system (Rogers, 1983:10-11). Activity Theory (AT) can be used as a framework to examine the desired graduate qualities of South African Construction Built Environment (CBE) students, which arise from different pedagogical intentions. AT methodically examines the abilities of individuals and the social resources that are accessible to them, which influence a shared goal. Additionally, it considers the specific individuals involved (Gedera & Williams, 2016:xi).

In the prelude to the 4IR, South Africa has an immense skills shortage compared to other nations, not to mention complications due to infrastructure, weak governance and state capture (Sutherland, 2020:233). The 4IR is primarily promulgated as a flag post to create a particular economic and commercial future. A certain amount of disruption may be caused by automation and connectivity, according to Beweja (Sutherland, 2020:233). Through the voice of Schwab, the World Economic Forum (WEF) has sought to increase its profile through the propagation of the 4IR (Sutherland, 2020:234). South Africa, however, is not seen as one of the leading countries towards the implementation of the 4IR, with an economy based mainly on the farming, mining and informal sectors. Furthermore, the country has been experiencing the highest unemployment rate globally, at 35,8%, since measurements started in 2008 (Trading Economics, 2022:online).

Loosemore (2015) indicates that construction produces a unique product every time, unlike routine-based production and mass production, and has the advantage of task specialisation, repetition and learning, for example, car manufacturing. Construction resembles the development phase of the above. Modularisation, standardised designs and specifications and institutionalised routines are efforts to make the complexity manageable. The temporary nature of construction does not assist with linking firms in the CI (Orstavik et al., 2015:13-26). The COVID-19 pandemic has exacerbated higher education challenges worldwide, mostly affecting poorer students and vulnerable tertiary institutions (Paterson, 2021). With an increasing trend to automate, computers and robotic technologies are predicted to replace routine human manual work as the Fourth Industrial Revolution (4IR) unfolds (Hattingh, 2017).

Ideally, the South African construction industry could embrace the efficiencies that Construction 4.0 promises by producing new graduates with well-balanced scholarly attributes towards the Fourth Industrial Revolution and beyond to Construction 5.0. However, the reality of the divergence of the South African socio-economic and industry backdrop requires more consideration than just apparent institutional restructuring. This study's objectives included establishing the fundamental attribute requirements for Construction Economics undergraduates against the foreseen 4IR within the South African context. Secondly, the study aimed to assess the readiness of South African higher educational institutions (SA HEI) within the CBE to embrace and adapt to the 4IR regarding employment skills, continuous professional development (CPD), management of construction projects, and educational preparedness. Identifying opportunities, challenges, strategies, priorities, and implications for various stakeholders such as educational institutions, public sector clients, and contracting and consulting firms (e.g. construction managers and quantity surveyors) presented by the 4IR are key. With this said, this particular paper focuses on a particular higher education institution (HEI) within the South African (SA) construction built environment (CBE). Further study would, however be required to include a broader study base on the topic as it is a largely emerging topic within the HEI CBE in SA. The particular research question that informed this study is:

> How do the proposed scholarly attributes of certain tertiary institutions compare to the accredited curricula of undergraduate Quantity Surveying and Construction

Management programmes in terms of preparing students for Construction 4.0, and where do these attributes fit within the prescribed programmes?

With technology constantly changing and evolving, the fundamental focus of the CBE curriculum remains the established industry standards and guidelines which enable technological advancement. *Ultimately, the study aims to enhance understanding of the pedagogical requirements for realising Construction 4.0. and beyond within South African higher institutions, utilising the evaluation of specific student attributes through the lens of Activity Theory.*

LITERATURE REVIEW

Higher education institutions (HEI) within the construction industry (CI) are subjected to pressures from within the industry and professional bodies or, in South Africa's case, regulatory councils (Perera et al., 2011:10). According to Levy and Murnane (2005, cited in Saavedra & Opfer, 2012:8-12), employers demand more skills sets with fewer people, increasing complex thinking and communication skill requirements. The construction industry (CI) is not excluded, with Ahmed et al. (2014:240) concluding that out of the many attributes and skills required for Construction Management undergraduates, the following five attributes could be regarded as the most important: knowledge of health and safety regulations, interpretation of contract documents, listening ability or attention to detail, knowledge of building codes and regulations, and time management. The challenge remains to establish how the diverse social backgrounds of students may be developed to meet the requirements of the industry and the resources available to HEIs. Barrie (2007:439) states that universities are increasingly concerned with developing attributes to equip students better for the work environment that spreads from the increasing demands placed on graduates. For example, RIB Software International Limited (2016:online) highlights seven traits of a good quantity surveyor, namely efficient and concise communication between parties, critical thinking, being attentive to detail, keeping composure, being organised, keeping humility and being team orientated. With the workplace constantly changing through new technologies, Wagner (2008:67) proposes seven basic requirements for scholars, namely critical thinking, collaboration and leadership, agility and adaptability, initiative and entrepreneurship, effective oral and written communication, accessing and analysing information, and curiosity and imagination. Equally, Saavedra and Opfer (2012:8-13) propose nine lessons for 21st-century learning to address pedagogy requirements: making it relevant, teaching through the disciplines, developing thinking skills, encouraging learning transfer, teaching students how to learn, addressing misunderstandings directly, treating teamwork like an outcome, exploiting technology to support learning, and fostering creativity.

Equally important is the importance of the professional attributes of academia, which act as the routes that feed the graduate attribute development of students, dubbed the 'rhizomatic thinking' of teaching (Dhunpath et al., 2021:126-129), highlighting the mentorship role that lecturers play in the students' development. Some specific graduate attributes (GAs) propose to produce employable graduates with adequate social skills include (UFS, 2019:10): academic competence, critical thinking, problem-solving, oral communication, written communication, community engagement, ethical reasoning, and an entrepreneurial mindset. With the development of a pedagogical framework for curriculum, the 'how' is asked, while the 'what' forms the content (Hill et al., 2021). GAs are concerned about the relationship between the 'what' and the 'how', delving deeper into the students' studies, from the generic content towards the profession-specific. Likewise, the focus moves from teacher-centred to more learning-focused as the tenure progresses (Barrie, 2007:452).

CONSTRUCTION 4.0 AND 5.0

Before discussing Construction 5.0 (C5.0), it is crucial to differentiate between Industry 4.0 (I4.0) and the Fourth Industrial Revolution (4IR) and its relationship to Construction 4.0 (C4.0). While these terms are often used interchangeably, they represent distinct concepts (Najafi, 2023:online). I4.0, which debuted at the Hannover Fair in 2011 in Germany, focuses on revolutionising value chains and production systems through the development of smart factories. These factories optimise the integration of virtual and physical systems, enhancing operational efficiency (Schwab, 2016a:12). In contrast, the 4IR is characterised by a fusion of technologies that blur the traditional boundaries between the digital, physical, and biological spheres, expanding the scope and impact of digital transformation across societies (Prisecaru, 2016; Schwab, 2016b:online).

The implications of 4IR are significant, yet understanding the full range of its benefits and challenges is challenging due to the rapid pace of technological innovation (Morrar et al., 2017). Prisecaru (2016:58) discusses potential economic growth versus increased unemployment and social inequality as primary considerations of 4IR. Further, Chung and Kim (2016:1314) and Stăncioiu (2017:76) highlight several benefits, including enhanced employee efficiency, improved data accuracy, cost reduction, and optimised product life cycles. Xu et al. (2018:91) additionally suggest that 4IR can reduce barriers between inventors and markets, enhance the role of AI, and merge technologies to improve the quality of life. From a more specific perspective, the outcomes of the 4IR on the CI are expected to be substantial. The World Economic Forum (2018:7) highlights six imperatives, namely attracting new talent to enhance the required skills, integration and collaboration, adapting to technology, maximising the use of data, reviewing product portfolios, and being adaptable towards change management. Hattingh (2017:21-23) aptly submits that it is important for industry stakeholders to understand these technological shifts and ensure that relevant skills sets and other adaptive strategies are put in place to survive the industrial turbulence occasioned by the 4IR.

Though the CI is often heavy-footed in responding to innovative changes, stakeholders must have a holistic plan to accommodate these disruptions. The response to the changes, disruptions or challenges created by the 4IR needs a proactive approach (Orstavik et al., 2015:48). All stakeholders in the CI need strategic planning and implementation. This presupposes that current business models and operations adopted by most stakeholders in the CI might not be sufficient in the world of the 4IR. A need exists for a strategic and well-planned response to these anticipated disruptions to business and operations in the CI. The stakeholders in the CI must consciously seek out new opportunities and develop the required skill sets and adaptability to respond adequately to the changes triggered by the innovations accompanying the 4IR (Sawhney et al., 2020:46).

Professionals within the SA CBE are regulated by the Council for the Built Environment, under which the applicable councils for the paper, the South African Council for the Project and Construction Management Professions (SACPCMP) and the South African Council for the Quantity Surveying Profession (SACQSP) (Hauptfleisch 2024:4-45; Maritz & Siglé, 2016:4-6; SACPCMP, 2019:2). These professional councils have multiple standards and guidelines that graduates should be familiar with after completing their undergraduate studies. These requirements revolve around the standardisation of the Project Life Cycle (PLC) (Project Management Institute, 2016:20; SACPCMP, 2019:5) C4.0 is the convergence of these core requirements to industrial production, cyber-physical systems and digital technologies (Sawhney et al., 2020:5). For instance, Begić and Galić (2021:2) highlight the main drivers of Construction 4.0 as Building Information Modelling (BIM), the Internet of Things (IoT) and Big Data (BD) predominantly within the design phases of the project life-cycle. Ultimately, C4.0 is the evolution of existing processes within the CBE (Sawhney et al., 2020:45).

Understanding the significance of a profession's epistemology in relation to the results of their pedagogical frameworks is essential. For instance, law schools may structure their teaching methods around "case dialogue". Simultaneously, pedagogies in the field of medicine may prioritise the significance of engaging in professional practice (Shulman, 2005:22). Transactional disciplines necessitate the exchange of ideas and communication between teachers, students and educators (Cousin, 2009:201-212). Information literacy instruction focuses on a more critical understanding of information than skills acquisition (Hunt & Chalmers, 2021:90-91). It is essential to determine the minimum level of proficiency that students have in important concepts in order to facilitate in-depth learning and foster the development of key skills required for their chosen profession (Land et al., 2016; Hunt & Chalmers, 2021:92). Similarly, CBE HEI programmes may first want to highlight their epistemological stance and identify the core content before adding the necessary layers to their pedagogical outcomes. The South Africa CBE has a well-established pedagogical stance clearly stated and prescribed within their accreditation councils' accreditation guidelines for HEI programmes (SACPCMP, 2020; SACQSP, 2015). However, the epistemological contribution (Zou, 2008:26) seems to require rekindling with the South African CBE HEI mainly pragmatic approach, focusing on the prescribed knowledge, skills and competencies (SACQSP, 2015; SACPCMP, 2020).

THE COMPLEXITY OF THE CONSTRUCTION INDUSTRY AND RELATED SYSTEMS

The construction industry consists of multiple systems with constraints that depend on one another. The accuracy of one system cannot ignore the other, with no single improvement that can be made to any element in a system that would create a net gain for the system (Orstavik et al., 2015:13-25). In South Africa, many qualifications neglect the skills needed in a rapidly changing work environment shaped by disruptive technologies, emphasising job-specific training rather than entrepreneurial skills (Hattingh, 2017:20-23). Equally, HEI and the industry could improve their relationship with the industry (O’Neill et al., 2023:3), building on social scientific theories, such as Vygotsky’s concepts of the effect of culture or the tools of intellectual adaptations, proximal development (Mcleod, 2014), to understand better how novel thinking is influenced within the South African CBE. The Activity Theory (AT) is proposed to investigate undergraduate CBE graduates and lecturers’ perceptions and objectives, which has its roots in the Vykotsky Project (Fleer, 2016:2). The AT perspective is a useful framework that brings out the dynamics, fluidity, complexity, and contradictions in implementation and provides insights into gauging effects rather than assuming outcomes as the sole indicator of success (Van Der Westhuizen & Basson, 2011:14). The theory originated from the study of human activities and started with the identification of a triad (see Figure 1) (Engeström et al., 1999:30; Gedera & Williams, 2016:21), where the subject and tools would interact to achieve an object, named the second generation of activity theory (2GAT)(Jones & Hashim, 2014). This was further expanded to include subjects, tools, community, rules and roles to achieve an object with a caused outcome (Gedera & Williams, 2016:21), named the cultural-historical activity theory (CHAT) or third generation of activity theory (3GAT)(Spinuzzi, 2020:20).

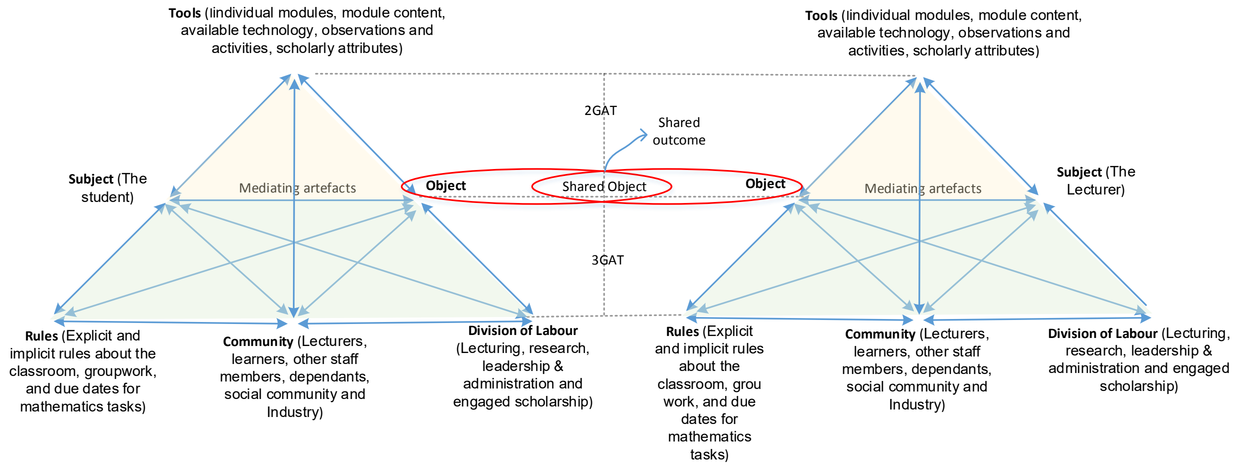

Figure 1: Human activity system structure interaction between SA CBE students and lecturers

Adapted from Engeström (2001:35); Fujioka (2014); Jones & Hashim (2014); Naidoo (2014)

To align the object of the activity to produce a C4.0-equipped student, prescribing the object of C4.0 within a single pedagogical outcome of an undergraduate degree proves daunting if entry requirements of an entry-level QS and CM are considered (SACPCMP, 2020; Ashworth & Higgs, 2023:12). Suppose the activity is defined as the process of obtaining a degree that equips graduates to be employable (Hattingh, 2017:22) in the CBE; then C4.0 attributes/competencies would rather form part of the object than the sole object. The following definitions are proposed for the mediation of the artefacts: Tools may define the individual modules, technological tools and teaching, while the subject may refer to students (Gedera & Williams, 2016:20-21). The meaning of community lies in the word itself, describing the community, such as fellow students – campus community where the students find themselves. Rules may refer to the general rules of the institution, cultural rules and rules set by individual modules. Division of labour can refer to the time prioritisation for study and personal obligations. The object may be defined as producing a well-rounded and employable graduate (UFS, 2019:2), of which one of the outcomes is being prepared for Construction 4.0 (Adapted from Fujioka, 2014; Jones & Hashim, 2014; Naidoo, 2014). Spinuzzi (2020:26) highlights the following differences between the first and third generations of AT:

- 1GAT: Mediation, internalisation, proximal development.
- 2GAT: Activity system, the structure of activity (mediation of artefacts).
- 3GAT Activity networks, contradictions, rules (cultural-historical activity theory).

The 3GAT is utilised to analyse the mediation of artefacts within a specific department of the South African Construction HEI arena, both in the past and present. This investigation aims to gain a more comprehensive understanding of the current epistemological approach and how it may affect the alignment of the subsequent C4.0 preparedness in teaching (Engeström, 2001:136; Gedera & Williams, 2016:vii & 6).

RESEARCH METHODOLOGY AND METHOD

Using the Activity Theory framework, a mixed-method study was conducted through which students' conflicting obligations were highlighted to establish how student attributes contribute to realising a well-rounded student for the emergence of Construction 4.0. An explanatory sequential design(Jacobs & Cornelius, 2022:111) was used, which allows for two phases in which the quantitative data are gathered and evaluated before the qualitative data are gathered and evaluated (Kumar, 2014:47). This approach aims to have the quantitative data inform the qualitative data to be gathered. After the data have been evaluated, a concluding discussion may be used to make relevant conclusions (Creswell & Creswell, 2018:15).

To initiate the first phase, a structured survey questionnaire (Naoum, 2007:103) was employed with the primary aim of establishing a starting point for the focus-group discussions involving both students and lecturers (Du Plooy-Cilliers et al., 2014:1833; Creswell & Creswell, 2018:187). A combination of ordinal data collection tools was utilised for the structured survey, such as ranking statements and Likert-scale tables (Naoum, 2007:73). Additional open-ended questions were also presented to understand respondents' comprehension of specific terms better. A tendency measurement was used mainly to interpret the results by allocating the mean to the two data sets (Naoum, 2007) from the lecturers and the students. Descriptive statistics were also utilised to highlight significant information obtained from the survey (Naoum, 2007:73). In line with AT, the analysis focused on identifying the underlying tensions (Fleer, 2016:6) within the data, considering the GAs' relationship with Construction 4.0. A questionnaire was distributed among 80 students and 7 permanent lecturers at an HEI department within the SA CBE HEI. Response rates of 42,5% and 100%, respectively, were achieved.

The second phase involved conducting focus-group discussions with lecturers within the South African CBE HEI. The main focus of the focus-group discussions was attitudes, behaviours and preferences towards Construction 4.0 and the proposed GAs (Du Plooy-Cilliers, Davis & Bezuidenhout, 2014:183). The subsequent focus-group discussion was conducted with the respondent lecturers and students to establish semantic and latent themes for thematic analysis (TA)(Maguire & Delahunt, 2017:3353). Data were transcribed and coded to search for themes before categorising the data for analysis (Creswell & Creswell, 2018:194).

RESEARCH RESULTS (QUANTITATIVE ANALYSIS)

This study deployed a questionnaire among 80 students and 7 permanent lecturers within a Department of a Higher Education Institution (HEI) in the South African Construction Built Environment (CBE). The response rates achieved were 42,5% from students and 100% from lecturers. The collected data revealed insights into the department's student composition and preparedness for Construction 4.0.

The demographic breakdown shows that 35,3% of the student respondents were first-generation tertiary students, with 5,9% uncertain of their generational status. A significant majority (88,2%), reported having an adequate infrastructure to complete assignments and access study materials, while 2,9% lacked such infrastructure, and 8,8% faced occasional challenges. Prior to university, smartphones were the primary technological device for 64,7% of the students, which likely contributed to 64,7% of them reporting excellent digital skills upon entry to university; another 26,5% reported fair digital skills. Remarkably, 97% of the respondents owned private laptops.

Financial dependency is a crucial aspect of student life, with 32,4% of the department's students reliant on the National Student Financial Aid Scheme (NSFAS), compared to the national average of 46,3% in the 2021/22 financial year (South Africa, 2023).

In terms of academic preparedness, most respondents indicated minimal or no experience with construction sites before enrolling in the Construction Economics and Management programme. Despite this, critical thinking and problem-solving were identified in the survey as the graduate attributes (GAs) most crucial for preparing students for the demands of C4.0.

The following section investigates and compares both the student and lecturer data. A simple t-test (value of 0.01) suggested a good correlation between the responses of the two groups (Johnson & Christensen, 2014:573-574). When comparing the means and rankings of the two datasets, tensions and outliers became evident. There were marked differences in how students and lecturers valued academic competence, oral communication, and entrepreneurial mindsets. Lecturers valued academic competence and entrepreneurial mindset more, whereas students preferred oral communication skills.

Table 1: Attributes according to their significance (importance) in preparing students to be Construction 4.0 ready

Many attributes produce a well-rounded graduate. Please rate the following attributes according to their significance (importance) in preparing students to be Construction 4.0 ready.		Lecturers		Students	
		Lecturer mean (on a scale of 4)	Ranking	Student mean (on a scale of 4)	Ranking
1	Academic competence	3.57	3.00	3.03	6.00
2	Critical thinking	3.86	1.00	3.35	2.00
3	Problem-solving	3.86	1.00	3.56	1.00
4	Oral communication	3.43	6.00	3.30	3.00
5	Written communication	3.43	6.00	3.09	5.00
6	Community engagement	3.14	8.00	2.82	8.00
7	Ethical reasoning	3.57	3.00	3.21	4.00
8	Entrepreneurial mindset	3.57	3.00	3.03	6.00
				Std Dev	0.30
				T-test	0.01
				Pearson's Coefficient	0.8129

Both groups identified community engagement as the least important characteristic in preparing students for Construction 4.0, with students placing less emphasis on academic competence. Further inquiry indicated that both students and lecturers concurred and comprehended that fundamental knowledge and skills are important in equipping students for Construction 4.0, correlating with Vygotsky's theory of proximal development (Mcleod, 2014).

In relation to the investigation of the Activity Theory (AT), a subsequent series of inquiries were raised regarding the role of artefacts in attaining the state of being C4.0 ready. The survey evaluated students and lecturers' perceptions of GA development. Participants were instructed to rate the importance of five statements using a Likert scale, ranging from 1 (Completely disagree) to 4 (Completely agree). The initial three statements were expressed affirmatively, whereas the final two were expressed negatively. Each of the datasets provided requires additional investigation. However, this section aims to comprehend the connection between the lecturers and the students, as well as the perceived contribution of the GA towards C4.0 preparedness. This was achieved using Pearson's correlation coefficient (Du Plooy-Cilliers et al., 2014:214).

Table 2: Activity theory (AT) based on GA and their significance (importance) in preparing students to be Construction 4.0 ready

Students N = 34 Lecturers N = 7 *Data based on means*		Student's role in developing attributes		Importance of tools in attribute development		Role of communities in attribute development		Rules as constraints in attribute development		Labour/time management constraints on attributes	
		Lects	**Studs**	**Lects**	**Studs**	**Lects**	**Studs**	**Lects**	**Studs**	**Lects**	**Studs**
1	Academic competence	3.43	3.15	3.57	3.38	3.43	3.42	3.43	2.61	2.00	3.09
2	Critical thinking	3.71	3.26	3.14	2.97	3.71	3.21	3.71	2.7	2.29	2.81
3	Problem-solving	3.71	3.41	3.29	3.12	3.71	3.24	3.71	2.76	2.29	2.54
4	Oral communication	3.57	3.12	2.86	2.74	3.57	3.30	3.57	2.76	2.29	2.66
5	Written communication	3.43	3.18	3.29	3.09	3.29	3.24	3.29	2.67	1.71	2.81
6	Community engagement	3.43	2.76	2.86	2.71	3.57	3.09	3.57	2.79	2.57	2.88
7	Ethical reasoning	3.57	3.09	3.29	3	3.57	3.12	3.57	2.67	2.43	2.68
8	Entrepreneurial mindset	3.71	3.03	3.14	2.91	3.71	3	3.71	2.52	2.43	2.88
	Pearson coefficients	0.501		0.978		-0.459		0.045		-0.232	

From Table 2, visualisation could be drawn on the AT's mediation of artefacts to illustrate the results better. Within Figure 2, the solid green line represents a robust correlation, whereas the orange dashed lines indicate a less strong correlation, and the red dashed lines indicate the weakest relationship between the data sets.

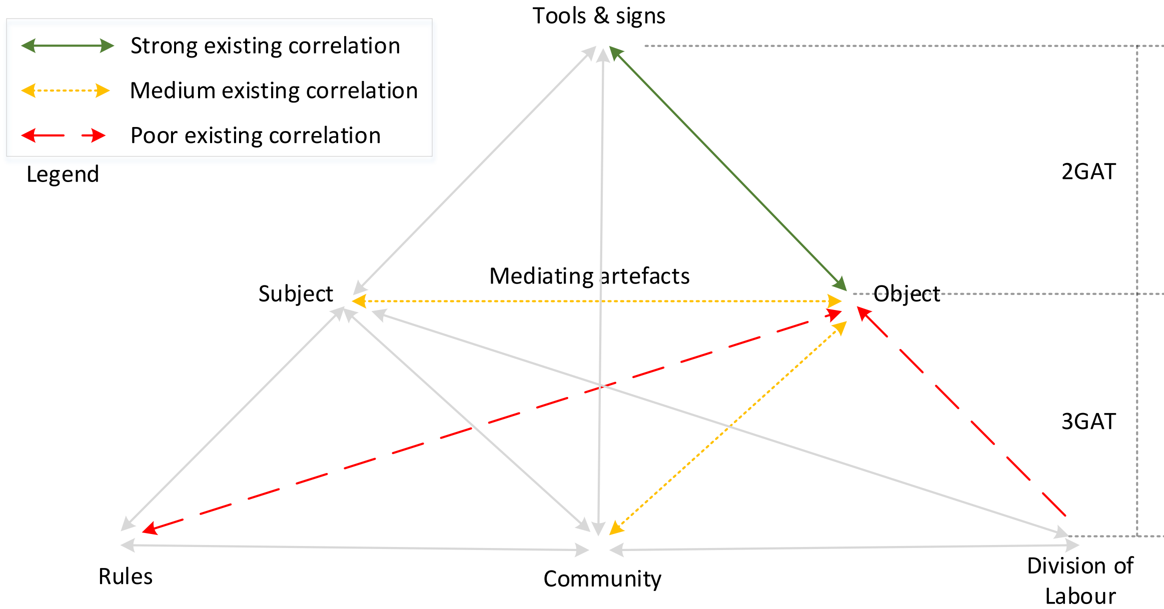

Figure 2: 3GAT illustration of the strong and weak correlation between lecturers and students observed

Adapted from Engeström (2001:135); Fujioka (2014); Jones and Hashim (2014); Naidoo (2014)

Based on the data presented, it can be observed that lecturers interact effectively with students regarding the content of their respective modules, particularly up to the 2GAT level. It is important to emphasise that gaining a deeper understanding of additional activities can enhance students' engagement and comprehension of the obstacles they face in acquiring knowledge, skills and competencies. The available data suggest that Higher Education Institutions (HEIs) in the Competency-Based Education system can greatly benefit from a thorough understanding of their students. The intricate nature of cultivating a proficient graduate is evident in the fundamental knowledge, skills and competencies that serve as the foundation of Competency-Based Education in Higher Education programmes. However, GA emphasises the possibility of improving how lecturers facilitate the module content by evaluating the students' progress and identifying unexplored opportunities to foster more profound learning and engagement. By incorporating the recommended fundamental material and providing students with guidance on their professional trajectories, it is possible to improve their capacity to navigate the complexities of the extensive knowledge and skills covered in their curriculum.

RESEARCH RESULTS (QUALITATIVE)

Two focus-group discussions were conducted with seven fourth-year students and five lecturers, respectively. A thematic analysis (TA) was used, a process of familiarising the data, generating codes, searching for semantic and latent themes, and summarising the themes (Braun & Clarke, 2006:5 & 14). While semantic themes focus on the explicit content of the data, latent themes involve a deeper exploration of the underlying ideas and assumptions that contribute to the surface meanings(Braun & Clarke, 2006). The coding process included allocating pseudonyms for lecturers denoted by the letter "L" and for students the letter "S", followed by a number. From the focus-group discussion with the lecturers, the following semantic themes could be identified:

Table 3: Thematic themes from the lecturers' focus-group discussion

	Semantic themes
1	A diverse group of students who enter the institution and subsequently find themselves in a wide range of work environments have to be catered to.
2	The South African industry is characterised by its traditional nature and a reluctance to embrace change at a rapid pace.
3	C4.0 is not the alternative objective. Emphasising creativity within the subject matter is highly significant.
4	Generic GA can address a wide range of requirements in C4.0.
5	Promoting the development of creativity within the chosen field is highly significant.
6	C4.0 is characterised by its sporadic and evolving nature, focusing on core knowledge, skills and the competencies necessary for adopting C4.0.
7	Understanding tools and rules is considered to be of the utmost importance in facilitating teaching and learning.
8	Lecturers perceived community involvement as less significant.

The following three main themes emerged from the themes highlighted above:

Diverse student needs and work environments: Acknowledging the diverse group of students entering the institution and emphasising the need to cater to them as they find themselves in a wide range of work environments.

- L2: "*I think the goal is to produce a well-rounded student who can work anywhere in the Industry*."

- L5: "*I believe our construction industry is far from Construction 4.0. I think we should give students a career foundation and prepare them for work. South Africa has yet to fully integrate technology into information management from start to finish, project life cycles, and integrated models*."
- L4: "*The goal is to prepare them for the real workplace and teach them to apply critical thinking in a given situation*."

Traditional nature of South African C4.0: Highlighting the traditional nature of the South African industry and its reluctance to embrace rapid change. Emphasising that C4.0 is not an alternative objective but underlining the significance of creativity within the subject matter.

- L3: "*The problem is that the engineer, QS, and project manager all have to work on the BIM model simultaneously.*"
- L5: "*Construction 4.0 involves the entire consultant team working on an integrated data model from start to finish*."

Teaching facilitation and community involvement perception: Emphasising the importance of understanding tools and rules in facilitating teaching and learning. Also, the perception among lecturers is that community involvement is less significant.

- L3: "*The tools are less important than knowing what opportunities towards the work outcome it may present*."
- L1: "*I think knowledge affects community but not relationships. I doubt students can form meaningful career groups. My closeness to my classmates made us inseparable in class. After graduating, it ended. So, I support knowledge-sharing, but students don't grasp industry connections*."

To provide context, the group of students in their fourth year who participated in the focus group had firsthand experience with the COVID-19 pandemic for two years during their three-year undergraduate studies. The student focus group identified the following thematic themes:

Table 4: Thematic themes from the student focus-group discussion

	Semantic themes
1	Students were eager to start working and were not sure what they wanted to specialise in.
2	Students were more interested in completing the tasks than conducting their own learning.
3	Proximal development planning and orientation would benefit students – justification for module structure is crucial.
4	Participants showed increased interest in learning about C4.0 after the survey.
5	Students recognised the professionalism that GA brings to the workforce.
6	Students demonstrated a strong grasp of GA definitions, including their connections and scope.
7	When prompted, participants could identify opportunities to improve experiences.
8	Participants welcomed rules in their modules.
9	Participants highlighted the importance of core knowledge before connecting it to C4.0.
10	Participants continually emphasised the importance of site exposure.
11	Participants highlighted the social connections across the cohort groups, first-year orientation, and the importance of facilities and resources in expanding their learning experience.

The following three main themes emerged from the themes highlighted above:

Career uncertainty and task focus: Students are eager to start working but are unsure about their specialisation. They are more interested in completing tasks than conducting their own learning.

- S2: "*I know we (fellow students) are career-focused and just starting out, and you can see current technology in use, but we do not fully understand how it is applied in industry*."
- S1: "*I think the main outcome is getting the qualification*."
- S2: "*In terms of assignments, I always aim to look for a template that the lecturer would approve of instead of thinking of my own*."

Interest in C4.0 learning and GA professionalism: Participants showed increased interest in learning about C4.0 after the survey. Students recognise the professionalism that Graduate Attributes (GA) bring to the workforce. Additionally, students demonstrated a strong grasp of GA definitions, including their connections and scope.

- S3: "*We would have used new tech more if we had more exposure and access to it. Skills and competencies, or the combination of graduate attributes, are most important in the workplace*."

- S4: "*I think graduate attributes are important early in your career. These attributes involve small tasks to evaluate performance. Employers value team and organisational collaboration. As you noted, these competencies lay the groundwork for demonstrating extensive experience later in your career*."
- S5: "*I understood the definition of the Graduate Attributes quite well, and they cannot function alone*."

Learning environment and improvement opportunities: Proximal development planning and orientation would benefit students, and justification for module structure and rules are crucial for them. Participants, when prompted, could identify opportunities to improve experiences. Participants continually emphasise the importance of site exposure and highlight social connections, first-year orientation, and the importance of facilities and resources to expand their learning experience.

- S1: "*We improved from first year. Considering the current question format. The questions make us think critically, like studying our own definitions for an exam that doesn't ask us to define what something is but may use it to answer questions*."
- S2: "*We had little practical training in our cohort. Even just seeing the theory in practice would help us understand the foundations' basic construction, as shown on slides*."
- S3: "*It is the small things that made the process easier for me, e.g. knowledge about the library, which has discussion rooms where you can sit and talk. If you want to discuss this, a facility here may help. In general, computer labs have these hours and rules, which you can print*."

In addressing the study's main aim, it was deemed appropriate to highlight some of the latent themes to assist in the thematic analysis of the data (Braun & Clarke, 2006). Some of the latent themes that could be identified were:

- Lecturers were distant from students and did not understand some of their socio-economic circumstances. This relates to the lecturers indicating that they lacked the necessary educational background to understand educational teaching philosophies and methods fully.

- The programme coordinator is crucial in conducting a thorough horizontal and vertical module alignment of the specific programme and conveying this to the teaching staff. It was observed that lecturers struggled to understand the students' existing GA levels, what is taught in service modules and how students can be challenged to increase their abilities.
- Students also emphasised the potential advantages of improving facilities for exploring C4.0 technologies, outcome-focused orientation towards the first year, and promoting cohort interaction to enhance inclusivity and educational support.

To summarise, the qualitative data indicated the necessity of addressing the varied needs of students, acknowledging their diverse backgrounds, and recognising the significance of meeting their needs in different work settings. The importance of creativity is emphasised in the context of C4.0 technologies and the comprehension of its fundamental principles. The significance of utilising tools and adhering to rules in the context of teaching facilitation was recognised. Following surveys and the recognition of the professionalism that Graduate Attributes (GA) bring to the workforce, students displayed a heightened interest in C4.0 learning.

DISCUSSION

Based on the qualitative data, it can be determined that there is a positive relationship towards the 2GAT within the department being evaluated. Expressing a firm belief in the current systems that prioritise the acquisition of specific skills, knowledge, and competencies as outlined by the councils within the South African Council for the Built Environment (SACPCMP, 2020b; SACQSP, 2015). Nevertheless, the ongoing development of a generic GA has the potential to enhance the learning process by accelerating it, bridging the gap between academia and the requirements of Industry 4.0 and the 4IR, and ultimately achieving the goals of C4.0 and the developing C5.0. Figure 3 illustrates the existing teaching methods in the particular programme, represented by green lines. Even though the orange dotted connections exist, they depict the potential influence of artefacts that can be improved to achieve the desired outcome of preparing graduates for Construction 4.0.

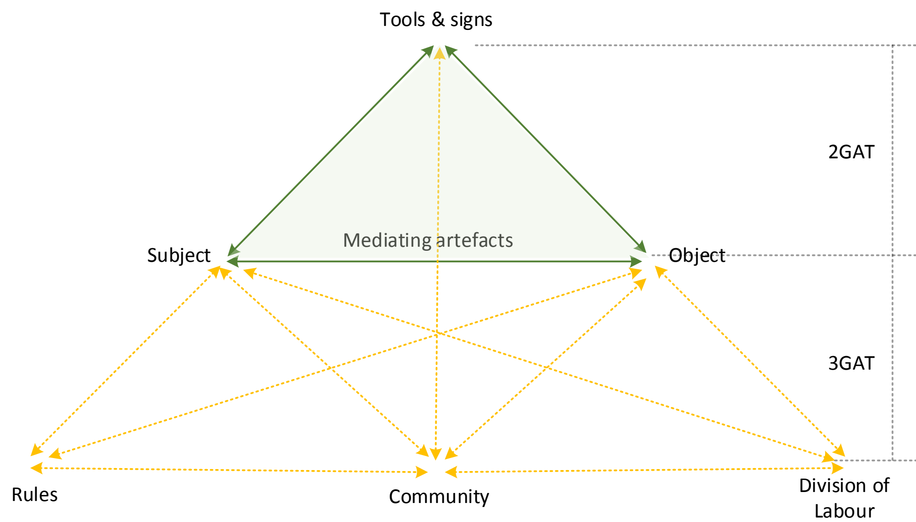

Figure 3: Existing and potential contributions to existing methods of teaching and learning

The literature emphasises that C4.0 is founded on the underlying principles of the QS and CM professions (Sawhney et al., 2020). The fundamental knowledge, skills and competencies outlined by Perera et al. (2011) serve as a solid framework for contemporary teaching. The empirical data and literature emphasise that lecturers have a significantly impact on students' frame of reference and proximal development (Dhunpath et al., 2021; Fleer, 2016; Mcleod, 2014). While obtaining a construction-related undergraduate degree in South Africa may not primarily focus on C4.0 preparedness and the development of C4.0 attributes and beyond, generic GA fosters the epistemological thought process that leads to relevant pedagogical development. The data closely align with the existing literature, suggesting that generic Graduate Attributes (GAs) offer a solid foundation for creating effective programme content that tackles the challenges of Construction 4.0. This approach serves as a basis for transforming the existing attributes of current students into desirable and adaptable qualities for graduates in the South African Construction Built Environment (SA CBE) and the development of C5.0 frameworks.

CONCLUSION

The construction industry, renowned for its practical approach and transition from experiential learning to knowledge acquisition (Perera et al., 2011; O'Neill et al., 2023), is currently experiencing substantial transformations towards Construction 4.0 and 5.0 (C4.0 & C5.0). Higher education institutions (HEI) in the South African construction built environment (CBE) face both opportunities and challenges. During the condensed three-year undergraduate programme, students are expected to progress from mandatory student attributes to applicable graduate attributes (GA), which serve as the basis for their professional attributes. Higher education institutions (HEIs) are essential for entry into postgraduate studies and the Industry. They play a vital role in facilitating continual professional development and bridging the divide between academia and industry. Programme directors are accountable for ensuring the coordination and integration of programmes in both a vertical and horizontal manner, with a particular focus on fostering clear and efficient communication with teaching staff and students. Lecturers should acknowledge the importance of soft skills and general aptitude in the comprehensive growth of students. Students must recognise their role in their own and their peers' development, understanding their responsibility as future ambassadors of their profession. C4.0 attributes are considered essential in Competency-Based Education Higher Education Institutions (HEIs). Nevertheless, the robust determination of generic GA is tackling many anticipated difficulties. However, in order for the CBE to have control over the adoption of C4.0 developments, it is crucial to have a robust research-based understanding of pedagogical development. This approach assures a proactive position in managing the intricacies of incorporating C4.0 attributes into the educational framework.

RECOMMENDATIONS

Ultimately, it is highly advisable for South African (SA) Construction and Built Environment (CBE) Higher Education Institution (HEI) departments to thoroughly explore the potential of graduate attributes (GAs) within their teaching frameworks. This investigation aims to evaluate how these characteristics can influence the quality of graduates they intend to cultivate. The proposed incorporation of specified knowledge, skills and competency prerequisites is recommended as the basis for horizontal and vertical coordination. A comprehensive approach is achieved by incorporating generic GA as an extra layer before developing industry-specific attributes. Moreover, the scope of this study could be expanded to incorporate perspectives from supplementary stakeholders, such as professionals in the field and other higher education institutions in South Africa. The involvement of various perspectives in a collaborative effort will likely enhance the comprehension and application of effective teaching strategies in the context of Competency-Based Education. Further research is crucial due to the abundant opportunities for exploration in the South African CBE and education. The current frameworks identify areas that require further examination, underscoring the importance of continuous research to continuously improve and enrich the educational environment in light of changing industry demands and technological progress towards C4.0 and C5.0.

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APPENDIX D – ARTICLE 1 DATA COLLECTION TOOLS

D.1 SURVEY QUESTIONNAIRE STUDENTS – QUEST BACK FORM

D.2 FOCUS-GROUP QUESTIONNAIRE AND PROTOCOL

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_UCT

Dear respondent

My name is Hendri du Plessis, a Researcher in the Faculty of Natural and Agricultural Sciences, the Department of Quantity Surveying and Construction Management at the University of the Free State. I am conducting a Ph.D. research study to evaluate the Construction 4.0 attributes of South African Construction Built Environment students from an Activity Theory perspective (Ethical Clearance No.: **UFS-HSD2022/0241/22**).

Considering the knowledge, skills and competency requirements of regulating councils, the study endeavours to establish the relevance of Graduate Attributes (GA) through the lens of Activity Theory, particularly Construction 4.0 Graduate Attributes. The study is aimed explicitly at undergraduate Quantity Surveying and Construction Management programmes (or similar).

Knowledge, skills, competencies, and attributes are all essential components of an individual's overall capabilities. Knowledge refers to a subject's theoretical or factual understanding, while skills are the practical abilities to perform specific tasks. Competencies are the behaviours and attitudes that enable effective performance, while attributes are the personal characteristics that underpin these competencies. These components comprise an individual's overall capabilities and determine their ability to perform a specific job or task. These components are necessary to achieve their professional goals and contribute effectively to their chosen field.

Participation in this study is voluntary, and your information will be kept confidential. You are also free to withdraw from the study at any point if you wish to do so without any consequences. Furthermore, you may also withdraw from the study by emailing the Principal Researcher of the study.

By completing the survey, you agree that your responses may be included in the study's final results. The results of the study will be published in an accredited and peer-reviewed journal. The Researcher will maintain confidentiality throughout the process.

This survey comprises 13 background questions and 9 outcome questions. **If you are willing to participate in the survey, select yes below to continue.**

- Yes
- I prefer not to participate

Next

6 % completed

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_UCT

Section A: Background Information

Which of the following is the best description of the programme that you are currently enrolled for?

- ○ BSc Quantity Surveying
- ○ BSc Construction Management
- ○ BSc Construction Economics and Management
- ○ BSc Construction Studies
- ○ BSc Honours Quantity Surveying
- ○ BSc Honours Construction Management

How many years have you been enrolled on the programme mentioned above?

- ○ Less than 1 year
- ○ 1 year
- ○ 2 years
- ○ 3 years
- ○ 4 years
- ○ 5 years
- ○ Other (specify):

Next

13 % completed

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_UCT

Does your parent(s) or grandparent(s) hold a formal qualification obtained from a University?

- ○ Yes
- ○ No
- ○ Unsure

How are your tuition fees funded?

- ☐ Self-funded
- ☐ Through NSFAS
- ☐ Study loan
- ☐ Personal Loan
- ☐ Other (Specify e.g. sponsor):

Next

19 % completed

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_UCT

Do you have all the necessary (sufficient) infrastructure (internet connectivity, computers etc.) to conduct your assignments and access your study material during the semester?

- Yes
- No
- Sometimes

Which living arrangements describe your situation best during the semester?

- An on-campus hostel.
- A shared commune with other students.
- A private apartment (shared with one or two fellow students).
- A private apartment (on your own).
- A family member's home, who is not your immediate guardian.
- Your parent's (guardian's) home.
- Other, please specify:

Next

25 % completed

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_UCT

Before entering the University, what was the technological device you were most exposed to?

- ○ A personal computer (maybe a shared computer at home)
- ○ A shared computer at school, library
- ○ A computer at an internet café or similar
- ○ A smartphone
- ○ Tablet
- ○ Other, please specify:

How would you rate your skills towards using the "required" technologies when you entered University:

- ○ Poor
- ○ Fair
- ○ Proficient
- ○ Excellent
- ○ Other, please specify:

How would you rate your skills improvement since you entered University:

- ○ No significant improvement
- ○ Somewhat of an improvement
- ○ A fair improvement
- ○ Excellent improvement
- ○ Other, please specify:

Next

31 % completed

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_UCT

Do you currently have access to a private laptop or computer to work from:

- ○ Yes
- ○ No
- ○ Sometimes

Next

38 % completed

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_UCT

Before entering the degree programme mentioned before, did you have any access/ exposure to a construction site? Please select the most appropriate answer:

- ○ Have never been exposed
- ○ Very limited exposure
- ○ Frequently visited a construction site
- ○ Worked on a construction site from time to time
- ○ Did extensive work on a construction site

Which three software programmes do you use most often for academic purposes specific to assignments:

- ☐ Microsoft Word (or equivalent)
- ☐ Microsoft Excel (or equivalent)
- ☐ Microsoft PowerPoint (or equivalent)
- ☐ Acrobat PDF (or equivalent)
- ☐ WinQS (or equivalent)
- ☐ DimX (or equivalent)
- ☐ Sketchup (or equivalent)
- ☐ Other, please specify:

Next

50 % completed

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_UCT

Section B: Outcome-based questions

Objective (Goal orientated):

In your opinion, what is the main objective of obtaining your degree?

0/4000

Tools and artefacts:

Construction 4.0 is associated with the Fourth Industrial Revolution's influence on the construction industry (CI). The following figure provides a short illustration of the possible future of Construction 4.0:

Appendix D.1 - Page 10

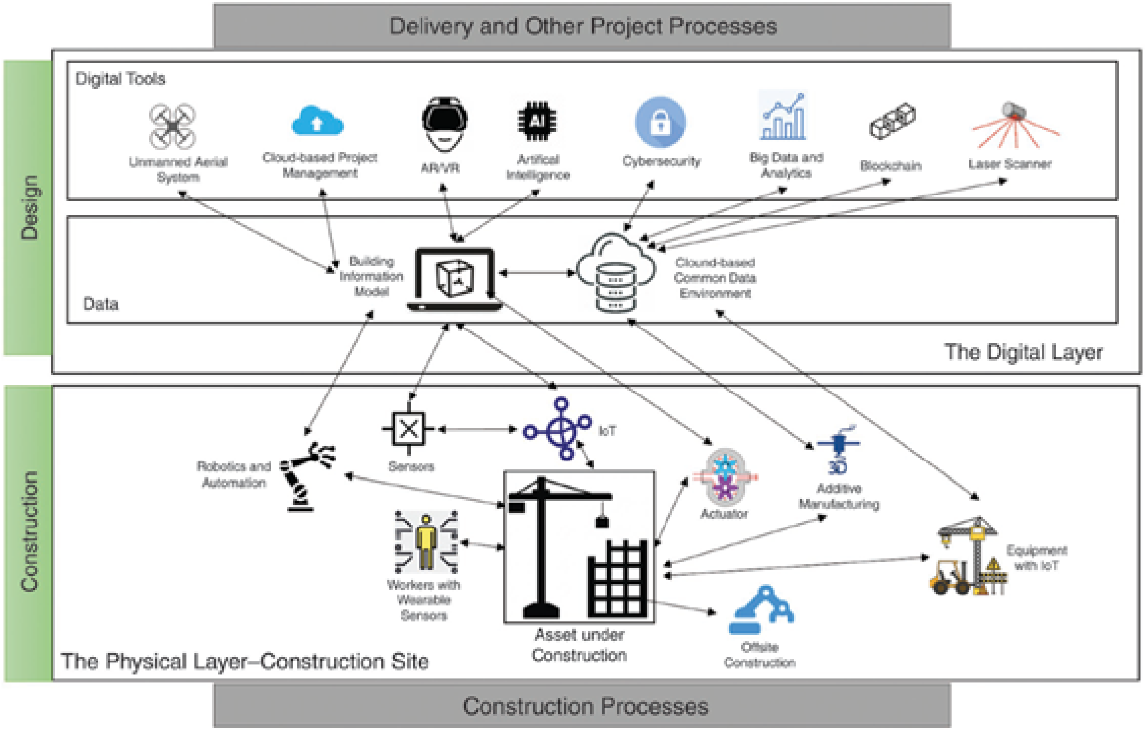


Figure 1: Physical to Digital to physical transformation(Source: Sawhney, Riley & Irizarry, 2020: 14)

If Graduate Attributes focuses on the mediation of 'what' and 'how' students learn (University specific), please rate the relevance of the following generic Graduate Attributes towards the preparedness of relevant employees towards future Construction 4.0:

	Not relevant at all	Somewhat relevant	Relevant	Very relevant	Cannot go without (Vital)
Academic competence: Students develop **knowledge, skills and attitudes** (including values) through their interaction with discipline-specific content.	○	○	○	○	○
Critical thinking: It is a habit of mind that **comprehensively explores** issues, ideas, artefacts, and events **before accepting or formulating an opinion or conclusion.**	○	○	○	○	○
Problem-solving: It is the process of designing, evaluating and implementing a strategy to answer	○	○	○	○	○

Appendix D.1 - Page 11

	Not relevant at all	Somewhat relevant	Relevant	Very relevant	Cannot go without (Vital)
an open-ended question or achieve a desired goal.					
Oral communication: Purposeful presentation is designed to increase knowledge, foster understanding, or promote change in the listeners' attitudes, values, beliefs, or behaviours.	○	○	○	○	○
Written communication: It can involve working with various **writing technologies** and mixing texts, data, and images.	○	○	○	○	○
Community engagement: Working to make a difference in the community life of our communities and developing the combination of **knowledge, skills, values and motivation** to make that difference through an understanding of our country's social and cultural diversity.	○	○	○	○	○
Ethical reasoning: It is reasoning about right and wrong human conduct. It requires students to be able to **assess their own** ethical values and the social context.	○	○	○	○	○
Entrepreneurial Mindset: Students need a set of **attitudes, skills and behaviours** to **succeed** academically, personally and professionally.	○	○	○	○	○
Digital literacy: The ability of an individual to **effectively and confidently** use digital technologies to access, evaluate, create, and **communicate information** in various contexts is becoming increasingly important in today's technology-driven world.	○	○	○	○	○

Do you feel that additional Attributes could be added to the list above that may contribute to the preparedness for Construction 4.0 for the graduates:

- ◯ Yes
- ◯ No

Next

56 % completed

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_UCT

Do you feel that some of the listed Attributes may be removed from the list?

- Yes
- No

Next

69 % completed

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_UCT

Please allocate a % to the following capabilities you think an undergraduate graduate would rely on to conduct their day-to-day functions as a newly employed graduate (*please refer to the definitions provided below if you are unsure*). The percentages should add up to 100:

Knowledge (e.g. procurement processes, planning and control processes etc.)	
Skills (e.g. quantity take-offs, rate-buildups etc.)	
Competencies (e.g. quality management, financial management etc.)	
Attributes (e.g. critical thinking, problem-solving etc.)	

Knowledge refers to a subject's theoretical or factual understanding, while skills are the practical abilities to perform specific tasks. Competencies are the behaviours and attitudes that enable effective performance, while attributes are the personal characteristics that underpin these competencies.

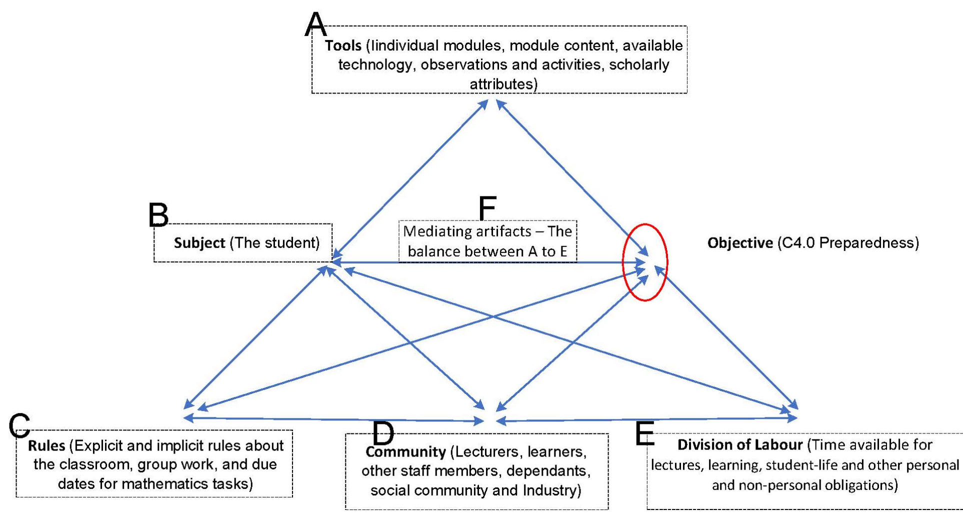
Next

81 % completed

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_UCT

Collaboration and communication:

Activity theory teaches us that achieving a specific goal (individual or group) requires the mediation of artefacts (elements) or, stated differently, balancing enablers and constraints. In meeting the above objective, a student must rely on the mediation of the several artefacts at their disposal, such as the module content, self-enhancement, the available community, the applicable rules, and the division of labour.



Please rank the above elements' contribution towards the fulfilment of the objective of being a Construction 4.0 ready graduate:

A

B

C

D

E

F

Next

88 % completed

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_UCT

Do you agree with the following statements:

	1 Disagree	2 Somewhat Disagree	3 Slightly agree	4 Agree completely	Not familiar/ opinion
We are moving into a C4.0 environment, regardless of the time and the current realisation thereof.	○	○	○	○	○
Employability summarises the desired objective of any HEI qualification best.	○	○	○	○	○
Industry-specific Graduate Attributes are required.	○	○	○	○	○
Graduate Attributes may assist in understanding how individual modules work together to provide a picture of what is expected from you when you graduate.	○	○	○	○	○
Graduate Attributes may assist a student in understanding their career path better.	○	○	○	○	○
Graduate Attributes are an over-complication and unnecessary addition to Higher Education curriculums.	○	○	○	○	○
Industry-specific Graduate Attributes are required in Construction curriculums.	○	○	○	○	○
Generic Graduate Attributes combined with module content	○	○	○	○	○

	1 Disagree	2 Somewhat Disagree	3 Slightly agree	4 Agree completely	Not familiar/ opinion
requirements would suffice.					

What is your experience or perception towards Graduate Attributes? Can it provide you with a sound foundation for diverse work or further study requirements that you may encounter after your undergraduate degree?

0/4000

Do you perhaps have any further contribution to the study that you want to make:

0/4000

Next

94 % completed

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_UCT

Thank you for participating in the survey; your contribution will contribute valuable information towards enhancing curriculum objectives. If you would like to receive feedback on, or further participate in the study, kindly provide your email address below:

Email address:

Send

100 % completed

Focus Group discussion on Construction 4.0 Attributes of South African Construction Built Environment students

Dear respondent

My name is Hendri du Plessis, a Researcher in the Faculty of Natural and Agricultural Sciences, the Department of Quantity Surveying and Construction Management at the University of the Free State. I am conducting a Ph.D. research study to evaluate the Construction 4.0 attributes of South African Construction Built Environment students from an Activity Theory perspective (Ethical Clearance No.: **UFS-HSD2022/0241/22**).

Considering the knowledge, skills and competency requirements of regulating councils, the Study endeavours to establish the relevance of Graduate Attributes (GA) through the lens of Activity Theory, particularly Construction 4.0 Graduate Attributes. The Study is aimed explicitly at undergraduate Quantity Surveying and Construction Management programmes (or similar).

Knowledge, skills, competencies, and attributes are all essential components of an individual's overall capabilities. Knowledge refers to a subject's theoretical or factual understanding, while skills are the practical abilities to perform specific tasks. Competencies are the behaviours and attitudes that enable effective performance, while attributes are the personal characteristics that underpin these competencies. These components comprise an individual's overall capabilities and determine their ability to perform a specific job or task. These components are necessary to achieve their professional goals and contribute effectively to their chosen field.

Today's proceedings are being recorded, and transcriptions of the recording are done anonymously through pseudonyms. Participation in this Study is voluntary, and your information will be kept confidential. You are also free to withdraw from the Study at any point if you wish to do so without any consequences. Furthermore, you may also withdraw from the Study by emailing the Principal Researcher of the Study.

CONSENT TO PARTICIPATE IN THIS STUDY

I confirm that I voluntarily agree to participate in the research study referred to as the

The evaluation of Construction 4.0 attributes of South African Construction Build Environment graduates: an Activity Theory perspective (the **"Study"**) in relation to

the focus group discussions and which Study is being conducted by

Mr Hendri du Plessis, (the "**Researcher**").

I, the undersigned Participant, further confirm that–

1. the Researcher has explained the nature, procedure, potential benefits and anticipated inconvenience of my participation in the Study;
2. I have read (or had explained to me) and understood the Study as explained in the attached information sheet;
3. I have had sufficient opportunity to ask questions and am prepared to participate in the Study;

4. I understand that the focus group discussion is being recorded and that my participation in the Study is entirely voluntary and that I am free to withdraw at any time without penalty (if applicable);
5. I voluntarily provide the UFS and the Researcher with the relevant personal information and consent to the UFS and the Researcher collecting, disclosing and processing my personal information in order to conduct the Study and any related activities in relation thereto;
6. I hereby acknowledge and confirm that I understand the purpose for which the UFS and the Researcher may collect, store, use, delete, destroy, outsource, transfer or otherwise process, as the context and circumstances may require and as contemplated in terms of POPIA, my personal information as set out herein;
7. I am aware that the findings of the Study will be anonymously processed into a research report, journal publications and/or conference proceedings and that my personal information will be aggregated and deidentified at such stage;

I, the Participant, agree to the questionnaire recording *and/or Focus group Discussion*.

Full Name of Participant: ____

Signature of Participant: ______________________________ Date: ________________

Full Name(s) of Researcher(s): ____

Signature of Researcher: ______________________________Date: ________________

Section B: Outcome-based questions

Objective (Goal orientated):

1. In your opinion, what is the main objective of obtaining your degree?

____

____

Tools and artefacts:

Construction 4.0 is associated with the Fourth Industrial Revolution's influence on the construction industry (CI). The following figure provides a short illustration of the possible future of Construction 4.0:

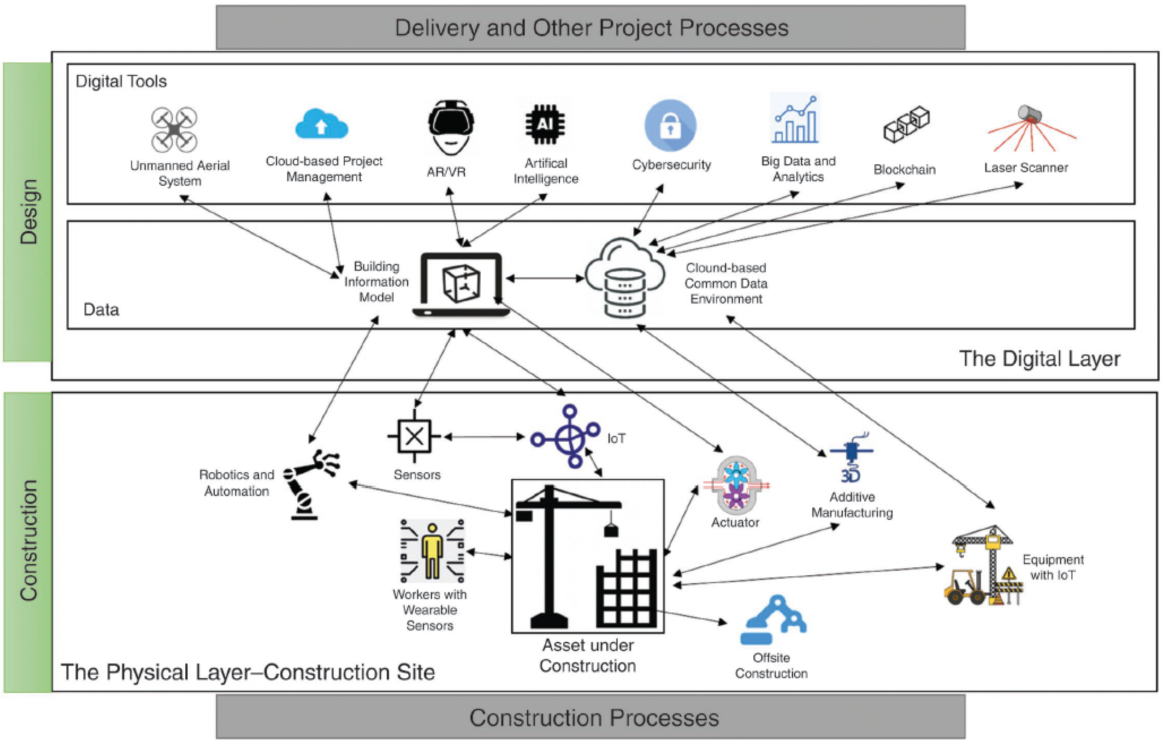


Figure 1: Physical to Digital to physical transformation (Source: Sawhney, Riley & Irizarry, 2020: 14)

2. If Graduate Attributes focuses on the mediation of 'what' and 'how' students learn (University specific), please rate the relevance of the following generic Graduate Attributes towards the preparedness of relevant employees towards future Construction 4.0:

	Not relevant at all	Somewhat relevant	Relevant	Very relevant	Cannot go without (Vital)
Academic competence: Students develop **knowledge, skills and attitudes** (including values) through their interaction with discipline-specific content.					

Critical thinking: It is a habit of mind that **comprehensively explores** issues, ideas, artefacts, and events **before accepting or formulating an opinion or conclusion.**					
Problem-solving: It is the process of designing, evaluating and implementing a strategy to answer an open-ended question or achieve a desired goal.					
Oral communication: **Purposeful presentation** is designed to increase knowledge, foster understanding, or promote change in the listeners' attitudes, values, beliefs, or behaviours.					
Written communication: It can involve working with various **writing technologies** and mixing texts, data, and images.					
Community engagement: Working to make a difference in the community life of our communities and developing the combination of **knowledge, skills, values and motivation** to make that difference through an understanding of our country's social and cultural diversity.					
Ethical reasoning: It is reasoning about right and wrong human conduct. It requires students to be able to **assess their own** ethical values and the social context.					
Entrepreneurial Mindset: Students need a set of **attitudes, skills and behaviours** to **succeed** academically, personally and professionally.					
Digital literacy: The ability of an individual to **effectively and confidently** use digital technologies to access, evaluate, create, and **communicate information** in various contexts is becoming increasingly important in today's technology-driven world.					

3. Do you feel that additional Attributes could be added from the list above that may contribute to the preparedness for Construction 4.0 for the graduates:
   - Yes
   - No

If yes, please provide the proposed Attribute(s):

____

4. Do you feel that some of the listed Attributes may be removed from the list?
   - Yes
   - No

If yes, please indicate which ones you would remove **(Selection from a list)**:

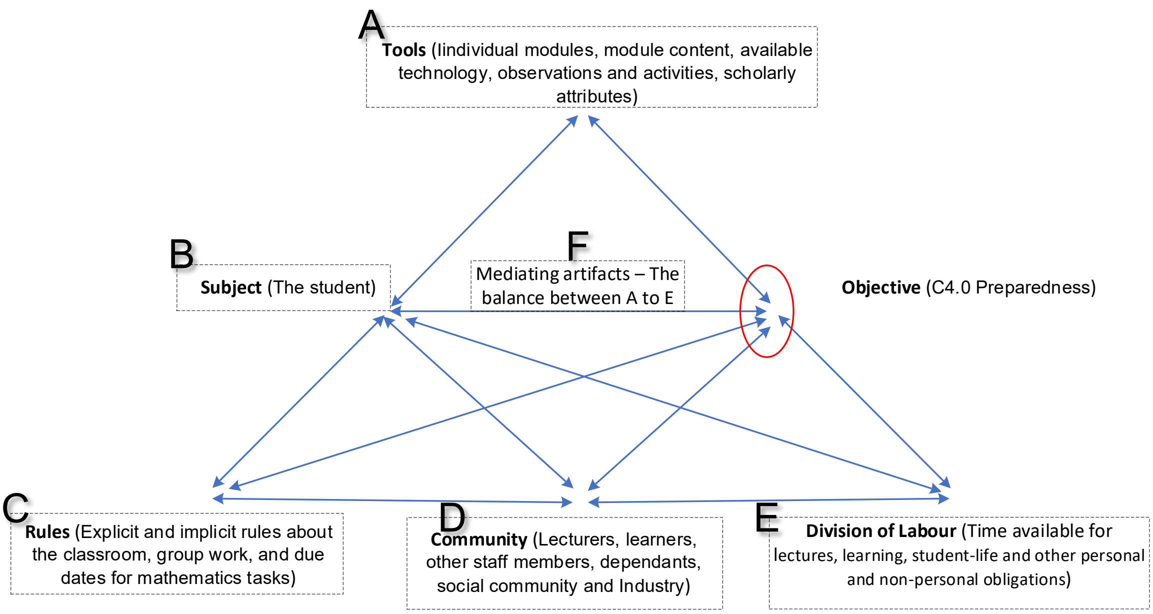
Academic competence: Students develop **knowledge, skills and attitudes** (including values) through their interaction with discipline-specific content. **Problem-solving:** It is the process of designing, evaluating and implementing a strategy to answer an open-ended question or achieve a desired goal.	**Critical thinking:** It is a habit of mind that **comprehensively explores** issues, ideas, artefacts, and events **before accepting or formulating an opinion or conclusion.** **Oral communication:** **Purposeful presentation** is designed to increase knowledge, foster understanding, or promote change in the listeners' attitudes, values, beliefs, or behaviours.
Written communication: It can involve working with various **writing technologies** and mixing texts, data, and images.	**Community engagement:** Working to make a difference in the community life of our communities and developing the combination of **knowledge, skills, values and motivation** to make that difference through an understanding of our country's social and cultural diversity.
Ethical reasoning: It is reasoning about right and wrong human conduct. It requires students to be able to **assess their own** ethical values and the social context.	**Entrepreneurial Mindset:** Students need a set of **attitudes, skills and behaviours** to **succeed** academically, personally and professionally.
Digital literacy: The ability of an individual to **effectively and confidently** use digital technologies to access, evaluate, create, and **communicate information** in various contexts is becoming increasingly important in today's technology-driven world.	

5. Please allocate a % to the following capabilities you think an undergraduate graduate would rely on to conduct their day-to-day functions as a newly employed graduate (please refer to the definitions provided in the introduction if you are unsure):

	Percentage:
Knowledge (e.g. procurement processes, planning and control processes etc.)	
Skills (e.g. quantity take-offs, rate-buildups etc.)	
Competencies (e.g. quality management, financial management etc.)	
Attributes (e.g. critical thinking, problem-solving etc.)	
	100%

Collaboration and communication:

Activity theory teaches us that achieving a specific goal (individual or group) requires the mediation of artefacts (elements) or, stated differently, balancing enablers and constraints. In meeting the above objective, a student must rely on the mediation of the several artefacts at their disposal, such as the module content, self-enhancement, the available community, the applicable rules, and the division of labour.



6. Please rank the above elements' contribution towards the fulfilment of the objective of being a Construction 4.0 ready graduate:

	Ranked 1	Ranked 2	Ranked 3	Ranked 4	Ranked 5	Ranked 6
A						
B						
C						
D						
E						
F						

7. Do you agree with the following statements:

	1 Disagree	2 Somewhat Disagree	3 Slightly agree	4 Agree completely	Not familiar/ opinion
We are moving into a C4.0 environment, regardless of the time and the current realisation thereof.					
Employability summarises the desired objective of any HEI qualification best.					

Industry-specific Graduate Attributes are required.					
Graduate Attributes may assist in understanding how individual modules work together to provide a picture of what is expected from you when you graduate.					
Graduate Attributes may assist a student in understanding their career path better.					
Graduate Attributes are an over-complication and unnecessary addition to Higher Education curriculums.					
Industry-specific Graduate Attributes are required in Construction curriculums.					
Generic Graduate Attributes combined with module content requirements would suffice.					

8. What is your experience or perception towards Graduate Attributes? Can it provide you with a sound foundation for diverse work or further study requirements that you may encounter after your undergraduate degree?

____

____

9. Do you perhaps have any further contribution to the Study that you want to make:

____

____

Thank you for participating in the following survey; your contribution will contribute valuable information towards enhancing curriculum objectives. If you would like to receive feedback on the Study, kindly provide your email address below: ____________________________

Schedule for focus group discussion:

Phase	Action	Time	Notes
Opening	Ice-breaker	0:05	
	Purpose	0:03	
	Ground Rules	0:02	
	Introductions	0:05	
Warm-up	Section A questions	0:10	
Main body	Section B questions	0:25	
	- Knowledge of Construction 4.0		
	- Student life and learning balance		
	- Construction 4.0 requirements		
	- Construction 4.0 content requirements		
Closure	Closure	0:10	
	Total	**1:00**	

APPENDIX E – ARTICLE 2 DATA COLLECTION TOOLS

E.1 SURVEY QUESTIONNAIRE LECTURERS – QUEST BACK FORM

E.2 FOCUS-GROUP/INTERVIEW QUESTIONNAIRE AND PROTOCOL – LECTURERS

Survey on construction 4.0 attributes of South African Construction Built Environment students_UFS Lecturers

Dear respondent

My name is Hendri du Plessis, a Researcher in the Faculty of Natural and Agricultural Sciences, the Department of Quantity Surveying and Construction Management at the University of the Free State. I am conducting a Ph.D. research study to evaluate the Construction 4.0 attributes of South African Construction Built Environment students from an Activity Theory perspective (Ethical Clearance No.: **UFS-HSD2022/0241/22**).

Considering the knowledge, skills and competency requirements of regulating councils, the study endeavours to establish the relevance of Graduate Attributes (GA) through the lens of Activity Theory, particularly Construction 4.0 Graduate Attributes. The study is aimed explicitly at undergraduate programmes in Quantity Surveying and Construction Management.

Knowledge, skills, competencies, and attributes are all essential components of an individual's overall capabilities. Knowledge refers to a subject's theoretical or factual understanding, while skills are the practical abilities to perform specific tasks. Competencies are the behaviours and attitudes that enable effective performance, while attributes are the personal characteristics that underpin these competencies. These components comprise an individual's overall capabilities and determine their ability to perform a specific job or task. These components are necessary to achieve their professional goals and contribute effectively to their chosen field.

Participation in this study is voluntary, and you are guaranteed complete confidentiality in the treatment of your responses; you have the right not to respond to any questions you deem inappropriate; any information provided will be used solely for this research.

You may withdraw from the study at any point if you wish to do so by emailing the Principal Researcher of the study.

By completing the survey, you agree that your responses may be included in the study's results, which will be published in an accredited and peer-reviewed journal.

This survey comprises eight background questions and ten outcome questions. **If you want to participate in the survey, select yes below to continue.**

- Yes
- I prefer not to participate

Next

7 % completed

Survey on construction 4.0 attributes of South African Construction Built Environment students_UFS Lecturers

Section A: Background Information

Which of the following categories best describes your Industry experience and/or background? More than one may be chosen:

- ☐ Architect
- ☐ Quantity Surveyor
- ☐ Structural Engineer
- ☐ Civil Engineer
- ☐ Electrical and/or Mechanical Engineer
- ☐ Project manager
- ☐ Contractor
- ☐ Developer
- ☐ Other, please specify:

For this question, please distinguish between your industry work and teaching. There will be questions to follow that pertain to your teaching experience.

Please indicate your years of experience in the profession highlighted above – Industry only

- ○ 5 years or less
- ○ 6 – 10 years

- 11 – 15 years
- 16 to 20 years
- 21 to 25 years
- Above 25 years of experience

Next

13 % completed

Survey on construction 4.0 attributes of South African Construction Built Environment students_UFS Lecturers

The following questions pertain to your teaching experience.

Please select the best options below to describe your undergraduate educational tenure to date. More than one option may be chosen:

- ☐ BSc Quantity Surveying
- ☐ BSc Construction Management
- ☐ BSc Construction Economics degree (combined QS and CM – undergraduate degree.)
- ☐ Other (e.g. Bachelors, B-Tech etc.). Please name:

Are you a full-time lecturer or a part-time lecturer:

- ○ Full time
- ○ Part-time

Please indicate your years of experience as a lecturer – Lecturer only (academic experience).

- ○ 5 years or less
- ○ 6 – 10 years
- ○ 11 – 15 years
- ○ 16 to 20 years
- ○ 21 to 25 years

◯ Above 25 years of experience

Please select the best options below to describe your post-graduate educational tenure to date. More than one option may be chosen:

- ☐ Not applicable
- ☐ B.Sc. QS (Hons.)
- ☐ B.Sc. CM (Hons.)
- ☐ Masters' degree or equivalent
- ☐ PhD
- ☐ Other (e.g. MBA etc.). Please name:

Next

20 % completed

Survey on construction 4.0 attributes of South African Construction Built Environment students_UFS Lecturers

Are you registered with one of the following Councils (more than one may be chosen):

- ☐ SACQSP as Pr QS
- ☐ SACQSP as Candidate
- ☐ SACPCMP as Pr CPM
- ☐ SACPCMP as Candidate CPM
- ☐ SACPCMP as Pr CM
- ☐ SACPCMP as Candidate CM
- ☐ Other (please specify):

Are you registered with any of the following built environment associations (more than one may be chosen)?

- ☐ Association of South African Quantity Surveyors (ASAQS)
- ☐ Association of Construction Project Managers (ACPM)
- ☐ Consulting Engineers of South Africa (CESA)
- ☐ Master Builders South Africa (MBSA)
- ☐ South African Institute of Architects (SAIA)
- ☐ South African Property Owners Association (SAPOA)
- ☐ Other (specify)

Next

27 % completed

Survey on construction 4.0 attributes of South African Construction Built Environment students_UFS Lecturers

Section B: Outcome-based questions

Objective (Goal orientated):

In your opinion, what is the main objective of Graduate Attributes of Higher Education Institutions within the South African Construction Build Environment?

0/4000

Please allocate a % to the following capabilities you think an undergraduate graduate would rely on to conduct their day-to-day functions as a newly employed graduate (please refer to the definitions provided below if you are unsure). The percentages should add up to 100:

Knowledge (e.g. procurement processes, planning and control processes etc.)	
Skills (e.g. quantity take-offs, rate-buildups etc.)	
Competencies (e.g. quality management, financial management etc.)	

Attributes (e.g., critical thinking, problem-solving etc. – The softer skills of graduates)

Knowledge refers to a subject's theoretical or factual understanding, while skills are the practical abilities to perform specific tasks. Competencies are the behaviours and attitudes that enable effective performance, while attributes are the personal characteristics that underpin these competencies.

Next

33 % completed

Survey on construction 4.0 attributes of South African Construction Built Environment students_UFS Lecturers

Tools and artefacts:

Construction 4.0 is associated with the Fourth Industrial Revolution's influence on the construction industry (CI). The following figure provides a short illustration of the possible future of Construction 4.0:

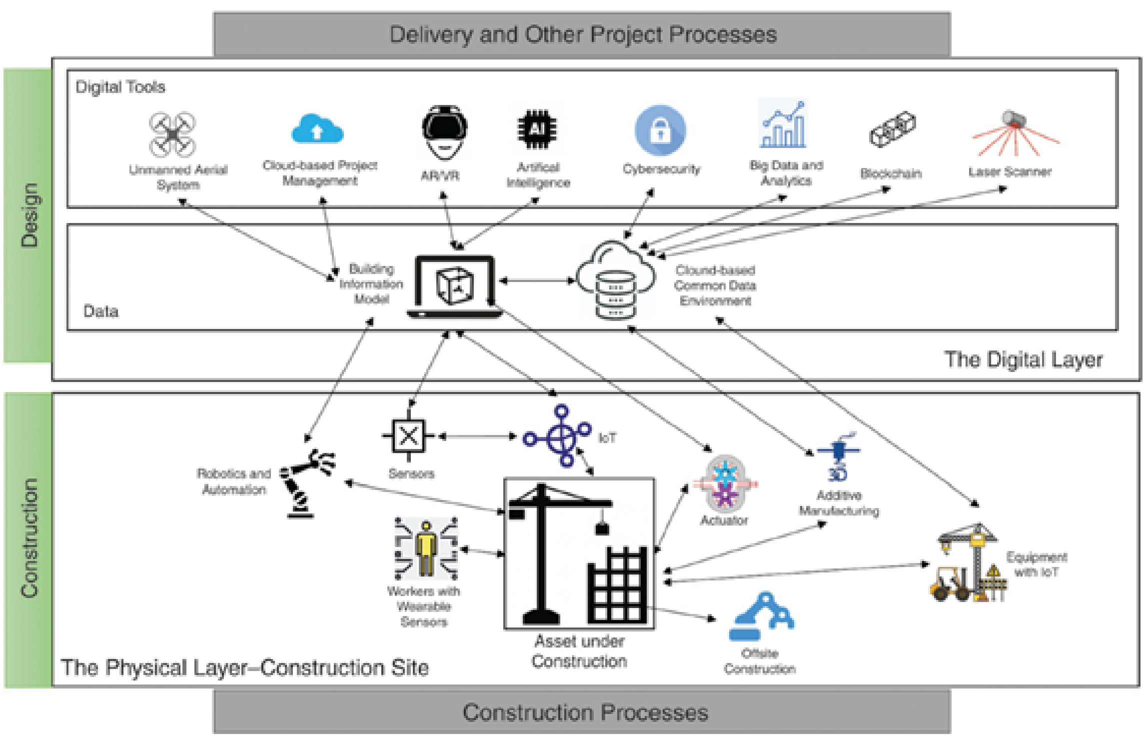


Figure 1: Physical to Digital to physical transformation (Source: Sawhney, Riley & Irizarry, 2020: 14)

If Graduate Attributes focuses on the mediation of 'what' and 'how' students learn, please rate the relevance of the following generic Graduate Attributes towards the preparedness of relevant employees towards future Construction 4.0:

	Not relevant at all	Somewhat relevant	Relevant	Very relevant	Cannot go without (Vital)
Academic competence: Students develop **knowledge, skills and attitudes** (including values) through their interaction with discipline-specific content.	○	○	○	○	○
Critical thinking: It is a habit of mind that **comprehensively explores** issues, ideas, artefacts, and events **before accepting or formulating an opinion or conclusion.**	○	○	○	○	○
Problem-solving: It is the process of designing, evaluating and implementing a strategy to answer an open-ended question or achieve a desired goal.	○	○	○	○	○
Oral communication: Purposeful presentation is designed to increase knowledge, foster understanding, or promote change in the listeners' attitudes, values, beliefs, or behaviours.	○	○	○	○	○
Written communication: It can involve working with various **writing technologies** and mixing texts, data, and images.	○	○	○	○	○
Community engagement: Working to make a difference in the community life of our communities and developing the combination of **knowledge, skills, values and motivation** to make that difference through an understanding of our country's social and cultural diversity.	○	○	○	○	○

	Not relevant at all	Somewhat relevant	Relevant	Very relevant	Cannot go without (Vital)
Ethical reasoning: It is reasoning about right and wrong human conduct. It requires students to be able to **assess their own** ethical values and the social context.	○	○	○	○	○
Entrepreneurial Mindset: Students need a set of **attitudes, skills and behaviours** to **succeed** academically, personally and professionally.	○	○	○	○	○
Digital literacy: The ability of an individual to **effectively and confidently** use digital technologies to access, evaluate, create, and **communicate information** in various contexts is becoming increasingly important in today's technology-driven world.	○	○	○	○	○

Do you feel that additional Attributes could be added to the list above that may contribute to the preparedness for Construction 4.0 for the graduates:

○ Yes

○ No

Next

40 % completed

Survey on construction 4.0 attributes of South African Construction Built Environment students_UFS Lecturers

Do you feel that some of the listed Attributes should be removed from the list?

- Yes
- No

Next

53 % completed

Survey on construction 4.0 attributes of South African Construction Built Environment students_UFS Lecturers

For a curriculum to excel, a combined fulfilment is required of the curriculum, pedagogy, assessments, and the environment (CPAE) (Saad, 2019: 2). Please indicate each areas relevance towards the acquisition of knowledge, skills, competencies and Graduate attributes (KSCG) respectfully.

Knowledge (e.g. procurement processes, planning and control processes etc.)

	Not relevant	Somewhat relevant	Relevant	Essential (Vital)
Curriculum/ Content: what will be taught?	○	○	○	○
Pedagogy: how will it be delivered?	○	○	○	○
Assessments: how can learning be measured?	○	○	○	○
Environment: what are the required resources, and what did the students experience?	○	○	○	○

Skills (e.g. quantity take-offs, rate-buildups etc.)

	Not relevant	Somewhat relevant	Relevant	Essential (Vital)
Curriculum/ Content: what will be taught?	○	○	○	○
Pedagogy: how will it be delivered?	○	○	○	○
Assessments: how can learning be measured?	○	○	○	○

	Not relevant	Somewhat relevant	Relevant	Essential (Vital)
Environment: what are the required resources, and what did the students experience?	○	○	○	○

Competencies (e.g. quality management, financial management etc.)

	Not relevant	Somewhat relevant	Relevant	Essential (Vital)
Curriculum/ Content: what will be taught?	○	○	○	○
Pedagogy: how will it be delivered?	○	○	○	○
Assessments: how can learning be measured?	○	○	○	○
Environment: what are the required resources, and what did the students experience?	○	○	○	○

Graduate Attributes – as depicted earlier

	Not relevant	Somewhat relevant	Relevant	Essential (Vital)
Curriculum/ Content: what will be taught?	○	○	○	○
Pedagogy: how will it be delivered?	○	○	○	○
Assessments: how can learning be measured?	○	○	○	○
Environment: what are the required resources, and what did the students experience?	○	○	○	○

Construction 4.0 requirements

	Not relevant	Somewhat relevant	Relevant	Essential (Vital)
Curriculum/ Content: what will be taught?	○	○	○	○
Pedagogy: how will it be delivered?	○	○	○	○
Assessments: how can learning be measured?	○	○	○	○

	Not relevant	Somewhat relevant	Relevant	Essential (Vital)
Environment: what are the required resources, and what did the students experience?	○	○	○	○

Any further comments?

0/255

Next

67 % completed

Survey on construction 4.0 attributes of South African Construction Built Environment students_UFS Lecturers

Similarly, please indicate the emphasis of each of the focus areas (KSCG) and its relevance during the specific year of study:

Year 1

	Not relevant	Somewhat relevant	Relevant	Essential (Vital)
Knowledge (e.g. procurement processes, planning and control processes etc.)	○	○	○	○
Skills (e.g. quantity take-offs, rate-buildups etc.)	○	○	○	○
Competencies (e.g. quality management, financial management etc.)	○	○	○	○
Graduate Attributes – as depicted earlier	○	○	○	○
Construction 4.0 requirements	○	○	○	○

Year 2

	Not relevant	Somewhat relevant	Relevant	Essential (Vital)
Knowledge (e.g. procurement processes, planning and control processes etc.)	○	○	○	○
Skills (e.g. quantity take-offs, rate-buildups etc.)	○	○	○	○
Competencies (e.g. quality management,	○	○	○	○

	Not relevant	Somewhat relevant	Relevant	Essential (Vital)
financial management etc.)				
Graduate Attributes – as depicted earlier	○	○	○	○
Construction 4.0 requirements	○	○	○	○

Year 3 (exit year 1)

	Not relevant	Somewhat relevant	Relevant	Essential (Vital)
Knowledge (e.g. procurement processes, planning and control processes etc.)	○	○	○	○
Skills (e.g. quantity take-offs, rate-buildups etc.)	○	○	○	○
Competencies (e.g. quality management, financial management etc.)	○	○	○	○
Graduate Attributes – as depicted earlier	○	○	○	○
Construction 4.0 requirements	○	○	○	○

Year 4 (honours exit year 2)

	Not relevant	Somewhat relevant	Relevant	Essential (Vital)
Knowledge (e.g. procurement processes, planning and control processes etc.)	○	○	○	○
Skills (e.g. quantity take-offs, rate-buildups etc.)	○	○	○	○
Competencies (e.g. quality management, financial management etc.)	○	○	○	○
Graduate Attributes – as depicted earlier	○	○	○	○
Construction 4.0 requirements	○	○	○	○

Any further comments?

0/255

Survey on construction 4.0 attributes of South African Construction Built Environment students_UFS Lecturers

Collaboration and communication:

Activity theory teaches us that achieving a specific goal (individual or group) requires the mediation of artefacts or, stated differently, balancing enablers and constraints. In meeting the above objective, a student must rely on the mediation of the several artefacts at their disposal, such as the module content, self-enhancement, the available community, the applicable rules, and the division of labour.

Do you agree with the following statements:

	1 Disagree	2 Somewhat Disagree	3 Slightly agree	4 Agree completely	Not familiar/ opinion
We are moving into a C4.0 environment, regardless of the time and the current realisation thereof.	◯	◯	◯	◯	◯
Employability summarises the desired objective of any HEI qualification best.	◯	◯	◯	◯	◯
GA contributes more towards addressing "how" module content is presented than "what" is presented.	◯	◯	◯	◯	◯
GA can assist in module alignment.	◯	◯	◯	◯	◯
Graduate Attributes may assist in breaking down the silos that exist	◯	◯	◯	◯	◯

	1 Disagree	2 Somewhat Disagree	3 Slightly agree	4 Agree completely	Not familiar/ opinion
within Curriculums.					
Graduate Attributes may assist a student in understanding their career path.	○	○	○	○	○
Graduate Attributes are an over-complication and unnecessary addition to Higher Education curriculums.	○	○	○	○	○
Industry-specific Graduate Attributes are required in Construction curriculums.	○	○	○	○	○
Generic Graduate Attributes combined with Industry knowledge, skills and competencies requirements would suffice.	○	○	○	○	○

Next

80 % completed

Survey on construction 4.0 attributes of South African Construction Built Environment students_UFS Lecturers

The realisation of Construction 4.0 is dynamic and at different stages, depending on multiple factors such as the employer, the client, individual projects (team compositions), suppliers, available funds, time etc. When considering new technologies and ways of conducting work, please rank the following parameters according to their priority in achieving a work-specific goal (1 = Most important contributor; 5/6 = least contributor):

Data set 1:

- Knowledge (e.g. procurement processes, planning and control processes etc.)
- Skills (e.g. quantity take-offs, rate-buildups etc.)
- Competencies (e.g. quality management, financial management etc.)
- Attributes (e.g. critical thinking, problem-solving etc.)
- The physical understanding of existing assets

Data set 2:

- The combination of your knowledge, skills and competence.
- Digital literacy - the ability to effectively use digital technologies and tools to find, evaluate, create, communicate, and share information.
- The ability to answer open-ended questions and to critically evaluate the challenge.
- Attitude, skills and behaviours.
- Collaboration – verbal, written and observation
- Ethical considerations and community engagement.

Data set 3:

- Physical understanding of existing assets (buildings, civil works etc.)
- Digital design
- The transition of physical into digital designs
- The physical construction process
- The utilisation of new assets (buildings, civil

works etc.)

Next

87 % completed

Survey on construction 4.0 attributes of South African Construction Built Environment students_UFS Lecturers

What is the role of graduate attributes in the South African Construction Built Environment (CBE) curricula, and how do you experience and perceive their importance for transforming teaching and development?

0/4000

Do you perhaps have any further contribution to the study that you want to make:

0/255

Next

93 % completed

Survey on construction 4.0 attributes of South African Construction Built Environment students_UFS Lecturers

Thank you for participating in the following survey; your contribution will contribute valuable information towards enhancing curriculum objectives. If you would like to receive feedback on the study, kindly provide your email address below:

Email address:

Send

100 % completed

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS

Focus Group discussion on Construction 4.0 Attributes of South African Construction Built Environment students

Dear respondent

My name is Hendri du Plessis, a Researcher in the Faculty of Natural and Agricultural Sciences, the Department of Quantity Surveying and Construction Management at the University of the Free State. I am conducting a Ph.D. research study to evaluate the Construction 4.0 attributes of South African Construction Built Environment students from an Activity Theory perspective (Ethical Clearance No.: **UFS-HSD2022/0241/22**).

Considering the knowledge, skills and competency requirements of regulating councils, the Study endeavours to establish the relevance of Graduate Attributes (GA) through the lens of Activity Theory, particularly Construction 4.0 Graduate Attributes. The Study is aimed explicitly at undergraduate Quantity Surveying and Construction Management programmes (or similar).

Knowledge, skills, competencies, and attributes are all essential components of an individual's overall capabilities. Knowledge refers to a subject's theoretical or factual understanding, while skills are the practical abilities to perform specific tasks. Competencies are the behaviours and attitudes that enable effective performance, while attributes are the personal characteristics that underpin these competencies. These components comprise an individual's overall capabilities and determine their ability to perform a specific job or task. These components are necessary to achieve their professional goals and contribute effectively to their chosen field.

Today's proceedings are being recorded, and transcriptions of the recordings are done anonymously through pseudonyms. Participation in this Study is voluntary, and your information will be kept confidential. You are also free to withdraw from the Study at any point if you wish to do so without any consequences. Furthermore, you may also withdraw from the Study by emailing the Principal Researcher of the Study.

CONSENT TO PARTICIPATE IN THIS STUDY

I confirm that I voluntarily agree to participate in the research study referred to as the

The evaluation of Construction 4.0 attributes of South African Construction Build Environment graduates: an Activity Theory perspective (the **"Study"**) in relation to the focus group/ interview discussions and which Study is being conducted by

Mr Hendri du Plessis, (the "**Researcher**").

I, the undersigned Participant, further confirm that–

1. the Researcher has explained the nature, procedure, potential benefits and anticipated inconvenience of my participation in the Study;

2. I have read (or had explained to me) and understood the Study as explained in the attached information sheet;

3. I have had sufficient opportunity to ask questions and am prepared to participate in the Study;

4. I understand that the focus group discussion is being recorded and that my participation in the Study is entirely voluntary and that I am free to withdraw at any time without penalty (if applicable);

5. I voluntarily provide the UFS and the Researcher with the relevant personal information and consent to the UFS and the Researcher collecting, disclosing and processing my personal information in order to conduct the Study and any related activities in relation thereto;

6. I hereby acknowledge and confirm that I understand the purpose for which the UFS and the Researcher may collect, store, use, delete, destroy, outsource, transfer or otherwise process, as the context and circumstances may require and as contemplated in terms of POPIA, my personal information as set out herein;
7. I am aware that the findings of the Study will be anonymously processed into a research report, journal publications and/or conference proceedings and that my personal information will be aggregated and deidentified at such stage;

I, the Participant, agree to the questionnaire recording *and/or Focus group Discussion*.

Full Name of Participant: ____

Signature of Participant: _______________________________ Date: _________________

Full Name(s) of Researcher(s): ____

Signature of Researcher: _______________________________Date: _________________

____

Section A: Background Information

1. Which of the following categories best describes your Industry experience? More than one may be chosen:

• Architect	
• Quantity Surveyor	
• Engineer:	
- Structural	
- Civil	
- Electrical and/or Mechanical	
• Project manager	
• Contractor	
• Developer	
• Other (Please specify) ………………………………………	

2. Please indicate your years of experience in the profession highlighted above – Industry only (Please distinguish between your industry work and teaching – The next question(s) pertains to your teaching experience).

Less 5 years	
6 – 10 years	
11 – 15 years	
16 to 20 years	
21 to 25 years	
Above 25 years of experience	

3. Are you a full-time lecturer or a part-time lecturer:
   - Full time
   - Part-time

4. Please indicate your years of experience as a lecturer – Lecturer only (academic experience).

Less 5 years	
6 – 10 years	
11 – 15 years	
16 to 20 years	
21 to 25 years	
Above 25 years of experience	

5. Please indicate your highest educational qualification:

Tertiary institution first degree (NQF level 7)	
Tertiary institution honours degree (NQF level 8)	
Tertiary institution master's degree (NQF level 9)	
PhD (NQF level 10)	
If other, please specify: ………………………………	

6. Are you registered with a professional statutory council?

Yes	
No	

7. In your opinion, are you adequately equipped to conduct your teaching and learning obligations at current standards (e.g. have the necessary hardware and, software, facilities):

   - Yes
   - No

8. If no, kindly assist with an elaboration of what requirement(s) is needed:

____

Section B: Outcome-based questions

- In your opinion, how important is each of the following abilities for new graduates to meet their job objectives (to make them employable): (1 = Unimportant; 4 = Essential)

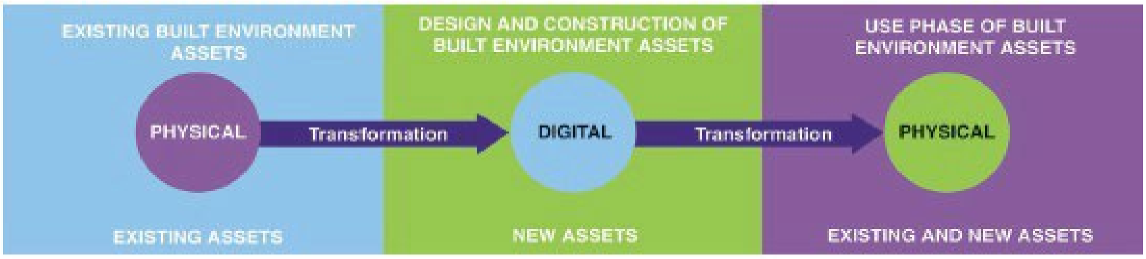
	1 (Not Important)	**2 (Somewhat Important)**	**3 (Very Important)**	**4 (Essential)**
Educational preparation and knowledge				
General work or job-related experience				
Technical knowledge and skills				

- How familiar are you with the term "Construction 4.0": (1 = Very familiar; 5 = Not familiar at all)

1 (Very familiar)	**2 (Somewhat Familiar)**	**3 (Not familiar)**	**4 (Not familiar at all)**

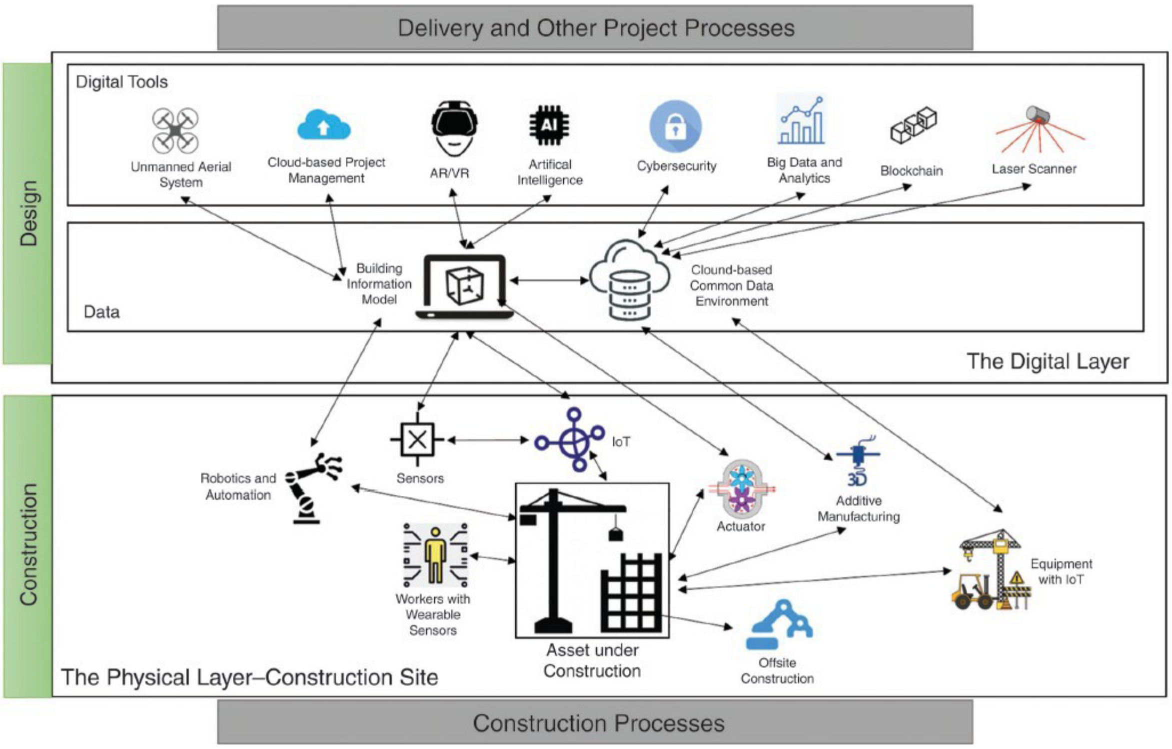
Presentation:

Construction 4.0 is a term associated with the Fourth Industrial Revolution's influence on the construction industry, aptly summarised by the following figure highlighted below. The figure indicates how new designs are influenced by existing assets, which are translated into new physical assets before starting the cycle again:



Physical to Digital to physical transformation (Source: Sawhney, Riley & Irizarry, 2020: 5)

Specific technological influencing the cycle are shown below:



Physical to Digital to physical transformation (Source: Sawhney, Riley & Irizarry, 2020: 14)

- Many Attributes produce a well-rounded graduate. Please rate the following Attributes according to their significance (importance) in preparing students to be Construction 4.0 ready. (1 = Unimportant; 5 = Essential):

	1 (Not Important)	**2 (Somewhat Important)**	**3 (Important)**	**4 (Very Important)**	**5 (Essential)**
Academic competence: Refers to the **knowledge, skills and attitudes** (including values) students develop through their interaction with discipline-specific content.					
Critical thinking: It is a habit of mind characterised by comprehensively exploring issues, ideas, artefacts, and events before accepting or formulating an opinion or conclusion.					
Problem-solving: It is the process of designing, evaluating and implementing a strategy to answer an open-ended question or achieve a desired goal.					
Oral communication: Purposeful presentation is designed to increase knowledge, foster understanding, or promote change in the listeners' attitudes, values, beliefs, or behaviours.					

Written communication: It can involve working with various writing technologies and mixing texts, data, and images.					
Community engagement: Working to make a difference in the community life of our communities and developing the combination of knowledge, skills, values and motivation to make that difference through an understanding of our country's social and cultural diversity.					
Ethical reasoning: It is reasoning about right and wrong human conduct. It requires students to be able to assess their own ethical values and the social context.					
Entrepreneurial Mindset: Students need a set of attitudes, skills and behaviours to succeed academically, personally and professionally.					

- Do you feel that additional Attributes might be added to the list above that may contribute to the preparedness for Construction 4.0 for the graduates:
  - Yes
  - No

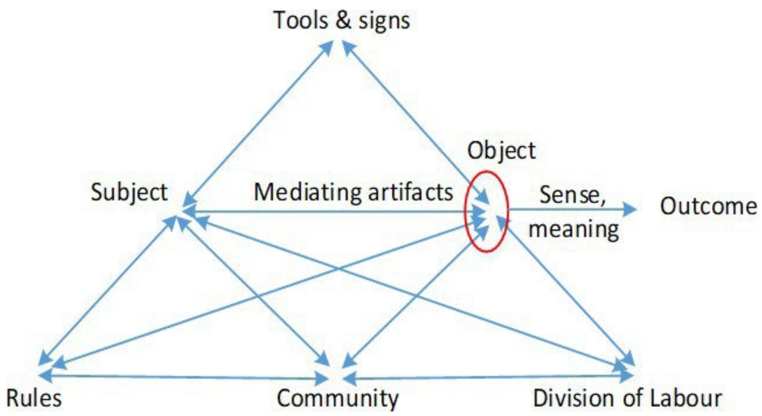
If yes, please provide the proposed Attribute(s):

____

Presentation:

The Activity Theory provides a lens through which a specific objective might be evaluated. The following definitions are used:

- **Subject:** may represent the student.
- **Tools:** may define the study material, technological tools and teaching
- **Community:** may refer to fellow students, lecturers and industry, etc.
- **Rules:** may refer to the general rules of the institution, cultural rules and rules set by individual modules
- **Division of labour**: can refer to the **time** prioritisation for study and personal obligations



Human activity system structure (Source: Engeström, 2001: 135)

With Construction 4.0 preparedness as the objective, please mark the most appropriate answer based on the following statements:

- The subject: The student plays a pivotable part in the realisation of the following student attributes:

	1 Fully agree	2 Somewhat agree	3 Slightly disagree	4 Disagree completely
Academic competence:				
Critical thinking:				
Problem-solving:				
Oral communication				
Written communication:				
Community engagement				
Ethical reasoning:				
Entrepreneurial Mindset:				

- Tools: Tools may include study material, technological tools, and teaching. In your opinion, how important in the achievement of the student attributes:

	1 Fully agree	2 Somewhat agree	3 Slightly disagree	4 Disagree completely
Academic competence:				
Critical thinking:				
Problem-solving:				
Oral communication				

Written communication:				
Community engagement				
Ethical reasoning:				
Entrepreneurial Mindset:				

- Community: Fellow students, lecturers and industry, etc., are fundamental in producing a well-rounded graduate:

	1 Fully agree	**2 Somewhat agree**	**3 Slightly disagree**	**4 Disagree completely**
Academic competence:				
Critical thinking:				
Problem-solving:				
Oral communication				
Written communication:				
Community engagement				
Ethical reasoning:				
Entrepreneurial Mindset:				

- Rules such as social, institutional, module, assignment etc., can be seen as a constraint towards fulfilling the required student attributes.

	1 Fully agree	**2 Somewhat agree**	**3 Slightly disagree**	**4 Disagree completely**
Academic competence:				
Critical thinking:				
Problem-solving:				
Oral communication				
Written communication:				
Community engagement				
Ethical reasoning:				
Entrepreneurial Mindset:				

- Division of labour can refer to the time prioritisation for study and personal obligations, which further constrain the acquisition of the required student attributes:

	1 Fully agree	2 Somewhat agree	3 Slightly disagree	4 Disagree completely
Academic competence:				
Critical thinking:				
Problem-solving:				
Oral communication				
Written communication:				
Community engagement				
Ethical reasoning:				
Entrepreneurial Mindset:				

- Considering the constraints as depicted through the Activity Theory Framework, how important are the following criteria in the education of a well-rounded graduate for Construction 4.0 preparedness? Please rank the following statements according to their relevance (1 = Most important contributor; 5 = least contributor):

	Ranking
Core concepts or knowledge areas of the and knowledge on the subject field – **Academically**	
Competencies prescribed by Accreditation bodies within the Student's Attributes as depicted above	
Core concepts or knowledge areas of the and knowledge on the subject field – **Explicit training** in "high-end" technologies that form the basis for Construction 4.0.	
Core concepts or areas of knowledge on the subject field – **Exposure** to "high-end" technologies that form the basis for Construction 4.0.	
Core concepts or knowledge areas of the and knowledge on the subject field – **practical skills training with basic exposure to the technology.**	

- Are there any other important factors not mentioned in the items listed above:
  - Yes
  - No

If yes, please provide any suggestions:

___

- Concerning Construction 4.0 preparedness, please rank the following criteria according to their importance (1 = Most important contributor; 6 = least important contributor):

	Ranking
Traits/ Attributes to becoming a Quantity Surveyor or Construction Manager	
Knowledge of Quantity Surveying and Construction Management core functions	
Skills (competencies) towards becoming a Quantity Surveyor or Construction Manager	
Traits/ Attributes towards becoming Construction 4.0 "savvy."	
Knowledge of Construction 4.0	
Specific skills toward Construction 4.0	

- Are there any other important factors not mentioned in the items listed above:
  - Yes
  - No

If yes, please provide any suggestions:

___

- Do you conduct your own research and training on available technologies?
  - Yes
  - No

- If yes, how do you conduct this research and training?

___

- If yes, to what degree and based on which motivation:
  - Only when needed
  - To be ahead of your pears
  - You are simply interested in it
  - Other

- Which technological competency do you think is most important to master for the workplace?
  - Open-ended

- With specific scholarly attributes proposed by Tertiary Institutions, how should they be incorporated into accredited curriculums of Quantity Surveying and Construction Management programmes?

___

___

___

Schedule for focus group discussion:

Phase	Action	Time	Notes
Opening	Ice-breaker	0:05	
	Purpose	0:03	
	Ground Rules	0:02	
	Introductions	0:05	
Warm-up	Section A questions	0:10	
Main body	Section B questions	0:25	
	- Knowledge of Construction 4.0		
	- Student life and learning balance		
	- Construction 4.0 requirements		
	- Construction 4.0 content requirements		
Closure	Closure	0:10	
	Total	**1:00**	

APPENDIX F – ARTICLE 3 DATA COLLECTION TOOLS

F.1 SURVEY QUESTIONNAIRE INDUSTRY – QUEST BACK FORM

F.2 INTERVIEW QUESTIONNAIRE AND PROTOCOL – INDUSTRY

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_Industry

Dear respondent

My name is Hendri du Plessis, a Researcher in the Faculty of Natural and Agricultural Sciences, the Department of Quantity Surveying and Construction Management at the University of the Free State. I am conducting a Ph.D. research study to evaluate the Construction 4.0 attributes of South African Construction Built Environment students from an Activity Theory perspective (Ethical Clearance No.: **UFS-HSD2022/0241/22**).

Considering the knowledge, skills and competency requirements of regulating councils, the study endeavours to establish the relevance of Graduate Attributes (GA) through the lens of Activity Theory, particularly Construction 4.0 Graduate Attributes. The study is aimed explicitly at undergraduate Quantity Surveying and Construction Management programmes.

Knowledge, skills, competencies, and attributes are all essential components of an individual's overall capabilities. Knowledge refers to a subject's theoretical or factual understanding, while skills are the practical abilities to perform specific tasks. Competencies are the behaviours and attitudes that enable effective performance, while attributes are the personal characteristics that underpin these competencies. These components comprise an individual's overall capabilities and determine their ability to perform a specific job or task. These components are necessary to achieve their professional goals and contribute effectively to their chosen field.

Bowden, Hart, King, Trigwell and Watts (2000) defined GA as "...the qualities, skills and understandings a university community agrees its students would desirably develop during their time at the institution and consequently shape the contribution they can make to their profession and as a citizen." (cited: Nagarajan & Edwards, 2014: 12).

Being a professional from the Industry, you are invited to participate in this research study by completing the questionnaire. Participation in this study is voluntary, and you are guaranteed complete confidentiality in the treatment of your responses; you have the right not to respond to any questions you deem inappropriate; any information provided will be used solely for this research.

You may withdraw from the study at any point if you wish to do so by emailing the Principal Researcher of the study.

By completing the survey, you agree that your responses may be included in the study's results, which will be published in an accredited and peer-reviewed journal.

The survey comprises nine background questions and twelve outcome questions. **If you want to participate in the survey, select yes below to continue.**

- ○ Yes
- ○ I prefer not to participate

Next

6 % completed

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_Industry

Section A: Respondent profile

Which of the following categories best describes your Profession? (More than one may be chosen):

- ☐ Construction Project Manager
- ☐ Construction Manager
- ☐ Quantity Surveyor – Building/"standard"
- ☐ Quantity Surveyor – Engineering
- ☐ Other (Please specify):

Please indicate how many years of experience you have in the abovementioned Profession.

- ◯ 5 years or less
- ◯ 6 – 10 years
- ◯ 11 – 15 years
- ◯ 16 to 20 years
- ◯ 21 to 25 years
- ◯ Above 25 years of experience

Please indicate the employee size of the company you are employed in.

- ◯ 1 - 10 employees
- ◯ 11 - 20 employees
- ◯ 21 - 30 employees
- ◯ 31 - 40 employees

- ○ 41 – 50 employees
- ○ Above 50 employees

Next

13 % completed

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_Industry

Please select the most relevant options below to indicate your completed programme of study. (More than one option may be chosen):

- ☐ BSc Quantity Surveying
- ☐ BSc Construction Management
- ☐ BSc Construction Economics degree (combined QS and CM – undergraduate degree)
- ☐ Other (e.g., Bachelor, B-Tech etc.) Please name:

Was the degree obtained from a South African Institution?

- ○ Yes
- ○ No, please specify:

Next

19 % completed

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_Industry

Please select the best options below to describe your highest qualification obtained for post-graduate study. (More than one option may be chosen):

- ☐ Not applicable
- ☐ B.Sc. QS (Hons.)
- ☐ B.Sc. CM (Hons.)
- ☐ Master's degree or equivalent
- ☐ Ph.D.
- ☐ Other (e.g., MBA etc.) Please name:

Was the degree obtained from a South African Institution?

- ○ Yes
- ○ No, please specify:

Please indicate your professional affiliation from the following Councils (more than one may be chosen):

- ☐ SACQSP as Pr QS
- ☐ SACQSP as Candidate
- ☐ SACPCMP as Pr CPM
- ☐ SACPCMP as Candidate CPM
- ☐ SACPCMP as Pr CM
- ☐ SACPCMP as Candidate CM
- ☐ Other (please specify):

Please indicate your registration from the following built environment associations. (more than one may be chosen):

- [ ] Association of South African Quantity Surveyors (ASAQS)
- [ ] Association of Construction Project Managers (ACPM)
- [ ] Consulting Engineers of South Africa (CESA)
- [ ] Master Builders South Africa (MBSA)
- [ ] South African Institute of Architects (SAIA)
- [ ] South African Property Owners Association (SAPOA)
- [ ] Other (specify):

Next

25 % completed

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_Industry

Section B: Capabilities

In your opinion, what is the most critical capability of a Graduate from a Higher Education Institution (HEI) within the South African Construction Build Environment (CBE) that you want to see:

0/255

Please allocate a % weight to the following capabilities you rely on to conduct your day-to-day functions as a professional (*please refer to the definitions provided below if you are unsure*). The percentages should add up to 100.:

Capabilities

Knowledge (e.g., procurement processes, planning & control processes etc.)	
Skills (e.g., quantity take-offs, rate-buildups etc.)	
Competencies (e.g., quality management, financial management etc.)	
Attributes (e.g., critical thinking, problem-solving etc. – **The softer skills of graduates**)	

Knowledge refers to a subject's theoretical or factual understanding, while skills are the practical abilities to perform specific tasks. Competencies are the behaviours and attitudes that enable effective performance, while attributes are the personal characteristics that underpin these competencies.

Would you look for similar capabilities (as indicated in the previous question) when hiring a new staff member?

- Yes
- No

Please rank from most important to least important to show which capabilities you consider when hiring Higher Education Institutions (HEI) CBE graduates.

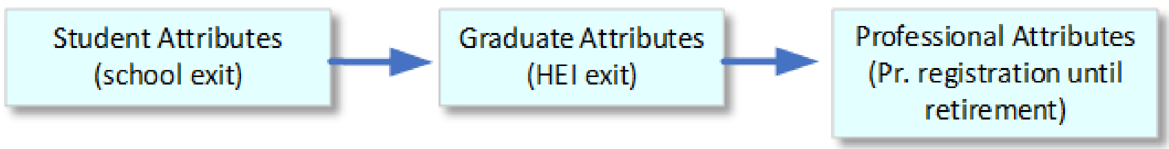
- Knowledge (e.g., procurement processes, planning and control processes etc.)
- Skills (e.g., quantity take-offs, rate-buildups etc.)
- Competencies (e.g., quality management, financial management etc.)
- Attributes (e.g., critical thinking, problem-solving etc. – The softer skills of graduates)

Next

31 % completed

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_Industry

Section C: Attributes



Do the following statements describe the conceptualisation of the professional within the Construction Built Environment (CBE)? Choose the response that best describes your level of agreement with the statements.

	1 Agree	2 Disagree	3 Not applicable
Student Attributes refer to attributes when students enter a tertiary institution.	○	○	○
Graduate Attributes refer to the qualities that are developed through the acquisition of a University Degree.	○	○	○
Professional Attributes refer to the key characteristics and competencies expected of professionals.	○	○	○

Any comment or motivation of selections above?

0/255

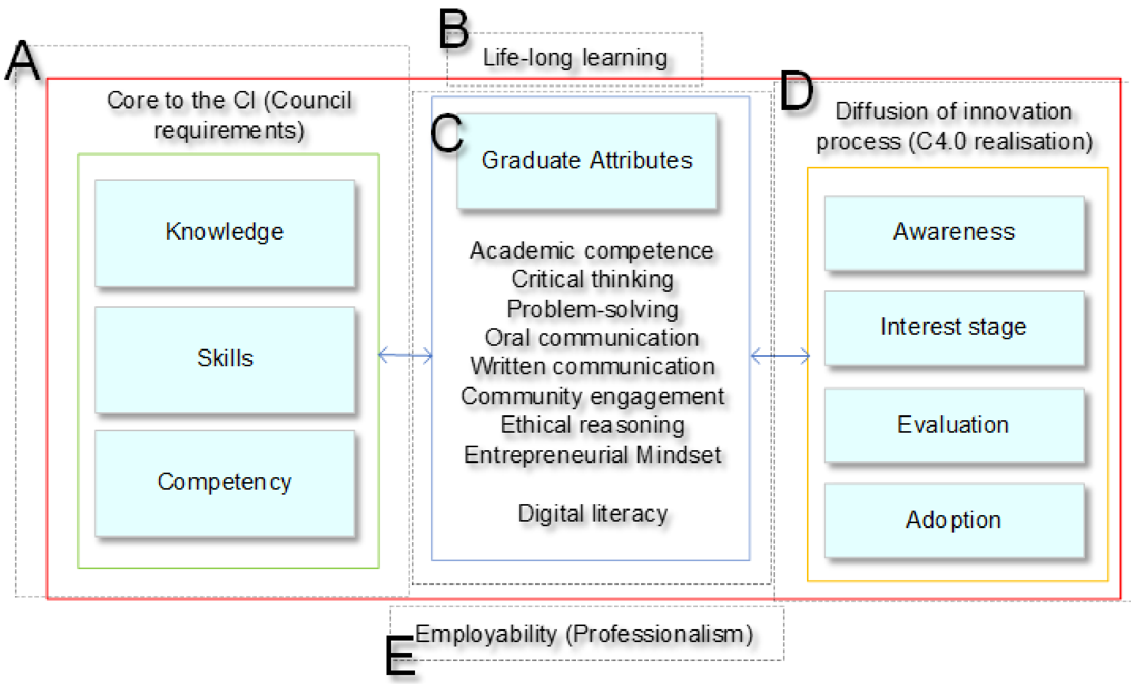
Next

38 % completed

Appendix F.1 - Page 10

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_Industry

Please observe the following possible framework and answer the following:



Please rank from most significant to least significant to show which criteria, based on their relevance to your work environment and their significance, do you consider when appointing a new employee in your company.

- A
- B
- C
- D
- E

Next

44 % completed

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_Industry

Construction 4.0 is associated with the Fourth Industrial Revolution's influence on the construction industry (CI). The following figure provides a short illustration of the possible future of Construction 4.0:

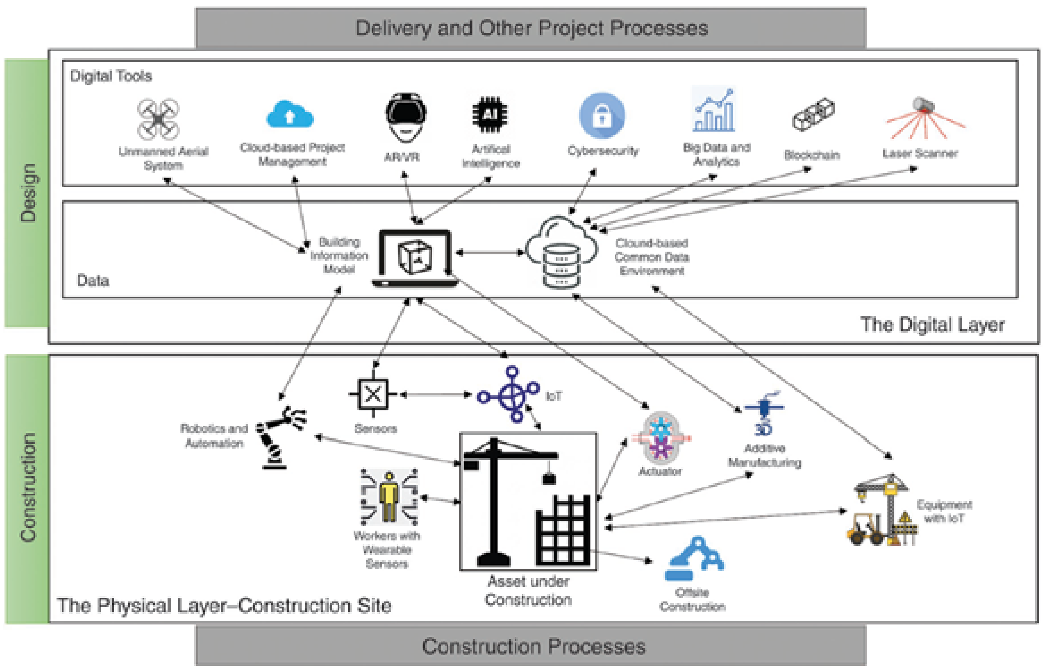


Figure 1: Physical to Digital to physical transformation (Source: Sawhney, Riley & Irizarry, 2020: 14)

If Graduate Attributes focuses on the mediation of 'what' and 'how' students learn, please rate the relevance of the following generic Graduate Attributes towards the preparedness of relevant employees towards future Construction 4.0. Please choose the response which best describes your level of agreement with the statements.

	1 Disagree	2 Somewhat Disagree	3 Slightly agree	4 Agree completely	Not familiar/ opinion
Academic competence: Students develop **knowledge, skills and attitudes** (including	○	○	○	○	○

	1 Disagree	2 Somewhat Disagree	3 Slightly agree	4 Agree completely	Not familiar/ opinion
values) through interacting with discipline-specific content.					
Critical thinking: A mind that **comprehensively explores** issues, ideas, artefacts, and events **before accepting or formulating an opinion or conclusion.**	○	○	○	○	○
Problem-solving: A designing, evaluating and implementing a process as a strategy to answer an open-ended question or achieve a desired goal.	○	○	○	○	○
Oral communication: Purposeful presentation is designed to increase knowledge, foster understanding, or promote change in the listeners' attitudes, values, beliefs, or behaviours.	○	○	○	○	○
Written communication: Working with various **writing technologies** and mixing texts, data, and images.	○	○	○	○	○
Community engagement: Making a difference in the community life of our communities by developing the combination of **knowledge, skills, values and motivation** through an understanding of our country's social and cultural diversity.	○	○	○	○	○
Ethical reasoning: Reasoning about right and wrong in human conduct, where students to be able to **assess their** ethical values and the social context.	○	○	○	○	○
Entrepreneurial Mindset: Students need a set of **attitudes, skills and behaviours** to	○	○	○	○	○

	1 Disagree	2 Somewhat Disagree	3 Slightly agree	4 Agree completely	Not familiar/ opinion
succeed academically, personally and professionally. **Digital literacy:** The ability of an individual to **use digital technologies effectively and confidently** to access, evaluate, create, and **communicate information** in various contexts is becoming crucial in today's technology-driven world.	○	○	○	○	○

Next

50 % completed

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_Industry

Do you feel that additional attributes could be added to the previous list that may contribute to the preparedness for Construction 4.0 for the graduates:

- ◯ Yes
- ◯ No

Next

56 % completed

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_Industry

Do you feel that some of the previously listed attributes should be removed?

- ◯ Yes
- ◯ No

Next

69 % completed

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_Industry

Please indicate which ones you would remove (Selection from a list):

- ☐ **Academic competence:** Students develop **knowledge, skills and attitudes** (including values) through their interaction with discipline-specific content.
- ☐ **Critical thinking:** It is a habit of mind that **comprehensively explores** issues, ideas, artefacts, and events **before accepting or formulating an opinion or conclusion.**
- ☐ **Problem-solving:** It is the process of designing, evaluating and implementing a strategy to answer an open-ended question or achieve a desired goal.
- ☐ **Oral communication: Purposeful presentation** is designed to increase knowledge, foster understanding, or promote change in the listeners' attitudes, values, beliefs, or behaviours.
- ☐ **Written communication:** It can involve working with various **writing technologies** and mixing texts, data, and images.
- ☐ **Community engagement:** Working to make a difference in the community life of our communities and developing the combination of **knowledge, skills, values and motivation** to make that difference through an understanding of our country's social and cultural diversity.
- ☐ **Ethical reasoning:** It is reasoning about right and wrong human conduct. It requires students to be able to **assess their own** ethical values and the social context.
- ☐ **Entrepreneurial Mindset:** Students need a set of **attitudes, skills and behaviours** to **succeed** academically, personally and professionally.
- ☐ **Digital literacy:** The ability of an individual to **effectively and confidently** use digital technologies to access, evaluate, create, and **communicate information** in various contexts is becoming increasingly important in today's technology-driven world.

Next

75 % completed

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_Industry

Activity theory teaches us that achieving a specific goal (individual or group) requires the mediation of artefacts or stated differently, balancing enablers and constraints. In meeting the above objective, a student must rely on the mediation of the several artefacts at their disposal, such as the module content, self-enhancement, the available community, the applicable rules, and the division of labour. On a 1 – 4 ranking scale, which statements based on their relevance to your work environment do you consider when appointing a new employee in your company?

Please choose the response that best describes your agreement level with the statements.

	1 Disagree	2 Somewhat Disagree	3 Slightly agree	4 Agree completely	Not familiar/ opinion
We are moving into a Construction 4.0 environment, regardless of the time and the current realisation thereof.	○	○	○	○	○
Employability summarises the desired objective of any HEI qualification best.	○	○	○	○	○
A graduate must continuously be trained when they enter the CBE environment.	○	○	○	○	○
Understanding the goal of a work task (outcome) is crucial in evaluating possible new technologies.	○	○	○	○	○
Developing the "person" during their academic tenure is more important than teaching students the required knowledge, skills and competencies.	○	○	○	○	○

	1 Disagree	2 Somewhat Disagree	3 Slightly agree	4 Agree completely	Not familiar/ opinion
The application of knowledge, skills and competencies are becoming more dynamic.	○	○	○	○	○
Graduate Attributes provide a stable and grounded framework for a graduate to build their career.	○	○	○	○	○
Graduate Attributes will assist in breaking down the silos that exist within curriculums.	○	○	○	○	○
Graduate Attributes may assist a student in understanding their career path.	○	○	○	○	○
Graduate Attributes are an over-complication and unnecessary addition to Higher Education curriculums.	○	○	○	○	○
Construction 4.0 technologies and practices can improve the efficiency of the South African construction industry.	○	○	○	○	○
Traditional construction methods are just as effective as Construction 4.0 technologies and practices.	○	○	○	○	○
Graduate Attributes in curricula are necessary for graduates to succeed in their careers.	○	○	○	○	○

Next

81 % completed

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_Industry

The realisation of Construction 4.0 is dynamic and at different stages, depending on multiple factors such as the employer, the client, individual projects (team compositions), suppliers, available funds, time etc. When considering new technologies and ways of conducting work, please rank the following parameters according to their priority in achieving a work-specific goal (1 = Most important contributor; 5/6 = least contributor):

Data set 1:

- Knowledge (e.g. procurement processes, planning and control processes etc.)
- Skills (e.g. quantity take-offs, rate-build-ups etc.)
- Competencies (e.g. quality management, financial management etc.)
- Attributes (e.g. critical thinking, problem-solving etc.)
- The physical understanding of existing assets

Data set 2:

- The combination of your knowledge, skills and competence.

Digital literacy - the ability to effectively use digital technologies and tools to find, evaluate, create, communicate, and share information.

The ability to answer open-ended questions and to critically evaluate the challenge.

Attitude, skills and behaviours.

Collaboration – verbal, written and observation.

Ethical considerations and community engagement.

Data set 3:

Physical understanding of existing assets (buildings, civil works etc.)

Digital design

The transition of physical into digital designs

The physical construction process

The utilisation of new assets (buildings, civil works etc.)

Next

88 % completed

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_Industry

How can incorporating Graduate Attributes (GAs) into curricula facilitate the development and assessment of basic knowledge, skills, and competencies (KSC) required by regulating councils, thus providing a more stable foundation and career goals for graduates of higher education institutions?

0/4000

Do you have any further contribution to the study that you want to make:

0/4000

Next

94 % completed

Survey on Construction 4.0 Attributes of South African Construction Built Environment students_Industry

Thank you for participating in the survey; your responses will contribute valuable information towards enhancing curriculum objectives. If you would like to receive feedback on the study, kindly provide your email address below:

0/255

Send

100 % completed

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Survey on Construction 4.0 Attributes of South African Construction Built Environment Profesionals – Interview

Dear respondent

My name is Hendri du Plessis, a Researcher in the Faculty of Natural and Agricultural Sciences, the Department of Quantity Surveying and Construction Management at the University of the Free State. I am conducting a Ph.D. research study to evaluate the Construction 4.0 attributes of South African Construction Built Environment students from an Activity Theory perspective (Ethical Clearance No.: **UFS-HSD2022/0241/22**).

Considering the knowledge, skills and competency requirements of regulating councils, the study endeavours to establish the relevance of Graduate Attributes (GA) through the lens of Activity Theory, particularly Construction 4.0 Graduate Attributes. The study is aimed explicitly at undergraduate Quantity Surveying and Construction Management programmes.

Knowledge, skills, competencies, and attributes are all essential components of an individual's overall capabilities. Knowledge refers to a subject's theoretical or factual understanding, while skills are the practical abilities to perform specific tasks. Competencies are the behaviours and attitudes that enable effective performance, while attributes are the personal characteristics that underpin these competencies. These components comprise an individual's overall capabilities and determine their ability to perform a specific job or task. These components are necessary to achieve their professional goals and contribute effectively to their chosen field.

Bowden, Hart, King, Trigwell and Watts (2000) defined GA as "…the qualities, skills and understandings a university community agrees its students would desirably develop during their time at the institution and consequently shape the contribution they can make to their profession and as a citizen." (cited: Nagarajan & Edwards, 2014: 12).

Being a professional from the Industry, you are invited to participate in this research study by completing the questionnaire. Participation in this study is voluntary, and you are guaranteed complete confidentiality in the treatment of your responses; you have the right not to respond to any questions you deem inappropriate; any information provided will be used solely for this research.

You may withdraw from the study at any point if you wish to do so by emailing the Principal Researcher of the study.

By completing the survey, you agree that your responses may be included in the study's results, which will be published in an accredited and peer-reviewed journal.

This survey comprises nine background questions and twelve outcome questions. **If you want to participate in the survey, select yes below to continue.**

CONSENT TO PARTICIPATE IN THIS STUDY

I confirm that I voluntarily agree to participate in the research study referred to as the

The evaluation of Construction 4.0 attributes of South African Construction Build Environment graduates: an Activity Theory perspective (the **"Study"**) in relation to

the focus group discussions and which Study is being conducted by

Mr Hendri du Plessis, (the "**Researcher**").

I, the undersigned Participant, further confirm that–

1. the Researcher has explained the nature, procedure, potential benefits and anticipated inconvenience of my participation in the Study;
2. I have read (or had explained to me) and understood the Study as explained in the attached information sheet;
3. I have had sufficient opportunity to ask questions and am prepared to participate in the Study;
4. I understand that the focus group discussion is being recorded and that my participation in the Study is entirely voluntary and that I am free to withdraw at any time without penalty (if applicable);
5. I voluntarily provide the UFS and the Researcher with the relevant personal information and consent to the UFS and the Researcher collecting, disclosing and processing my personal information in order to conduct the Study and any related activities in relation thereto;
6. I hereby acknowledge and confirm that I understand the purpose for which the UFS and the Researcher may collect, store, use, delete, destroy, outsource, transfer or otherwise process, as the context and circumstances may require and as contemplated in terms of POPIA, my personal information as set out herein;
7. I am aware that the findings of the Study will be anonymously processed into a research report, journal publications and/or conference proceedings and that my personal information will be aggregated and deidentified at such stage;

I, the Participant, agree to the questionnaire recording *and/or Focus group Discussion*.

Full Name of Participant: ____

Signature of Participant: ______________________________ Date: ________________

Full Name(s) of Researcher(s): ____

Signature of Researcher: ______________________________Date: ________________

Name and Surname: ____

Company: ____

INSTRUCTIONS: Use a cross (X) to select the options

1. Which of the following categories best describes your Profession? (More than one may be chosen):

Construction Project Manager	
Construction Manager	
Quantity Surveyor – Building/"standard"	
Quantity Surveyor – Engineering	
Other (Please specify):	

2. Please indicate how many years of experience you have in the abovementioned Profession.

5 years or less	
6 – 10 years	
11 – 15 years	
16 to 20 years	
21 to 25 years	
Above 25 years of experience	

3. Please indicate the employee size of the company you are employed in.

1 - 10 employees	
11 - 20 employees	
21 - 30 employees	
31 - 40 employees	
41 – 50 employees	
Above 50 employees	

4. What is your highest qualification?

____
____
____
____
____
____

5. Please indicate your professional affiliation from the following Councils (more than one may be chosen):

SACQSP as Pr QS	
SACQSP as Candidate	
SACPCMP as Pr CPM	
SACPCMP as Candidate CPM	
SACPCMP as Pr CM	
SACPCMP as Candidate CPM	
Other (please specify):	

6. Please indicate your registration from the following built environment associations. more than one may be chosen):

Association of South African Quantity Surveyors (ASAQS)	
Association of Construction Project Managers (ACPM)	
Consulting Engineers of South Africa (CESA)	
Master Builders South Africa (MBSA)	
South African Institute of Architects (SAIA)	
South African Property Owners Association (SAPOA)	
Other (specify):	

Section B: Capabilities

7. What do you perceive is the meaning of Graduate Attributes.

8. Would Graduate Attributes be a good criterion when interviewing a potential candidate?

9. In other words? What should the focus be for 1st year, 2nd year and 3rd year of undergraduate students?

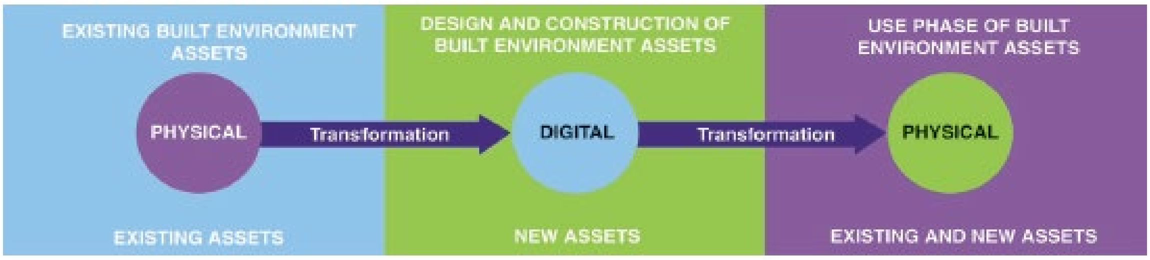


Figure 1: Physical to Digital to physical transformation (Source: Sawhney, Riley & Irizarry, 2020: 5)

10. The survey data said that GA is used most often when conducting the professional's work and when searching for quality in a potential candidate. But when appointing a new recruit, core knowledge areas are listed as more important. If this is the case, what quality are you looking for when appointing a candidate?

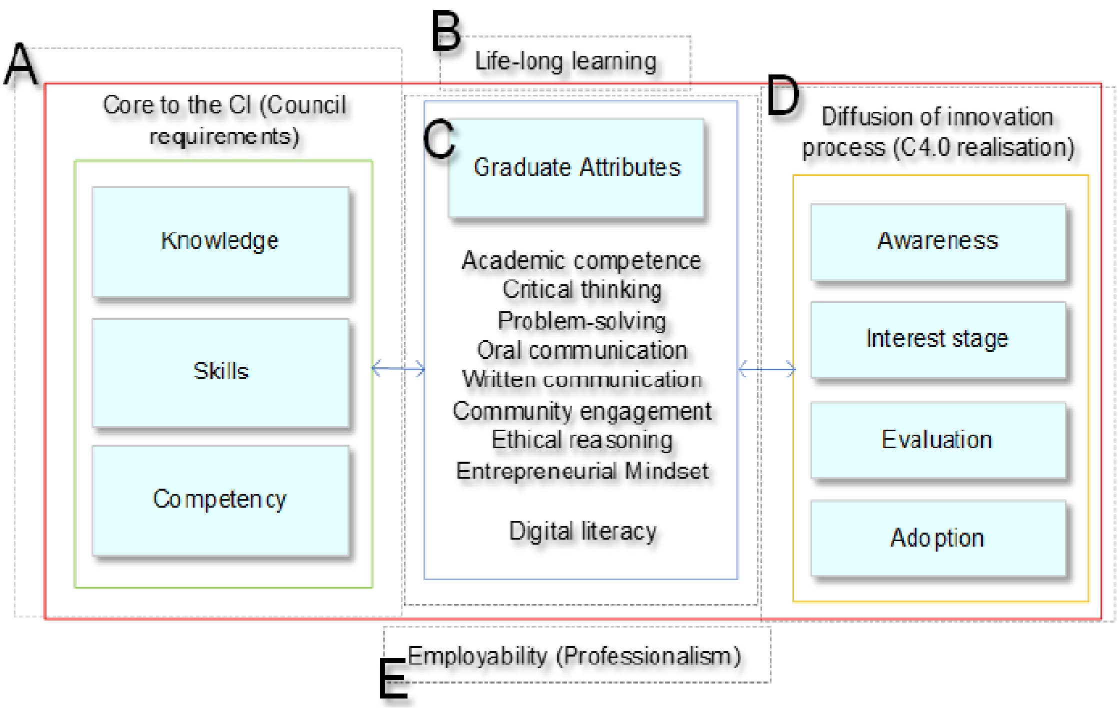
____

____

____

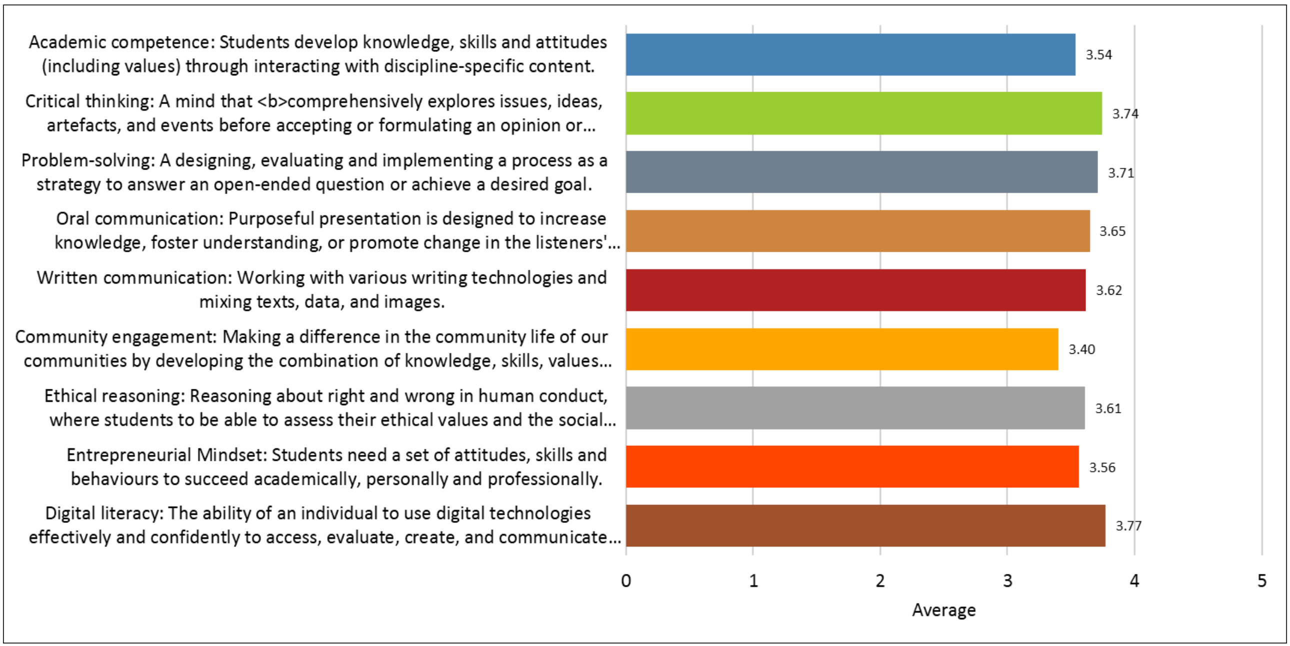
11. Can we discuss the following:

Please rank from the most significant to least significant to show which criteria you consider when appointing a new employee in your company.



12. Can we discuss the following in light of Construction 4.0 preparedness:

If Graduate Attributes focuses on the mediation of 'what' and 'how' students learn, please rate the relevance of the following generic Graduate Attributes towards the preparedness of relevant employees towards future Construction 4.0. Please choose the response which best describes your level of agreement with the statements.



20. Concerning the softer side, how can incorporating Graduate Attributes (GAs) into curricula facilitate the development and assessment of basic knowledge, skills, and competencies (KSC) required by regulating councils, thus providing a more stable foundation and career goals for graduates of higher education institutions?

21. Do you have any further contribution to the study that you want to make:

Additional reflection questions if there is time

Graduate Attributes and Industry Expectations: Reflecting on recent graduates you have worked with, can you identify any gaps between their educational preparation and the practical demands of Construction 4.0 projects?

Curriculum Development Suggestions: Based on your professional experience, what specific skills or knowledge areas do you believe should be emphasized within the QS and CM curriculums to better prepare students for Construction 4.0?

Future Outlook on Construction 4.0 and Education: How do you foresee the evolution of Construction 4.0 affecting the skillset required from graduates in the next 5-10 years, and how should education institutions adapt?

APPENDIX G – POPIA CONSENT FORM

RESEARCH STUDY INFORMATION LEAFLET AND CONSENT FORM

DATE

20 January 2023

TITLE OF THE RESEARCH PROJECT

The evaluation of Construction 4.0 attributes of South African Construction Built Environment graduates: an Activity Theory perspective

PRINCIPLE INVESTIGATOR / RESEARCHER(S) NAME(S) AND CONTACT NUMBER(S):

Hendri du Plessis *2005108812/ 0880629* *051 401 9624*

FACULTY AND DEPARTMENT:

Natural and Agricultural Sciences
Quantity Surveying and Construction Management

STUDY LEADER(S) NAME AND CONTACT NUMBER:

Dr. Somarie Holtzhausen
051 401 2046

WHAT IS THE AIM / PURPOSE OF THE STUDY?

The Study aimed to determine, by means of the Activity Theory perspective, the most important or relevant attributes for transforming South African Construction Built Environment student learning and development in Higher Education Institutions (HEI). Furthermore, how these Construction 4.0 graduate attributes might be managed or implemented best by HEIs to address the technological progress in the workforce, considering the three different stakeholders. The objectives for the three articles are as follows: 1. Identify, evaluate and measure student experiences towards the most important South African Construction Built Environment graduate attributes through the Activity Theory perspective and provide a rationale for the existence of these graduate attributes (Chapter 2, Article 1).2. Evaluate, through the Activity Theory perspective, the critical graduate attributes for lecturers in the South African Construction Built Environment and its implications (Chapter 3, Article 2).

WHO IS DOING THE RESEARCH?

Mr du Plessis is currently a lecturer and Programme Director (Open learning-, MSc. and PhD programmes) at the Department of Quantity Surveying and Construction Management at the University of the Free State. He obtained a Master's (MSc.) degree in Quantity Surveying in 2017 (Specialising in Building Contracts). He has four and a half years of teaching experience at

NQF levels 6, 8 and 9, with 8 publications, of which 3 have been at conference proceedings (1 x international) and 2 have been Journal papers.

Mr. du Plessis is also a Professional Quantity Surveyor and Construction Project Manager and is still active in the industry. He has worked in consulting engineering for over eleven years as a Construction Project Manager and Quantity Surveyor. As a Construction Project Manager, he was responsible for overseeing the construction of buildings and other structures and organising the physical and human resources involved in the construction process on the consulting side. He is also closely involved and responsible for drafting tender documentation with Bills of Quantities.

HAS THE STUDY RECEIVED ETHICAL APPROVAL?

This Study has received approval from the Research Ethics Committee of University of the Free State (UFS). A copy of the approval letter can be obtained from the Researcher.

Approval number: UFS-HSD2022/0241

WHY ARE YOU INVITED TO TAKE PART IN THIS RESEARCH PROJECT?

As a Built Environment lecturer or student within a Higher Education Institution, your insight into this compelling topic would be highly valued.

WHAT IS THE NATURE OF PARTICIPATION IN THIS STUDY?

Respondents are expected to complete a short questionnaire on their experience of the Graduate Attributes, within the Built Environment, particularly towards Construction 4.0 (C4.0). Those that are interested in the topic and who wish to partake in a Focus Group discussion may indicate that they would be interested in the questionnaire.

CAN THE PARTICIPANT WITHDRAW FROM THE STUDY?

Please note that participation is voluntary and that there is no penalty or loss of benefit for non-participation. Participation in this Study is voluntary, and you are not obligated to participate. If you decide to participate, you will be given this information sheet to keep and asked to sign a written consent form. You are free to withdraw at any time and without providing a reason. This can be done by sending an email to the Principal Investigator at: duplessishb@ufs.ac.za.

WHAT ARE THE POTENTIAL BENEFITS OF TAKING PART IN THIS STUDY?

With many HEIs moving towards developing specific student attributes (Barrie 2007: 439) and the seemingly limited amount of research devoted to Construction Industry (CI) teaching and learning in HEIs, this research will contribute to the body of knowledge on Quantity Surveying and Construction Management curricula.

WHAT IS THE ANTICIPATED INCONVENIENCE OF TAKING PART IN THIS STUDY?

The questionnaire will not take more than 15min of your time. You may also complete the survey at a convenient time that suits your schedule. Discussion groups for students will not take more than 60min and are aimed to be an enlightening discussion on the topic.

WILL WHAT I SAY BE KEPT CONFIDENTIAL?

Your name will not be recorded anywhere, and no one will connect you to the answers you give. Your responses will be given a fictitious code number or a pseudonym, and you will be referred to in this way in the data, any publications, or other research reporting methods, such as conference proceedings.

HOW WILL THE INFORMATION BE STORED AND ULTIMATELY DESTROYED?

The Researcher will store hard copies of your answers for five years in a locked cupboard/filing cabinet for future research or academic purposes; electronic information will be stored on a password-protected computer. Future use of the stored data will be subject to further Research Ethics Review and approval if applicable.

WILL I RECEIVE PAYMENT OR ANY INCENTIVES FOR PARTICPATING IN THIS STUDY?

No remuneration will be given for participation.

HOW WILL THE PARTICIPANT BE INFORMED OF THE FINDINGS / RESULTS OF THE STUDY?

If you would like to be informed of the final research findings, please get in touch with Mr Hendri du Plessis on 051 401 9624 or email: duplessishb@ufs.ac.za.

Thank you for taking the time to read this information sheet and for participating in this Study.

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YUNIVESITHI YA FREISTATA

UFS UV

CONSENT TO PARTICIPATE IN THIS STUDY

I confirm that I voluntarily agree to participate in the research study referred to as the

The evaluation of Construction 4.0 attributes of South African Construction Build Environment graduates: an Activity Theory perspective (the **"Study"**) in relation to

and which Study is being conducted by

Mr Hendri du Plessis, (the "**Researcher**").

I, the undersigned Participant, further confirm that–

1. the Researcher has explained the nature, procedure, potential benefits and anticipated inconvenience of my participation in the Study;
2. I have read (or had explained to me) and understood the Study as explained in the attached information sheet;
3. I have had sufficient opportunity to ask questions and am prepared to participate in the Study;
4. I understand that my participation in the Study is entirely voluntary and that I am free to withdraw at any time without penalty (if applicable);
5. I voluntarily provide the UFS and the Researcher with the relevant personal information and consent to the UFS and the Researcher collecting, disclosing and processing my personal information in order to conduct the Study and any related activities in relation thereto;
6. I hereby acknowledge and confirm that I understand the purpose for which the UFS and the Researcher may collect, store, use, delete, destroy, outsource, transfer or otherwise process, as the context and circumstances may require and as contemplated in terms of POPIA, my personal information as set out herein;
7. I am aware that the findings of the Study will be anonymously processed into a research report, journal publications and/or conference proceedings and that my personal information will be aggregated and deidentified at such stage;
8. I also give the UFS permission to share, without notification, the collected data with other researchers at the UFS or other Higher Education Institutions. This permission is dependent on the same principles of ethical research practices, anonymity/confidentiality, safekeeping of information, and other issues listed above applying.

I, the Participant, agree to the questionnaire recording *and/or Focus group Discussion*.

Full Name of Participant: ____

Signature of Participant: ________________________________ Date: __________________

Full Name(s) of Researcher(s): ____

Signature of Researcher: ________________________________Date: __________________

APPENDIX H – TURN-IT-IN REPORT

250105 Ch1 Ch2 Art1 2 3 Ch6 Cleaned version - Rev7 - Copy for Turn-it-in.pdf

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CORNELIA GELDENHUYS

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17 December 2024

TO WHOM IT MAY CONCERN

Herewith I, **Cornelia Geldenhuys (ID 521114 0083 088)** declare that I am a qualified, accredited language practitioner and that I have edited the following doctoral thesis:

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by

HENDRI BLIGNAUT DU PLESSIS

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..
C GELDENHUYS
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