SOCIAL COMMUNICATION TOWARDS SUSTAINABLE PHYSICAL SCIENCE LEARNING ENVIRONMENTS

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ABSTRACT

This article documents how social communication among actors in one of the projects in our academic network creates sustainable learning environments at a school and its local community. Social communication is understood to be the symbolic order that emerges when these actors (human beings), in a reciprocal manner, explain and share the intentions, processes and outcomes of their actions. In this study, actors who communicate among themselves in the academic network are teachers, learners, parents, members of the community, postgraduate student researchers and their supervisors. Such communication is deliberate and it is organised, among others, towards enhancing academic performance of school learners as well as the empowerment of other actors participating therein. Using network theory the author comes to understand how this network as the space of flows of knowledge and communication was created and meaningfully used to achieve the abovementioned objectives. Analysing the conversations of actors within this network further, using critical discourse analytic procedures, also shows how they combine their tacit community cultural wealth and global knowledge to scaffold themselves to higher forms of conceptual sophistication. Through this intersection of "knowledges", learning environments become sustainable as actors own them through self-generated communications and knowledge.

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INTRODUCTION AND BACKGROUND

This article documents how social communication anchors the creation of a sustainable learning environment in one of the 30 sub-projects of the research team (also known as Sustainable Learning Environments, or SuLE). Social communication refers to the symbolic order emerging and shared when human beings act and explain to one another the intentions, processes as well as the outcomes of their actions (Castells 2002; 2004; 2007; Staeheli 2006; Van der Wusten 2002; Van Dijk 2007; 2009). It is also based on the abstraction of the concrete materiality of one's context and portability thereof from one person to another (Berk 2000; Mahlomaholo & Netshandama 2011). It is furthermore a reflection on and in action, by the acting person as he/she makes sense of his/her own action(s) and the outcomes thereof. But most importantly it depends on conversations and negotiations among people sharing their fears, experiences and aspirations.

Social communication among people is a very potent and powerful force for change and transformation as demonstrated in the contestation for the human mind in the public sphere (Castells 2002; 2004; 2007; Staeheli 2006; Van der Wusten 2002; Van Dijk 2007; 2009). Once people are convinced of a particular line of argument they are very likely to act as persuaded although the outcomes of their actions can never be predicted (Castells 2002). In fact, social communication is performative as it encourages people to act in particular ways and not in others (Castells 2002; Staeheli 2006; Van der Wusten 2002; Van Dijk 2009). Human beings' identities are even formulated, reinforced and broken through social communication. Social communication serves as the material from which emotions and cognition are made.

A learning environment includes a formalised classroom setting(s) where one learner or more through the facilitation of the teacher acquires knowledge of an academic discipline (De Corte 2000; Driscoll 2005; Mahlomaholo 2010; Mahlomaholo & Netshandama 2011). The acquisition of knowledge always includes taking on particular attitudes and skills related to the mentioned subject (Development Bank of South Africa (DBSA) 2008). Furthermore, the learning environment includes the learner's socio-cultural background which he/she brings with to the classroom (De Corte 2000; Driscoll 2005; Fraser 2002; Mahlomaholo 2010; Mahlomaholo & Netshandama 2011). This extended learning environment is constituted by the community cultural wealth (Yosso 2005) of the learner over and above the learning content shared in the classroom. The parents of such a learner and other community members who are the custodians of, and who create and recreate this community cultural wealth, feature prominently in this learning environment as well (Kemmis & McTaggart 2000; Mahlomaholo 2010; Yosso 2005). In other words, the learning environment is a public space

where respect for one another, equity, social justice, freedom, peace and hope (Held 1980; McGregor 2003) are cultivated, practised and shared for purposes of sustainability (Kemmis & McTaggart 2000; Mahlomaholo 2010). All these are better operationalised through social communication. A learning environment is thus a social space made up of many people communicating with one another as they work/act towards a defined goal, namely the achievement of effective learning outcomes (Kemmis & McTaggart 2000; Habermas 1987). The involvement of these many people ensures sustainability of learning and the learning environment because their presence goes beyond the presence of the current learner(s), teachers and the learning content in terms of time and space. This goes across generations, especially if marked by respect and social justice.

The challenges which we are facing in South African education are due to the fact that our learning environments are truncated as they are regarded as one-teacher-to-one/many-learner(s) (DBSA 2008; Mahlomaholo 2010; Mahlomaholo & Netshandama 2011). The critical cross-field outcomes which are supposed to underpin all our education seem to exist on paper only. There is very limited public participation and accountability as a teacher does her/his "thing" alone with the learners. Monitoring of learning is not done in the public and social spaces. In many instances, especially in township schools, the critical cross-field outcomes which should inform all learning are totally ignored (Bereng 2007; DBSA 2008). For example, the mode of teaching and learning is such that it is based on rote memorisation (*ibid*.). There are limited opportunities for learners "to identify and solve problems in which responses demonstrate that responsible decisions using critical and creative thinking have been made" (Bender, Daniels, Lazarus, Naudé & Satter 2006: 40-45). The learners are not challenged to see the value of "working effectively with others as members of a team, group, organisation or community" (Bender *et. al.* 2006: 40-42). There is no evidence of them organising and managing themselves "and their activities responsibly and effectively" (*ibid*.). The learners rely heavily on the teacher for information:

> They do not collect, analyse, organise and critically evaluate information on their own. They do not communicate effectively using visual, mathematical and/or language skills in the modes of oral/written presentation, they do not show responsibility towards the environment and health of others, and they do not demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation (*ibid*.).

This article illustrates how one of the learning projects within the SuLE academic network uses social communication among participants to create sustainable learning environments at a school and local community involved in the study.

THE LENS

According to Castells (2002; 2004; 2007) a network in the information age is characterised by its ability to operate globally through the use of information and communication technology (ICT). This technology enables the network to collapse space(s) without eradicating distances. This means that actors (Latour 2004) in the network, while far away from one another, can function as though they were in the same vicinity through ICT that enables them to become "space of flows" where communication and access to information and knowledge readily and instantly occur (Curry & Lillis 2010). Such a network is also characterised by emotional support for mutual development and growth.

Linked to the above, the starting point for conducting this research is that knowledge is socially created (Basov 2012; Castell 2002; 2007; Kemmis & McTaggart 2000; Van Dijk 2007; 2009). The network is the best model to capture the idea of sociality. However, sociality does not have total sway over the creation of knowledge because, as Basov (2012) contends, all humans have structural autonomy. This is the inherited capacity of the individual to interpret and to make sense of information and stimuli coming from the social context and in the process constitute one's cognitive abilities, as Piaget's genetic epistemology contends (Berk 2000). Structural autonomy of one's cognition is made possible by one's central nervous system with which one is born. This, according to Freud, is the Id which is instinctual, primitive and almost inherited (see Mahlomaholo 1998 for a detailed discussion). Lacan, however, non-essentialises the Id as he argues that it also is socially authored as it consists of the fossilised egos of one's forbearers. For this author the understanding is that at the very beginning of the process of knowledge creation, communication takes place within the individual person himself/herself among various components of his/her being. This could be between the primitive Id, the overly social Superego and the balancing socio-cognitive Ego.

This communication relies on the use of words and/or language which does not have to be verbalised (Van Dijk 2007; 2009). Once structural autonomy has been established as described above, the process of structural coupling (Basov 2012; Basov & Nenko 2012) takes place when the individual interacts with the context or other individuals for further cognitive growth and development to take place (Latour 2004). This process is reliant on the continual creation of knowledge at increasing levels of sophistication. The process of communication again undergirds this more sophisticated level of interaction between the organism and

the environment (Berk 2000; De Corte 2000; De Corte *et al*. 2003; Driscoll 2005). Structural coupling is facilitated by processes of assimilation and accommodation where the existing cognitive schema of the central nervous system within the individual's structural autonomy opens up and broadens to accommodate the new idea which finally is assimilated therein (structural autonomy) to create knowledge and advanced forms of cognitive functioning within the individual knower/cogniser (Berk 2000; De Corte 2000; De Corte *et al*. 2003). This new structural autonomy at a higher level is possible, also because it influences the environment/other individuals therein to achieve structural congruence between the two (Basov 2012; Basov & Nenko 2012; Berk 2000; De Corte 2000; De Corte *et al*. 2003). The growth of the individual is dependent on the growth of the environment as it feeds on the knowledge that comes from it.

The concept of structural congruence emphasises in no uncertain terms the fact that new knowledge is not entirely new as it consists of the combination and recombination of meanings from the social and cultural contexts (Basov 2012; Ismail & Idris 2009; Kalliola 2009). The sequencing of processes forming and engaging structural autonomy, structural coupling and structural congruence are also not linear (*ibid*.). They are multidimensional and possible due to communication within the individual as the actor, between actors in a social context, and among groups of actors. The multidimensionality of the processes of knowledge creation are at the centre of the democratic processes which inform and are informed by these horizontal, multi-origin and multi-dimensional directions in knowledge creation (Bender *et al*. 2006; Basov 2012; Ismail & Idris 2009; Kalliola 2009). No one person or so-called expert has the entire monopoly over knowledge and its creation. It is always about many people from diverse contexts coming together to contribute their different knowledges which make solutions to real-life problems possible and achievable (Castells 2002; Kemmis & McTaggart 2000; Mahlomaholo 2011; Staeheli 2006; Van der Wusten 2002; Van Dijk 2009; Yosso 2005). In the words of Habermas (in Held 1980), this is communicative action: many people with different specialisms communicating and negotiating (structurally coupling) to find the common ground and persuaded only by the power of logic to agree on a defined course of action to solve a problem.

These actors (Van Dijk 2007; 2009) are responsible for the creation of the symbolic order which include "the word" as they work, create and recreate knowledge in the process. They create the symbolic order so that they can communicate the intentions and outcomes of their actions and thus collectively create requisite power to solve the problem(s). The Faucouldian (Mahlomaholo 1998) notion of "knowledge as power" is informed by this realisation that together and through communicative action, power is created by connected

individual actors (Castells 2002; Kemmis & McTaggart 2000; Van Dijk 2009). But this power goes beyond the individual and the language as it is now collectivised into a discourse of the many. These discourses over time, practiced by many collectives, constitute the culture which in turn even informs how society is organised (Held 1980; Van Dijk 2007; 2009). The idea that one's spoken word is a reflection of the discursive practices of one's context which is also grounded on how the speaker's society is organised is clearly explained in this connection. For example, the continued marginalisation and exclusion of black people and thus their children in township schools could be understood to be a residue of the apartheid discourses that refuse to go away in this sense. Some of these learners have been subjected to discourses that undermine their intellectual abilities (hence their academic performance) to the extent that they have internalised these self-depreciating ideas (DBSA 2008).

A remedy for this state of affairs seems to be the intervention at the very same level of communicative action where actors, i.e. learners, parents, teachers and whole communities, could share in the creation of alternative discourses. This refers to that space where different cultural practices and social arrangements could inspire confidence, be equitable and socially just, facilitate freedom, engender peace and inspire hope for all. The wish expressed above is succinctly and clearly captured in the South African Qualification Authority's Critical Cross-field Outcomes (CCFO) in these words, that all educational conceptualisation and practice should enable learners to reflect on and explore "a variety of strategies to learn more effectively" and to be aware and keen of

> participating as responsible citizens in the life of local, national and global communities; being culturally and aesthetically sensitive across a range of social contexts; exploring education and career opportunities; developing entrepreneurial opportunities (Bender *et al*. 2006: 40-45).

The above emphasises the need for education that cultivates democratic citizenship among all learners through all curricula activities. Such a democratic education is relational and communicative as it involves sharing and explaining to the other the intentions, the processes and the outcomes of one's actions.

METHOD AND DESIGN

In order to operationalise this theorisation participatory action research was found to be the best *practical* approach to adopt in order to create sustainable learning environments through social communication at the school in this study (Kalliola 2009; Koirala-Azad & Fuentes 2010; Law & Hassad 1999). One of the student's subprojects focused on creating a sustainable physical science learning

environment at a school in the Free State. The researcher was not alone as she interacted with the school. Through a hybrid of physical presence and ICT connectivity the rest of the research team also participated in the study which is reported on here. This student is a teacher of physical science and her concern has been to improve the quality of teaching and learning in this important subject at the Further Education and Training (FET) level where she teaches. The FET level caters for 15 to 18 year old learners. She convened a team of participants which helped her to drive this participatory action research process. This team consisted of 14 people, including two retired teachers, two members of the local municipal council, two parents of learners at the mentioned school, two learners from those studying physical science at FET level, two members of faith-based organisations, two School Management and Governance Developers from the Free State Department of Education, and two teachers from the school mentioned above.

This team assisted the student and the rest of the research team to convene the first brainstorming and information session of all interested partners in the local community (Kalliola 2009; Koirala-Azad & Fuentes 2010; Law & Hassad 1999). Over 500 people participated. These included representatives of a number of civil society organisations, government departments and ordinary citizens in the immediate environment of the school. They were divided into 25 working groups of 20 people each. Each group had a chairperson and a scribe elected from among the participants. All of them had been informed beforehand about the meeting and that the aim was for them to assist the school in formulating strategies to improve the academic performance of the learners in the study of physical science at FET level. They were to prepare ways in which they could assist to resolve this problem as each would be given the opportunity to share and to present their contribution(s) in whatever manner possible. Participation was voluntary, and born out of a wish to contribute to the academic performance of the learners at this school. Informed consent forms were prepared and they had to sign these before participation. They were thus informed that should they feel uncomfortable with the process they were at liberty to withdraw and/or refuse to talk and to participate without any adverse consequences to them. They were also assured of confidentiality and that the information they shared was to be kept in the strictest possible confidence and that this information would be destroyed at the end of the study, if they so wished.

After the brainstorming and information session, which was held on a Saturday, the group met again two weeks later to reflect on strengths, weaknesses, opportunities and threats (a SWOT analysis) with regard to supporting the project in terms of designing the strategies to improve the academic performance of learners in physical science in particular. They worked first in plenary sessions

where the procedures of engagement and discussions were explained to them. Then they took part in smaller group discussions which reconvened into another plenary session at the end of the day to share the results of the SWOT analysis. Finally, the groups identified the five most important priorities which they suggested should be utilised to enhance learner performance in physical science. These priorities included fostering peer learning among learners where they would organise themselves into study groups focusing on particular and directed learning content like electricity, motion and chemical properties of matter. Other than peer learning there would also be opportunities to learn from knowledgeable people like technologists from the local municipality, amongst others, who worked with these matters on a daily basis. These activities were chosen in line with both the learning outcomes of physical science and the critical cross-field outcomes.

Another two weeks later the more or less 500 people came together again to work out the strategic plan based on the five priorities which were identified earlier. For each priority there were at least five activities planned which involved the learners, the teachers, the parents and the community respectively. An example of a peer learning activity was a planned visit by groups of learners to the water reticulation plant under the guidance of their teachers and municipal technologists to learn about the physical science subject content as identified earlier. The meeting also served to tie specific people to specific activities in terms of organisation and to ensure that the identified activities per priority did take place. Time-frames were set, and possible resources required were identified. The group agreed to monthly meetings to receive reports from the teachers, the learners, the principal and the school management team on the progress made.

These monthly meetings were to scrutinise the test marks over and above checking as to what progress was made with regard to the operationalisation of each of the priorities. These meetings also adjusted the strategic plan where necessary and planned for the subsequent months. The participants were made to feel comfortable through whatever means necessary. They could express themselves in whatever language they were comfortable with (Kalliola 2009; Koirala-Azad & Fuentes 2010; Law & Hassad 1999). They used whatever media they could effectively communicate their ideas in, be it pictures, personal stories, dramatisation, and so on. This made the participants feel validated in spite of their level of formal education. They went on to conduct thorough research in between meetings which they shared with their peers and the rest of the research team through cellphones and email communication. This process enabled them to become co-researchers as they were no longer passive respondents or powerless subjects in a research project (Kalliola 2009; Koirala-Azad & Fuentes 2010; Law & Hassad 1999). Eventually power was distributed across the entire project.

The participants were the ones who were driving the project because they shared in the positive outcomes thereof. They became informed participants as they continued to conduct research on matters like legislative and policy imperatives guiding effective teaching of physical science; the syllabus and content thereof; and the strategies which successful schools worldwide use.

All meetings and activities towards the realisation of the priorities were video and audio recorded with the permission of all involved. This data as well as minutes of meetings were transcribed verbatim and were analysed focusing on the spoken word as evidence of the analysis made at the discursive practices and social structural levels.

FINDINGS AND DISCUSSION

In the words of Castells (2002; 2004; 2007), the entire SuLE project, including this subproject at a school in the Free State, has become a global academic network operating through ICT connectivity as well as through monthly physical presence as participants present papers at conferences and meet to reflect on progress (Staeheli 2006; Van der Wusten 2002). The massive amount of data from this school subproject as well as the larger project involving 30 schools have been reported on in at least ten papers presented at conferences in Russia, Sweden, New York, Lesotho, South Africa and Croatia. Social communication within this network is at the order of the day. All involved have become empowered because each participant represents the network's thoughts and reflection at every moment when writing a paper, presenting a module, or writing a physical science test or examination. The participants have become the "space of flows" as Castells would argue (Castells 2002; 2004; 2007; Staeheli 2006; Van der Wusten 2002; Van Dijk 2007; 2009). The network has become a space of flows where knowledge is created and disseminated across 30 schools in South Africa and some schools of international collaborators. The structural autonomy of the individual learner, teacher, parent, academic or student-researcher has extended to be that of the network. We interact with other networks globally through structural coupling which has exponentially expanded the individual to include a team of continuously communicating participants.

Social communication in the community

The learning of physical science is no longer left to the teacher and the learner. It is taken to the *created* public sphere where the teacher is assisted by a team of 12 people (Fraser 2002). The 12 people in turn communicate with the 500 people who also communicate among themselves to create an even broader network where ideas flow and the spaces among them are collapsed through

cellphones and other ICT mechanisms. A minister of religion during the small group discussion commented that

> I am late for the meeting, but fortunately I did send an SMS to Thabile to indicate that I will be late. I actually have even given her my ideas that it would be best if these children could be taught such that they can assist in solving problems of pollution in our township as well as responding to the problem of unemployment in the community.

In response to the above Thabile (a pseudonym), who is in the smaller organising team and is a regular member of the school's governing body, indicated that she received the texted cellphone message from the pastor and had looked on the Internet for strategies which universities use when doing community service. In her own words:

> Many studies report that the level of understanding of the students at the university increased after doing projects in the community based on what they studied in their academic work at the university. I have actually prepared this PowerPoint which as you can see on what I am projecting; students in psychology were teaching children in MUCPP how to look after their mental health through engaging in exercises regularly so that their stress and anxiety levels could be normalised. If we are to enhance understanding of physical science, it would seem that the logical approach would be to let these learners conscientise the community about the wastage in terms of electricity, water and so on. Actually we need to have the work in collaboration with some agency in the community where they can apply their knowledge of physical science practically. What are those places which we have where these learners can learn?

The teacher who was leading the subproject on the learning of physical science explained that:

> Actually I have talked to Mr Lethola here who is on the local municipal council. He has agreed that we can take these learners to the water purification plant. There we can actually show these learners how movement of water is created through a slope. Then at the plant itself they will see how the dirty water is sifted through different grids until it is ready to be treated chemically. This will be an opportunity for them to see how different chemical bondings take place from the use of acids and alkaline.

A participant from the local municipality indicated that he would be there to take the learners through all these stages. He added:

> You see my advantage over the teacher in explaining to the learners is that I am almost in their age group. I speak their lingo and I am sure they will understand me more readily. (There is laughter). Please make sure that all have the masks ready because the smell can be very revolting out there.

Many parents of learners volunteered to support the teacher during this excursion and to be there for their children afterwards. One parent noted:

> Even though I do not know any physical science, I know what people throw into the toilets. I can provide the support and the advice. This will be good opportunity for these children to see what I have been telling them about respecting oneself and one's environment. If we destroy our water resources and our environment we destroy ourselves. I can keep an eye on these children every Thursday afternoon after work as I work only half a day at Spar. You know when these children see that we are interested in their learning and that we support the efforts of the teacher to ensure that they are learning, I am sure that they will want to do their best and not disappoint.

The above extracts were taken from the many opportunities for social communication which were created in the local subproject as described earlier. Social communication was also taking place within the organising committee which assisted the student-researcher to conduct participatory research as they engaged in activities which made the learning of physical science more effective and successful (Malcolm & Zukas 2009; Miller 2006; Muijs, West & Ainscow 2010).

These extracts are illustrations of social communication which confirms that the above-mentioned are actual networks of communication among actual participants in self-constituted public spheres where good performance is credited and negative conduct or lack of good performance is not (Muijs *et al*. 2010). These extracts are also indicative of the fact that the network has created a public sphere in response to "legitimation deficits", as Habermas would argue (1971; 1987; Held 1980). Existing practices of learning physical science, which are reductionist and are limited only to the learner and the teacher, are deconstructed and alternative modes of learning in a collaborative and inclusive public sphere marked by constant social communication, monitoring and validation are instituted (Castells 2007; Van der Wusten 2002; Van Dijk 2007; 2009).

The learning of physical science is now conceptualised as a public discourse in a public sphere where communicative action occurs (Habermas 1971; 1987; Held 1980; Philips, Berg, Rodriguez & Morgan 2010). Learning is collaborative and it is facilitated not by the authority vested in an office which someone occupies, such as that of the teacher, but by the power of the most valid, convincing and logical contribution (Philips, Berg, Rodriguez & Morgan 2010). Learning through this kind of communication is oriented towards intersubjective agreement, mutual understanding, and unforced consensus about what to do (Habermas 1987; Held 1980). This network is inclusive. It does not matter what

one's social standing is, communication is encouraged and structured in such a way that all can make a contribution on their own terms in the language and media they understand best (Philips *et al*. 2010). All participants now own the process of learning physical science as they have been involved at all the stages; from conceptualisation through operationalisation of this new mode of learning (Kemmis & McTaggart 2000; Philips *et al*. 2010). When the learners ultimately sit for their final grade 12 examination, all those who were involved would share in their anguish because they would be representing the collective's intellectual capital. This will also be the operationalisation of the critical cross-field outcomes which go beyond mere classroom learning to becoming a productive citizen of a democracy. Nobody stands to be blamed because all of us are responsible for the outcomes (Kemmis & McTaggart 2000; Philips *et al*. 2010). The network has managed to create a space for debate and alternative ways of learning. One could actually see this network and how it functions as a voluntary movement where communication is free.

A closer look at the above extracts from the identified public communicative spheres reveal that all the CCFOs found expression in the learning of physical science when it is supported and predicated as such. For example, the basis is already laid for the learners and the community members as role models in the learning of physical science to participate as responsible citizens in local, national and global communities, being culturally sensitive to a range of social contexts, and exploring education and career opportunities as well (Kemmis & McTaggart 2000; Philips *et al*. 2010; Ren & Langhout 2010). The project is about all of us learning to be free and to be citizens of a democracy. The processes of cognitive and social development encompass us all. It is not only the learners whose understanding of physical science is enhanced, but even the participants, the community members who had very little to do with the subject, now stand the chance to learn and to know through this social communication (Kemmis & McTaggart 2000; Ren & Langhout 2010). As Latour (2004) states, participants in the subproject and the network are aware of the problem facing the learners. Our *interessement* (Latour 2004) as such is based on the successful learning of physical science by our children. Participants have to facilitate this process irrespective of their level of education or standing in society. The participants in this network are fully enrolled to support.

Social communication in the classroom

The learners' level of conceptualisation has heightened significantly in physical science. They now talk fluently on concepts like the gradient of the slope, velocity and motion, gravitational pull, and so on. They are keen to write tests and, in their own words, they no longer have to "cram" before tests as their

"knowledge is now at the tips of their fingers". Their average performance in the five tests and assignment was above 65% in many of the grade 10 to 12 classes. An interesting point is that there was also related improvement in the other subjects, although not as significant. Attendance has improved from 50% to 75% in the extra classes and tutorials, which are jointly conducted by the teachers and colleagues from the department of water affairs in the local municipality. Learners whom the teacher thought were extreme introverts are now coming out as keen emerging scientists. They are asking questions. In some videos they can be seen taking the initiative to experiment with a new way of distilling water. One learner who has been participating fully in the project from its commencement to date, given the above, noted that:

> If I fail physical science this year I will not have anything or anybody to blame but myself. You see this subject is now in my face all the time. I cannot avoid it. Initially I could not understand what those things were: motion, force, joules, ohms, velocity. But it seems they are just shorthand to express very simple and easy processes some of which we saw when we visited the water plant. Those things take place every time and everywhere in our lives and we just have to pay attention.

Another learner confirmed what the first had said:

> The interesting thing is that my mother, who at first was reluctant to help me with my home work, has now volunteered to coordinate the afterschool study of all learners in my class. She used to complain about lack of time. But this time she is the one who is so ... punctual, who ensures that the materials are there all the time. When we went to the water plant she wanted to come. Although she was not able to go she can never keep quiet about how things are being messed up when we do not protect and jealously guard our resources. Yoh ... did you see those remains of the body of the foetus mixed with the dirty water? That really shocked me! Remember those teaspoons, forks and all the kitchen utensils? How do you think they got in there?

Instead of responding directly one learner was making calculations with his calculator and wanted to check the following with the teacher:

> You know at this rate, the amount of water we are losing through taps which are leaking will ultimately cost R5000 per household over three months? Am I right? What can we do about the treated sludge from the water plant? Is it not possible to dry it up after the toxic elements have been taken out and then use that as manure and fertilisers? Won't the remaining chemicals still kill the plants? I have been thinking that perhaps as the school we could help the municipality to facilitate the treatment of the water and then have a small business run by the school where we give some of these unemployed but hardworking youth the

> opportunity to work on it? Say we could market this product and sell it. It should not be hard to find ways of transporting it to the places of the buyers.

Another extract from another learner came up with a further suggestion:

> We should run campaigns door to door to make our people aware of the costs we are causing to our parents and community in general when we do not care for our water and our environment.

The above extracts indicate that learners' structural autonomies have expanded greatly (Basov 2012). Their level of cognitive functioning has moved beyond the mere recall and knowledge to operate where they can classify and invent. They are innovative and creative. They are always thinking of novel ways of learning and applying their knowledge of the subject content because this is how they have been taught. Many myths and stereotypes about learners from the township are beginning to crumble as the learners come into their own. The normal classroom contact sessions are used for debating and reporting on their findings, which they now work on independently. They are researching the solutions themselves on the Internet and they are in constant contact with their teachers on Twitter and cellphones regarding this "new thing" which they have found and would like to test out in the laboratory.

Initial structural congruence has happened for many of these learners. They are now becoming co-researchers and the SAQA CCFOs seem to be finding expression in their conduct and their academic performance. They are resources to one another in the context of their supportive community and parents (Kemmis & McTaggart 2000; Philips *et al*. 2010; Sjödin 2004). Among many points, the extracts above attest to the successful negotiation of meaning through communicative action within the individual learners, among groups of learners, between them and their teachers, among classrooms and between various classrooms in physical science as a subject and beyond to include the parents, the members of the community and the university (Kemmis & McTaggart 2000; Philips *et al*. 2010; Sjödin 2004). The network has even reached out to other contexts globally through ICT.

CONCLUSION

The discussion above shows that one of the ways in which sustainable learning environments can be created at school is by broadening communication beyond participation of the learners and teachers (De Corte *et al*. 2003). When many teachers work together and communicate among themselves, this increases the

multi-perspectives to the study on any one concept and improves understanding thereof accordingly. A team of teachers working together towards a defined goal is always more effective than one teacher working alone in isolation with his/her learners. Peer learning among learners where communication among equals is unrestricted seems to enhance understanding even more.

The study has also demonstrated that social communication increases the opportunities for actors in networks to achieve many of the critical cross-field outcomes referred to earlier. For example, there were ample opportunities for them "to identify and solve problems in which responses demonstrated that responsible decisions using critical and creative thinking have been made" (Bender *et al.* 2006: 40-45). They had opportunities to work "effectively with others" in both their immediate and global environments as "members of a team, group, organisation or community" (*ibid*.). They could "manage themselves well, collect, analyse, organise and critically evaluate information". Most importantly, they could capitalise on their community cultural wealth with which they were familiar and fluent to scaffold themselves to higher levels of meaning construction. Their modes of interaction and learning were expanded beyond the individual to include the network through communication.

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