CHAPTER 11

Assisting Learners to Take Up Agency in Problem-Solving Activities

Therese Lambrechts, Rob O'Donoghue and Ingrid Schudel

Introduction

The Centre for Renewable and Sustainable Energy Studies established the Schools Programme to provide professional development and learning materials to support school educators in the teaching of renewable energy topics (Van Niekerk 2008). Research undertaken in 2016 on the renewable energy learning material showed that while the learning material supported the development of factual and conceptual knowledge; opportunities for learner-led inquiry work, where learners are required to engage with open-ended problem-solving activities, needed to be included for higher order cognitive development (Lambrechts 2017). This study builds on the research done on the above-mentioned renewable energy learning material.

The study's argument is that in order to achieve sustainability, there is a need to facilitate learning processes where learners acquire sound knowledge and have opportunities to engage with this newly acquired knowledge that can lay a foundation for future changed patterns of energy use. It is therefore necessary that learners engage deeply with content knowledge in order to understand why it is important to make the changes.

One way for learners to develop their own curiosity, thus leading them to want to understand their own environmental impact, is to develop an awareness of how much energy they use on a daily basis, for example, through an energy audit in their homes

or school. The aim of this study was to determine in what way the learning materials developed for the Grade 11 Physical Science audit encouraged learner-led inquiry work, where learners were required to engage with open-ended problem-solving activities.

This study used a learning task sequence framework (Edwards 2014) as an analytical tool to determine how gained knowledge motivated learners to take up agency, in this case through assessing and acknowledging their own energy use by performing an energy audit. As the name suggests, the framework is made up of sequences, where learning tasks are scaffolded and build on one another, enabling learners to become familiar with new content, ideas and concepts in such a way that they internalise the content and reach specific knowledge goals (Edwards 2014). The required outcome of the learning material developed for this study of ESD was that the learners would engage with the learning material to such an extent that they would understand the consequences of electricity use on various levels, take responsibility and get involved in managing their own energy use.

The research question underlying the way in which the study was developed and implemented was the following:

Did the energy audit encourage learners to implement the acquired knowledge and show agency through skills necessary for a more open-ended problem-solving activity?

Renewable energy learning material in an ESD context

To date, the world economy has relied on fossil fuels as its main energy source. This has created a negative impact on the environment with regard to mining damage, resource depletion and climate change. The burning of fossil fuels has added certain gases to the atmosphere which are causing an increase in the greenhouse effect and resulting in changes in the climate (Boyle 2012). With climate change comes uncertainty and risk (Beck 1992) because of its complexity and its reliance on extensive time scales and predictive modelling. To add complexity to the uncertainty of climate change, the Planetary Boundaries 2.0 report notes that the boundaries of the earth's systems are interlinked, and there is uncertainty as to what will happen to one system if another system exceeds its boundary (Steffen 2015). Not only can renewable energy counteract climate change but it can also address the challenge of resource depletion (Boyle 2012).

South Africa's current energy supply is mainly derived from the burning of fossil fuels. South Africa is a relatively energy intensive country in Africa and relies on coal for its primary energy use. It is one of the largest emitters of greenhouse gases in Africa and one of the most carbon-emission-intensive countries in the world (South Africa DME 2003). South Africa's total energy demand is 51 GW of which 80% is generated from non-renewable energy sources. The dependence on coal alone is 72% (South Africa DOE 2018). It is therefore important that the focus within the country should be on increasing renewable energy, especially given that the solar power potential in South Africa is very high (South Africa DOE 2012). With more than 2 500 sunshine hours

per year, South Africa has the perfect climate for generating solar energy – in fact, one of the best in the world (Gauche, Von Backstrom & Brent 2013). It is important that the South African public is educated on how renewable energy can help combat climate change. This is in line with some of the key objectives of the government's enabling framework, namely to raise public awareness on renewable energy and to educate the public on the benefits and opportunities of renewable energy and how it can counteract climate change (South African NDP 2012).

It is to this end that the renewable energy learning material was developed to support teaching of the topics of climate change and renewable energy which have recently become included in the CAPS curriculum (South Africa DBE 2011). One negative offshoot of this is that teachers at secondary school level have to teach topics with which they are not necessarily familiar (Lambrechts 2017). To mitigate this, a research-based set of learner and teacher support material for high school teachers on renewable energy was developed. This aimed to empower teachers to effectively facilitate learning about non-renewable and renewable energy; broaden the knowledge base of teachers around climate change and renewable energy; and provide them with appropriate subject materials to ensure effective implementation in classrooms.

Education for Sustainable Development

This study also responds to a challenge in ESD of how one should design learning material so that learners can understand and engage with the educational topic at hand (Russo & Lotz-Sisitka 2006). In the study, the topic of the learning material was the use of electricity through developing an energy audit as the tool of inquiry. For the energy audit to be designed in line with ESD goals, it was important that teachers communicated to learners an understanding of not only the impact that the use of fossil fuels currently has on our environment, but also the fact that we need to do something about it (Boyle 2012). As such, the renewable energy learning material was developed to teach learners to switch from non-renewable to renewable energy use and to provide in-depth, solid content in order that they could develop sound knowledge to understand why this switch is important (South Africa DBE 2011).

It is a challenge to design learning material in such a way that it is both specific to ESD processes and can meet the teacher and curriculum goals (Russo & Lotz-Sisitka 2006). O'Donoghue (2015) argued that learning topics on the environment, sustainability and usable energy need to be presented in such a way that learners will internalise concepts and deduce meaning that is relevant to the context of the curriculum, as well as in their daily and future skills and actions.

In the development of learning content for ESD, different learning opportunities are influenced by the design, adaptation and use of the material (Russo & Lotz-Sisitka 2006). Effective and successful use of learning materials also depends on the curriculum requirements; relevant subject content; teacher support in the use of the learning material; and appropriate language use (Russo & Lotz-Sisitka 2006; Glover 2006; Riet 2012; Van der Merwe 2011). Sound learning materials for ESD should not

only benefit the learners' knowledge but also promote agency (NAAEE 2004).

This study focused on how teachers used the Physical Science energy audit within the Anne Edwards learning task sequence framework, and whether the audit could promote agency (Edwards 2014).

Vygotsky's influence in the development of the learning task sequence

Anne Edwards based her work on Vygotsky's view that learning is centered on externalisation and internalisation in order for a learner to develop his or her own learning processes. In other words, an internal reconstruction takes place where learners accept new information brought to them through external stimuli such as language or signs. This led Edwards to recognising the importance of the development of a learner's ability to take responsibility in the acquisition and use of knowledge (Edwards 2014; O'Donoghue 2015).

Vygotsky's theories of scaffolding, semiotic mediation and Zone of Proximal Development (ZPD) emphasise different processes that take place in learning acquisition (Daniels 2008). Edwards used these concepts in the framing of the four quadrants in her task sequencing framework for classroom learning. Here, scaffolding is a process through which learners are initially guided to develop concepts and skills that will enable them to complete the task required (Daniels 2008). O'Donoghue (2015) pointed out that the learning expands from acquisition, through participation in work with the teacher and texts, into learning activities that are more learner-led and reflexive. Smidt (2009) described the term 'scaffolding' as moving from the performance level to the potential level.

Daniels (2008) stated that the concept of Zone of Proximal Development (ZPD) was hypothesised by Vygotsky as a device for explaining the way in which social and participatory learning takes place as an expansive learning process. John-Steiner and Mahn (1996) described the ZPD in a learning process as the distance between the level of development where the learner performs alone and independently; and the potential level of development with assistance from an adult or a more capable peer. It could therefore be argued that the ZPD is a proposition which suggests the level of possibilities or potential for development of a learner in a mediated process of learning (John-Steiner & Mahn 1996). Two aspects of Vygotsky's notion of a ZPD are significant in the Edwards task sequence model: first, the development of a learner through the guidance of an adult teacher or in collaboration with more capable peers who understand the concepts being taught; and, second, the notion that in learning, instruction moves ahead of development (Daniels 2008).

Edwards used these Vygotskian concepts of scaffolding, semiotic mediation and ZPD in the framing of the four quadrants in her task sequencing model for classroom learning. She argued that if the sequencing was in a lesson, scaffolding would enable mediated learning to take place, whereby learners would make meaning and take control over their own learning processes (Edwards 2014). Here, the sequences of

learning instruction would precede development but development could enable learners to take control of their own learning and use their knowledge effectively. The learner-led agency explored by Edwards and the reflexivity associated with this were key for ESD as critical processes of learner-led change (O'Donoghue 2015).

Learning task sequencing

The learning task sequence is developed as an open-ended progression of learning tasks differentiated into four quadrants. The task sequence design focuses on the actions taken by the teacher in these tasks and the learners' responses. It also allows for an examination of patterns of lesson planning and delivery. Its employment as an analytical tool enabled a mapping and review of how the materials reflect learning sequences, and how this in turn sheds light on learning outcomes (Edwards 2014).

The four quadrants focus on the following aspects:

In Quadrant One (Q1) knowledge is being displayed by the teacher or a capable learner in the selective use of the learning materials. Here the teacher or capable learner selects and works with the materials to model and instruct key concepts. This is achieved through the use of different mediation tools, for example, language, text and multimedia on a specific topic.

In Quadrant Two (Q2) more tightly structured tasks are given to the learner as activities by the teacher. These demand engagement with key concepts (substantive knowledge) and ways of enquiring (syntactic knowledge), for example, the energy audit or measuring electricity use in their school or homes.

In Quadrant Three (Q3) more open tasks are given, for example, investigations and research on energy consumption and the related effects, which enable learners to apply key concepts and ways of enquiring. Here tasks may be phrased as open-ended questions for learners to research. This is where participation and inquiry will take place and where the learners take that inquiry into contemplating future sustainability.

In Quadrant Four (Q4) knowledge is being displayed by the learner through summative assessment, for example, writing a test or presenting their findings on the energy audit (Edwards 2014). Edwards is careful to specify that her task sequencing model of process is open-ended in that teachers can start a learning sequence in any quadrant and move through in any order. For example, a learning challenge can open with an inquiry where learners use what they know to undertake and scaffold inquiry tasks into which a teacher might insert activities to clarify concepts and also mediate learning with direct inputs.

This implies that the learning task sequence allows for an analysis of the classroom learning process through a mapping out of processes of knowledge acquisition (internalisation, mostly found in Q1 and Q2) and use (externalisation, mostly found in Q3 and Q4) (O'Donoghue 2015). Key aspects of the tasks are the amount of structure provided and the amount of control that allows learners to take over their own learning and develop higher order thinking skills (Edwards 2014). Edwards further notes that the task sequencing can take place in any order and that the model is a demonstration

of how learners can be developed and learning promoted. For example, as noted above, sometimes the teacher will start a sequence in Q3 and move back to Q1 or move from Q3 back to Q2 to clarify concepts. In short, the task sequencing is designed to enable a learner to discover or learn something. This applies not only with regard to the subject matter but also in developing the learners' own learning skills.

If the energy audit is going to be effective then the teachers need to be able to teach with it and set it as a project where learners can take the lead, and also test their own knowledge on the content. The mapping of this level of detail using the learning task sequence to probe lesson progressions enabled me to identify some of the learning sequences evident in the way in which teachers are teaching the energy audit, and to look for evidence of how learners are able to apply their new knowledge. Thus, the learning task sequencing work of Edwards enabled me to observe how the energy audit learning material was used in a classroom context, and how learning was facilitated by the teachers.

Energy audit activity

The energy audit assignment was provided to learners in the format of the scientific method. The objective was to investigate the amount of electrical energy that the school uses per month for six months.

Learners were expected to write a **literature review** where they had to investigate and provide a summary of definitions and formulas on electrical power; how to calculate power; how to calculate electrical energy; the unit in which electrical energy is measured; the cost of electrical energy in their area; and the formula and methods for calculating the cost of the electrical energy consumption of an institution or household. It was suggested that the **method** for how to do the investigation would take the form of work in groups. The responsibility for obtaining the information daily could then be shared among the group members so that every member had one task only. Monitoring their schools' total electrical energy consumption over six months required that the information be collected in more than one way. Therefore two methods from which they could choose were suggested for gathering data.

In Method 1 they had to do a survey of all electrical appliances used in the school and write down the power value (in kilowatts) for every appliance; study how long (in hours) each one of the electrical appliances was in use or turned on and record this information; obtain the average cost of electrical energy per kilowatt-hour (kWh) from the schools' electricity invoice; use the formula from the theoretical study to calculate the electrical energy consumption (in kilowatt-hours) and the total cost of electrical energy consumption per month (using the tariff for electrical energy consumption that could be obtained from the school's electricity invoice provided by the Municipality or Eskom).

Method 2 was based on the electricity meter readings. Learners had to read the electricity meter installed in the school building every afternoon after school from Monday to Friday and first thing Monday morning (to calculate weekend consumption).

This meter reading indicated the amount of electrical energy consumption (in kWh). They had to add up the daily/weekend meter readings (in kWh) to calculate monthly electrical energy consumption. However this method could only be used if the schools' meter was accessible.

The next step was to do the calculations and determine the **results**. Learners used a spreadsheet as template to record the daily data and did the required calculations to complete the database in full.

In the **data analysis** it was required that they draw a pie chart to compare the electrical energy consumption of the various appliances in the school (the spreadsheet could be used to draw the charts). They also had to draw a bar chart to compare the electrical energy consumption per month over a period of six months and discuss the charts obtained. They then had to compare the results in Method 1 to those of Method 2 and explain why the results might be different.

Finally they had to use all the information and graphs obtained from their investigation to formulate a complete and meaningful **conclusion**. They had to state clearly whether their hypothesis was confirmed or disproved and make meaningful suggestions about what could be done to save on electrical energy at the school. This had to be done very specifically and explained in full. They also had to make meaningful suggestions about what the school could do to generate its own electricity from a source that would be more environmentally friendly and possibly more cost-effective.

Prior to my intervention, I made the assumption that the learners knew the following concepts:

- Calculate electrical energy use
- Interpret an electricity bill

Research method

The learning material was workshopped in three different schools, in three sessions, with three teachers, to instruct them on how to use the material. This was followed by data generation from six classroom observations (Cohen et al. 2007); teacher accounts through questionnaires; emails and telephonic conversations; one focus group discussion with all the teachers; and two final presentations by the learners on how the materials were used (Creswell 2014).

Table 1 provides the profile, class size and socio-economic context of each school, and the activity timeframe in which the investigation took place. Please note that this was a pilot study, therefore the actual timeframe did not extend over six months, in accordance with the suggested timeframe.

The Vygotskian-based learning task sequence developed by Edwards was used as an analytical lens for mapping the learning tasks and task sequencing (Edwards 2014). Table 2 is a summary (created by the author) of key features of each quadrant in Edwards task sequencing framework. The table provides the framework of what the teacher or more expert learner is doing compared to other learners, and how this relates

to facilitating the learning interactions and understanding the content topic. This table was used to analyse all the data from the study.

Table 1. Profiles of the three Physical Science classes investigated

Grade 11	Case 1	Case 2	Case 3
Profile	Girls	Boys and girls	Boys
Class size	25	18	4 Grade 11 Science Club learners
Socio-economic context	High income	Low income	Low income
Activity timeframe	2 weeks	4 weeks	4 weeks

Table 2. The Anne Edwards learning task sequence

Knowledge is displayed			
Quadrant 4 Students display their understanding and knowledge through summative assessment.		Quadrant 1 Knowledge is displayed by the teacher or expert learners as they model and instruct on key concepts.	
What are the learners doing? <ul style="list-style-type: none"> • Complete the summative assessment task • Master the tool of uncertainty 	What are the teachers / expert learners doing? <ul style="list-style-type: none"> • Summative assessment of learning • Give grades for the display of new-found understandings • Jumping point for new cycle 	What are the learners doing? <ul style="list-style-type: none"> • Learners engage through meaning-making. • Respond to teachers questions. 	What are the teachers / expert learners doing? <ul style="list-style-type: none"> • Introduction of key concepts and revisiting what is already known • Help learners recognise a gap in their knowledge that can be filled • Imitation (Vygotsky) • <i>Demonstrate</i> knowledge • <i>Diagnose</i> interpretation by the learners • <i>Introduce</i> the learners to using <i>the language</i> and <i>other forms</i> of the knowledge displayed • <i>Courteous conversation</i> that leads learners towards mastery of the knowledge that matters in a subject
Quadrant 3 More open tasks that enable learners to apply key concepts and ways of enquiring. Task may be phrased as an open-ended question for learners to research.		Quadrant 2 Tightly structured tasks that demand engagement with key concepts (substantive knowledge) and ways of enquiring (syntactic knowledge).	

Knowledge is displayed			
What are the learners doing? <ul style="list-style-type: none"> • Open-ended, problem-solving activities • They take control of the knowledge they have just grasped and use it to solve problems • Students show agency 	What are the teachers / expert learners doing? <ul style="list-style-type: none"> • Require high levels of teacher subject knowledge • Responding to student questions. Only intervening if learners are experiencing real difficulty 	What are the learners doing? <ul style="list-style-type: none"> • Students show thinking skills and respond to the task demands, taking control and exploring what they can do • Students scope the tasks, allocate time, and identify needed resources • Students self-assess against criteria – referring to knowledge and strategies used 	What are the teachers / expert learners doing? <ul style="list-style-type: none"> • Teachers' formative assessment of quadrant 1 indicates that learners are starting to make the connections between already known and new knowledge • Individual, paired or grouped tasks are given • Teacher gives actively formative feedback on both the use of knowledge and the organisation of learning.
<p>ZPD takes place in Quadrant 2 and Quadrant 3. Semiotic mediation takes place through the use of different mediation tools, for example, language or readings. Quadrant 2 and Quadrant 3 are safe places, where mistakes can be made, misunderstandings revealed and risks taken. Here learners acquire and use, internalise and externalise; and substantive and syntactic knowledge is acquired and used. Learners develop higher order thinking skills and take control of their own learning through tasks given by the teacher.</p>			

What the data revealed

The following data was obtained from observations, feedback from teachers, and the focus group discussion. The four quadrants are identified in the data.

Case 1

The teacher ran the activity as a tightly structured task by controlling the process and focusing on information and data that had to be gathered (**Quadrant 2**). She divided the class into groups that aligned with the different sections of the scientific method, deciding who was in which group (**Quadrant 2**). She focused the learners' attention on the fact that they had to plan the project carefully because while some steps could run simultaneously, others could only start after the information was gathered by another group (**Quadrant 2**). Learners adhered to the instructions and collected the information and data (**Quadrant 2**). The learners responded by working in their groups, dividing the tasks among themselves in each group (**Quadrant 2**).

The teacher gave a specific timeframe for the learners to adhere to for submitting draft results and the final presentation (**Quadrant 2**). The learners presented a draft outline to the teacher where they discussed difficulties they foresaw occurring (**Quadrant 2 and 3** – knowledgeable teacher’s response), for example, the learners struggled to take accurate electricity use readings, possibly because they did not have access to the electricity meter and therefore their calculations did not correlate with the electricity bill. Some appliances were overlooked (**Quadrant 1**). Certain concepts had to be clarified, such as how to calculate electrical energy (**Quadrant 1**). The teacher gave support where needed, showed high levels of subject knowledge and was able to respond knowledgeably to learners’ questions (**Quadrant 3**).

The learners presented the final PowerPoint presentation according to the scientific method (**Quadrant 4**).

Table 3 provides a summary of the data obtained from Case 1 plotted in the Anne Edwards learning task sequence.

Table 3. Data summary of Case 1

Quadrant 4	Quadrant 1
Learners Presented a PowerPoint presentation	Teacher Clarified concepts by revisiting existing knowledge on how to calculate electricity and interpret an electricity bill Learners Struggled with conceptual knowledge
Quadrant 3	Quadrant 2
Teacher Gave support when asked and showed high levels of subject knowledge Learners Took control of the knowledge	Teacher Used the assignment as a tightly structured task Learners Showed thinking skills and responded to the task demands

Case 2

The teacher had to go away during the execution of the energy audit and could only guide the learners to a limited extent before leaving (**Quadrant 3**). The learners divided themselves into groups according to the task demands and chose a class representative to communicate with the teacher (**Quadrant 3** – learners show agency). Conversations followed between the teacher and learners via email; the guidance from the teacher empowered the learners to execute the task on their own (**Quadrant 3**).

As in the previous case, the learners struggled to take accurate electricity usage readings, as they did not have access to the electricity meter and therefore their calculations did not correlate with the electricity bill. Some appliances were overlooked, such as the school bell, and they also struggled with how to read and interpret the school electricity bill (**Quadrant 1**). Conversations followed between the learners themselves,

and between the teacher and learners about their findings and interpretation thereof: how the task needed to be done, what the results meant, and how they should be interpreted (**Quadrant 3**, ZPD).

The teacher requested postponing my follow-up observation visit to have time to respond to the learners' questions. Learners worked mostly on their own to execute the task. They took control of the knowledge needed for the assignment, used it to solve the challenge and completed the assignment (**Quadrant 3**).

The learners developed and presented a PowerPoint presentation based on their research and findings (**Quadrant 3 & 4**). The way in which the learners took responsibility was a revelation for the teacher, in seeing how capably the learners executed the task. She commented that this was the first assignment where it had worked so well.

Table 4 provides a summary of the data obtained from Case 2 plotted in the Anne Edwards learning task sequence.

Table 4. Data summary of Case 2

Quadrant 4	Quadrant 1
Learners Did final presentation	Teacher Revisited existing knowledge by clarifying concepts such as how to calculate electricity and interpret an electricity bill Learners Struggled with conceptual knowledge
Quadrant 3	Quadrant 2
Teacher Responded knowledgeably to learners' questions and only intervened when learners experienced real difficulty Learners Took control of the process and used the knowledge they had acquired to solve the challenge, showing agency	

Case 3

There was very little involvement by the teacher in this case and he was not available to guide and help the learners on the process that needed to be followed. Learners from the Science Club, comprising four highly motivated Grade 11 boys, did the task. The learners counted all the electrical appliances to be included in the audit but struggled to process the information (**Quadrant 3** – worked on their own). They were able to gather the information but could not understand the scientific process or how to present the results accordingly (**Quadrants 1 & 2** – lack of knowledge regarding how to calculate electricity [conceptual knowledge] and lack of guidance from the teacher).

Table 5 provides a summary of the data obtained from Case 3 plotted in the Anne Edwards learning task sequence.

Table 5. Data summary of Case 3

Quadrant 4	Quadrant 1
	Teacher Did not revisit conceptual knowledge Learners Struggled with conceptual knowledge
Quadrant 3	Quadrant 2
Teacher Uninvolved Learners The learners planned and tried to do the assignment on their own	Teacher Lack of guidance Learners Learners struggled to execute the task at hand

Discussion

The Vygotskian-based (Daniels 2008) learning task sequencing work of Edwards enabled me to look at the learning processes that took place in three cases: that is, the teaching processes of the same learning content by three different teachers to three different classes. The aim was to investigate whether teachers could use the energy audit learning material to engage learners in Quadrant 3 learning activities of the Anne Edwards framework. A Quadrant 3 learning activity was defined as an open problem-solving activity where teachers show high levels of subject knowledge and intervene only when learners experience real difficulty. It is also an activity where learners take control of existing knowledge and use it to solve problems (Edwards 2014), in other words, engaging with their gained knowledge and showing internalisation. An unintended but important outcome of the study was seeing the effect that differing levels of teacher involvement had on the way that learners engaged with the content and took responsibility for their own learning.

In Case 1, the teacher conveyed the learning topic as a tightly structured Quadrant 2 task (Edwards 2014), and the learners responded to the task demands by taking control and exploring what they could do. In Case 2, the teacher used the topic as a more open-ended Quadrant 3 task which enabled learners to apply key concepts and ways of enquiring (Daniels 2008; Edwards 2014; O'Donoghue 2015). The teacher responded knowledgeably to learners' questions and only intervened when the learners were experiencing real difficulty. This resulted in the learners taking control and showing skills in performing the audit (Daniels 2008; Smidt 2009; O'Donoghue 2015). In Case 3, there was little involvement from the teacher and not enough knowledge in the group to take control of the task demands (John-Steiner & Mahn 1996; Edwards 2014). As a result, the required learning and development could not take place.

The intention of the audit was a Quadrant 3 learning task activity where learners take responsibility for their own learning and implement their knowledge and acquired skills to complete the task (Edwards 2014). It was therefore important to determine whether learners had been guided through a process of scaffolding where the desired

concepts could be put into action. The evidence in all three cases showed that some concepts needed to be clarified, as was the case with how to calculate electrical energy, a Quadrant 1 process. The concept had to be revisited and learners helped to recognise and fill in their knowledge gap (Edwards 2014).

Two aspects of Vygotsky's notion of ZPD are significant in the Edwards task sequence model (Daniels 2008; Edwards 2014). These are, first, the development of a learner with the guidance of an adult teacher or in collaboration with more capable peers who understand the concepts being taught; and, second, the notion that in learning, instruction moves ahead of development (Daniels 2008; John-Steiner & Mahn 1996). Where there was minimal involvement from the teacher, as in Case 3, the learners did not receive the necessary guidance from the teacher, nor was there a capable peer who understood the concepts well enough to complete the task. Therefore, the required learning development could not take place effectively, because of the lack of instruction (O'Donoghue 2015). In Case 2, because the teacher was not present at school, the learners had to depend on one another to produce the desired results and access the availability of the teacher to clarify their uncertainties. This is an example of ZPD where the development of the learners took place with the guidance of a knowledgeable teacher and the collaboration with more capable peers who understood the concepts that were necessary to complete the task (John-Steiner & Mahn 1996; Daniels 2008; Smidt 2009; Edwards 2014; O'Donoghue 2015).

The audit itself proved to mediate learning in all four quadrants but particularly with regard to Quadrants 2 and 3 in the Anne Edwards learning task sequence. From the presentations of the learners in Cases 1 and 2, it was clear that the learners understood how their energy use patterns influenced the amount paid for electricity by the school, as well as the impact that energy use has on the environment. The solutions they gave to counteract the energy use, for example, informing learners more regularly on the schools electricity use or installing solar energy for the school, since the school's electricity needs are largely during daytime, were all feasible. In other words, the learners could display their understanding and knowledge, which also made it a Quadrant 4 activity.

The outcomes for Cases 1 and 2 were similar, in that both groups did the task according to the scientific method and both groups delivered a presentation on their findings with more or less the same outcome, struggles and recommendations. The main difference was that in Case 1 the teacher tightly controlled the learning activity; she divided the class into groups and allocated the next contact session when they would discuss their problems. The learners showed thinking skills and responded to the task demands, taking control and exploring what they could do as they scoped the task and self-assessed against criteria.

In Case 2 the learners scoped the task, allocated time, and identified the needed resources. They also self-assessed against criteria, but with the difference that *they* controlled the process, not the teacher – though they did ask her for help when they really got stuck. The result was that there were examples of ZPD and semiotic mediation where the expert learner took control and could help the class show agency (O'Donoghue

2015). By taking up control in relation to knowledge practices in the learning process the learners had the opportunity to show externalisation and internalisation of the knowledge acquired and the agency to deploy it in further learning actions (Daniels 2008; O'Donoghue 2015).

Conclusion

As can be seen from the evidence above, what emerged from this study is that the energy audit learning task had the potential to achieve the goal of open-ended, learner-led inquiry. The success of the activity appears to have been supported through mediation by the teacher across three quadrants, as in Case 1. In Case 2, the success of the activity was supported through mediation of the concepts and the problem-solving capacity of knowledgeable learners working proactively with the teacher (who had withdrawn from active mediation of the activity and played more of a support role in Quadrant 3). The difficulties arose when there was no proactive, knowledgeable teacher or more expert learner to mediate in Quadrant 3, as illustrated by Case 3.

The study recommends that for successful open-ended enquiries and agency in Quadrant 3, materials need activities to ensure that concepts are scaffolded through various processes of mediation and opportunities for externalisation and internalisation. This is achieved through teachers sharing knowledge with the learners (Quadrant 1) and through tightly structured tasks (Quadrant 2). Activities must also create the opportunity for learners to show that they have taken control of the knowledge and can use it to solve more open-ended problems. Teachers mediating the process need to be aware that support from a more knowledgeable person is still needed in Quadrant 3. They therefore cannot withdraw their support, but need to be prepared to intervene if learners are experiencing real difficulty.

References

- Beck U (1992) On the logic of wealth distribution and risk distribution. In: U Beck (ed.) *Risk Society: Towards a New Modernity*. London: Sage. pp. 19–50
- Bill of Rights, South Africa (1996) Bill of Rights (Chapter 2 of the Constitution of the Republic of South Africa) No. 108 of 1996, Western Cape Government. <https://www.westerncape.gov.za/legislation/bill-rights-chapter-2-constitution-republic-south-africa#2>
- Boyle G (2012) *Renewable Energy Power for a Sustainable Future*. 3rd edn. Oxford: Oxford University Press
- Cohen L, Manion K & Morrison K (2007) *Research Methods in Education*. 6th edn. Oxon: Routledge
- Creswell J (2014) *Research Design: Qualitative and Mixed Methods Approaches*. 4th edn. Los Angeles: Sage
- Daniels H (2008) *Vyotsky and Research*. New York: Routledge
- Edwards A (2014) Designing tasks which engage learners with knowledge. In: I Thompson (ed.) *Task Design, Subject Pedagogy and Student Engagement*. London: Routledge. file:///C:/Users/therese/Downloads/A_concentrating_solar_power_value_proposition_for_.pdf
- Gauche P, Von Backström T & Brent A (2013) A concentrating solar power value proposition for South Africa. *Journal of Energy in Southern Africa* 24(1): 67–76

- Glover D (2006) Evaluation of environmental learning support materials: A case study of the AAWARE teachers guide. Unpublished Master's thesis, Rhodes University, Makhanda
- John-Steiner V & Mahn S (1996) Sociocultural approaches to learning and development: A Vygotskian framework. *Educational Psychologist* 31(3/4): 191–206
- Lambrechts T (2017) A review of how teachers are using the Renewable Energy materials in their lessons. Unpublished Master's thesis, Rhodes University, Makhanda
- North America Association for Environmental Education (NAAEE) (2004) Guidelines for Excellence EE Materials. https://naaee.org/sites/default/files/gl_ee_materials_complete.pdf
- O'Donoghue R (2014) Think piece: Re-thinking Education for Sustainable Development as transgressive processes of educational engagement with human conduct: Emerging matters of concern and the common good. *Southern African Journal of Environmental Education* (30): 7–26
- O'Donoghue R (2015) Knowledge-informed enquiry and problem-solving actions. Makhanda: Rhodes University
- Riet A (2012) The use of teaching and learning support material for classroom teaching: Intermediate Phase. Unpublished Master's thesis, University of the Witwatersrand, Johannesburg
- Russo V & Lotz-Sisitka H (2006) Development, Adaptation and Use of Learning Materials, Source Book 4. Howick: Share-Net
- Smidt S (2009) *Introducing Vygotsky*. London and New York: Routledge
- South Africa Department of Basic Education (DBE) (2011) Curriculum and Assessment Policy Statement. <https://www.education.gov.za/Portals/0/CD/National%20Curriculum%20State-ments%20and%20Vocational/CAPS%20SP%20%20NATURAL%20SCIENCES%20GR%207-9%20%20WEB.pdf?ver=2015-01-27-160159-297>
- South Africa Department of Energy (DOE) (2011) Integrated Resource Plan for Electricity 2010–2030. http://www.energy.gov.za/IRP/irp%20files/IRP2010_2030_Final_Report_20110325.pdf
- South Africa Department of Energy (DOE) (2012) Renewable Energy Independent Power Producer Procurement Programme. <http://www.ipprenewables.co.za/>
- South Africa Department of Energy (DOE) (2018) Draft Integrated Resource Plan. <http://www.energy.gov.za/IRP/irp-update-draft-report2018/IRP-Update-2018-Draft-for-Comments.pdf>
- South Africa Department of Minerals and Energy (DME) (2003) White Paper on Renewable Energy. Department of Minerals and Energy. https://unfccc.int/files/meetings/seminar/application/pdf/sem_sup1_south_africa.pdf
- South African National Development Plan (NDP) (2012) Executive Summary of the National Development Plan (NDP) for 2030. Pretoria: South African Government
- Steffen EA (2015) Planetary boundaries – Stockholm Resilience Centre. <http://www.stockholmresilience.org/21/research/research-news/1-15-2015-planetary-boundaries-2.0---new-and-improved.htm>
- Steffen W, Richardson K, Rockström J, Cornell S, Fetzer I, Bennett E, Biggs R et al. (2015) Planetary boundaries: Guiding human development on a changing planet. *Science* 347(6223). doi: 10.1126/science.1259855
- Van der Merwe M (2011) The use of learning support materials in the rural schools of Maputaland, KwaZulu-Natal. Unpublished Master's thesis, Rhodes University, Makhanda
- Van Niekerk W (2008) Centre for Renewable and Sustainable Energy Studies. <https://www.crses.sun.ac.za/home-about-u>