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EDUCATION FOR SUSTAINABLE DEVELOPMENT: EXPERIENCES FROM ACTION RESEARCH WITH SCIENCE TEACHERS

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Abstract

This study reports on Egyptian science teachers' experiences in collective action research projects with a focus on education for sustainable development (ESD). Science teachers were enrolled in a study course "Teaching Strategies" that had been revised with a focus on sustainability. The course was introduced in the spring semester of the academic year 2011/2012. Throughout the course, 29 teachers worked in groups to develop projects that promote sustainable development through classroom teaching practices that encourage involvement with local communities around school premises. The framework that guided the study was based on experiential, constructivist and transformative learning theories known collectively as 'ExConTra'. A mixed methods methodology was used where teachers' responses to three open-ended reflective questions produced qualitative data that were analysed by identifying themes and patterns. The author developed two quantitative instruments: a Concept Mapping Rubric and a Sustainable Development Questionnaire. The former was to probe the cognitive organisation participants had in relation to the concept of sustainable development before and after developing the action research projects. The latter instrument was used to identify participants' attitudes towards teaching for ESD and their knowledge of classroom pedagogical practices. Statistical data analysis using Statistical Package for the Social Sciences indicates that teachers in their post-tests had developed: better cognitive organisation for the concept of sustainable development; positive attitudes towards teaching for sustainable development and ESD classroom teaching practices. Involvement in the action research projects where teachers were experiencing, reflecting, conceptualising, constructing, acting and transforming within the context of ESD may be responsible for these results where there are promises to help achieve successful implementation to include ESD in science education.

Key words: *education for sustainable development, science teachers, Egypt, action research*

Introduction

One of the fashion words found in recent literature is that of education for sustainable development (ESD). Its roots can be traced back to the 1990s at the United Nations conference in Rio de Janeiro. Since then, there have been major developments towards ESD, specifically the emphasis on ESD in the Earth Summit 2002, the United Nation's Declaration of the Decade of Education for Sustainable Development (DESD) in 2005–2014 and in Rio+20 United Nation's conference on sustainable development in June 2012. In general, sustainable development (SD) is perceived as the vision for a better world in which environmental, social, economic and cultural considerations are balanced. ESD, therefore, presents a tool for achieving this vision and improving quality of life. With this in mind, a new vision of education is formed, a vision that helps understand the world by addressing the complexity and interconnectedness of daily problems, locally and globally.

There is a strong evidence to suggest that the Arab countries, including Egypt, are lagging behind in practices related to sustainable development (Esty, Levy, & Winston, 2003). There is therefore a need to find ways to promote ESD. Teacher education programmes, whether pre-service or in-service, could be a powerful start, especially through reorienting teacher education courses to address sustainability. Teachers are agents of change in any reform effort who will shape the knowledge, skills and values of future generations given the regional priorities and the need to modernise curricula to address ESD. Paradoxically, they are also viewed as major obstacles to change if their emphasis is only on factual and procedural knowledge at the expense of deeper levels of understanding (Prawat, 1992).

This study introduces science teachers to sustainable development and highlights the importance of teachers in promoting ESD practices in schools and among their students. The process of infusing sustainability among science teachers was enabled through the reorientation of a study course "Teaching Strategies" at one of the public universities in Egypt. The reoriented course was presented as a means to counteract more limited manifestations of this type of course that often focuses on "…the facts of their subject and not deal with associated social or ethical issues" (Levinson & Turner, 2001, p. 2), resulting in misrepresentations of the nature of science education.

Theoretical framework and literature review

The theoretical framework that guided this study was the ExConTra learning model (Makrakis & Kostoulas-Makrakis, 2012) where there is an emphasis on three major learning theories, namely, experiential, constructivist and transformative learning theory. The model consists of six independent but interconnected components. These are experiencing, reflecting, conceptualising, constructing, acting and transforming, all of which are found throughout the process of action research. Through action research, teachers are likely to become aware of their own beliefs and practices, expand their commitment to developing a variety of teaching methods and renew their interest in learning about teaching. It is therefore a means to systemic inquiry into daily teaching practices, where teachers reflect on teaching on a deeper level (Kraft, 2002). Through such activity, teachers' roles change within a new perspective as they become active knowledge producers who continuously develop practical knowledge while solving

problems in practice (Schon, 1983; Darling-Hammond, 1996). Moreover, they become part of the educational reform process as they are empowered to change and initiate change and apply new ideas. Furthermore, action research can bridge the gap between theory and practice because it helps teachers to understand the purpose of educational research and, in turn, informs educational theory of the reality of the classroom (Briscoe & Wells, 2002). In addition, teachers are empowered by having ownership of their professional knowledge.

In the case of science education, there have been a number of attempts to identify the potential contribution of science curriculum to ESD (for instance, Wellington, 2003; United Nations Educational, Scientific and Cultural Organisation [UNESCO], 2004). There are suggestions that the aims of school science education need to be examined with respect to socio-scientific relevance in issues such as food scarcity and poverty and hense sustainable development (Holbrook, 2009). Others have seen ESD as one example of developing scientific literacy as the '21st century science' that incorporates a number of sustainable development issues within its vision of scientific literacy (Summers & Childs, 2007). When it comes to science teachers, envisioning teaching as inquiry is a relevant perspective of the science discipline. Studies that support teachers' involvement in action research on students' learning include, for instance, Hammer and Schifter (2001) and van Zee, Lay and Roberts (2003), while those that are speicifally related to science teachers and action research in terms of a means to professional development include, for instance, Ponte, Ax, Beijaard and Wubbels (2004). Action research in this study was used as a means for participants to reflect on their own practice and to understand and improve their practice and the situation in which they are practising. Through the process of engaging in action research, teachers gain deep insights into how they are working whilst looking forward to their future practices (Kraft, 2002) which enables them to 'transform' in their thoughts, feelings and actions in a paradigm shift.

Gedzune and Gedzune (2011) concluded that students through action research developed reflective skills on ecological consciousness and building sustainable and inclusive relationships with the world. In a study by Salite (2008), teachers' research skills were developed by involving them in action research. Nonetheless, attitudes and values towards environmental issues were developed through active involvement in action research that allowed for active participation in the course activities and responded to different learning needs that impacted pre-service teachers' transformative pedagogies (Pace, 2010). This insight is congruent with what sustainability opts for by calling for transforming to a new paradigm of thinking and acting. Action research therefore prompts a catalytic change for sustainability where teachers are likely to become aware of their own beliefs and practices, expand their commitment to developing a variety of teaching methods and renew their interest in learning about teaching. This is a role that teachers are not used to and need an effort to transform. In this new role teachers become researchers and active knowledge producers.

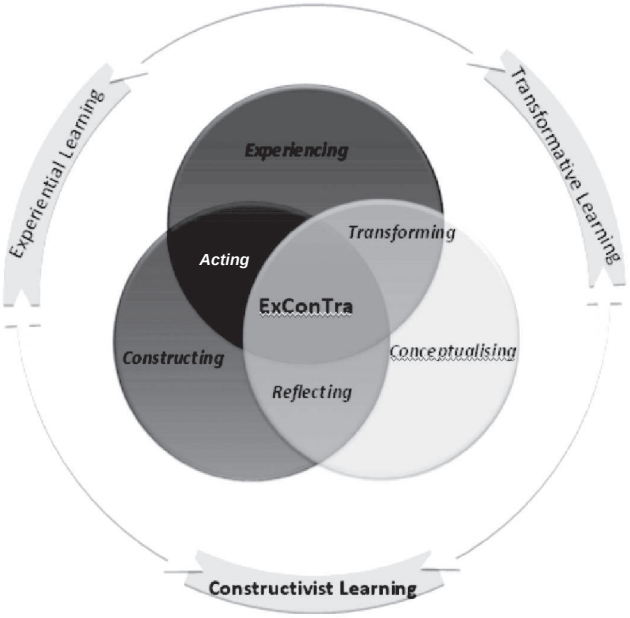

Figure 1. Theoretical framework of the study 'ExConTra'

Context of the study

The springboard of this study is mainly the global demands on all nations to preserve resources for future generations and improve the quality of daily life. Moreover, there are demands to nurture the sense of solidarity nationally, regionally and internationally. This is especially the case in Egypt and other nations that witnessed the Arab spring which asked strongly for change and for improved quality of life. The Arab spring asked for the main concepts of sustainability based on social equality and respect for human rights that lead to quality of life. In order to fulfil such a vision, a systematic and holistic approach is necessary with a collaborative effort of a large number of people taking many small steps in the right direction towards a sustainable world.

In the Arab region, the vision of ESD is in line with the United Nation's DESD global orientations (UNESCO, 2008). Through the UNESCO Regional Bureau for Education in the Arab States, the researchers administered a questionnaire in 14 Arab countries to document the status of ESD. The analysis of the responses illustrated the challenges facing the region. These challenges were classified into three main dimensions: economic, social and environmental. In each partner country of the 14 Arab countries, the Ministry of Education and Higher Education was informed of the follow-up and assessment of how to overcome these challenges. Although education is the first step towards a successful future and nurturing the human mind can foster a generation renowned for creativity, innovation, leadership and achievement, yet, education systems in the Arab countries are facing numerous challenges themselves, and this decreases their capacity to achieve the desired goals of ESD (UNESCO, 2008).

In Egypt, there are many decrees, especially those issued by the Ministry of Environment that foster one of the many dimensions of sustainable development, yet the

daily practices of the individuals are far from what the country needs. However, the author believes that education is the first step towards a successful future. ESD requires a combination of teaching strategies that together allow for transformative learning in a course with an ESD philosophy and practice. Visioning and creating new perspectives are important tasks because the transformative role of education is a key issue in ESD. Teachers' actions will change as a product of reflecting and visioning, because such future action will take into account reflection on what has happened and use this as a means to envision a transformation that will create new solutions and new ideas. Action research is therefore perceived as an effective tool to foster such reflection and visioning in order to improve teacher competencies.

From the above, the expected pathway for any development is in the hands of the schools of education that act as a vehicle for any anticipated change, especially as Egypt is working towards achieving the goals of Education for All (EFA) and the Millennium Development Goals (MDGs). ESD would therefore seem an integral part of achieving these two global agendas.

Nonetheless, this study is an attempt to introduce ESD at one of the governmental universities in Egypt where SD is not commonly found in courses and curricula. Even where SD is found, there exists a narrow interpretation linked to environmental issues only. This is specifically the case for courses offered at the School of Education whether at the undergraduate or postgraduate levels for teaching methodology courses.

Statement of the problem

Considering the vital roles teachers have to prepare and develop pupil's ability to become effective citizens in a sustainable society, teachers are required to apply practices that foster active and experiential learning approaches that are important for ESD. Courses offered at the School of Education, which is responsible for teacher education programmes and in-service training, seem to lack courses on ESD in its holistic and futuristic perspective. This result came from a preliminary analysis of the programmes offered at the undergraduate and postgraduate levels. Moreover, a questionnaire was administered to a group of 23 teachers attending a seminar at the Department of Curricula and Instruction in order to indicate their prior knowledge of the ESD to justify and document the need for a revised ESD course. The questionnaire consisted of 10 questions with a five-point Likert scale. The first part of the questionnaire consisted of questions directed to identifying teachers' perception of SD, while the second part asked teachers about their ESD teaching practices. The Likert scale was as follows: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree. Results illustrated that the majority of the teachers responded negatively, as they either agreed or strongly agreed that they lack ESD knowledge. They also identified that their current teaching practices are not focused on ESD practices. Based on these results, it seemed central to fill in a gap in the courses presented at the School of Education in order to develop the teaching practices of a sample of in-service science teachers through reorienting a teaching strategies course offered to postgraduate science teachers if Egypts aims to achieve a sustainable future. Therefore, the study seeks to answer the following research question: *What are science teachers' experiences from their involvement in action research in the reoriented course in relation to ESD?* A number of sub-questions were raised to formulate the stages of the study: *What are science teachers' perceptions of SD? What are science teachers' attitudes towards*

teaching for ESD? What are science teachers' pedagogical practices for ESD? and *How do science teachers perceive their experiences through developing action research in ESD?*

This study aims to reorient the teaching strategies course by infusing ESD, engage science teachers in action research as a means to transformative learning, develop science teachers' perceptions regarding SD and develop science teachers' attitudes towards ESD and its pedagogical practices.

Methods

Research design

A mixed method approach with quantitative and qualitative data was employed. This was mainly in order to deal with the processes proposed at the different stages of the study that answer the research questions and address its main aims. The study set out to investigate the possible impact of involvement in developing action research in ESD as part of the reoriented course within the stated theoretical framework on participants' perception of ESD in addition to their attitudes and pedagogical practices in class.

Profile of the participants

Convenience sampling was used to select participants of this study as they were enrolled in a compulsory course presented at the School of Education that the author of this study teaches. Demographic data were collected that specified gender, age range, years of experience in science teaching and experience with computers. There were nine male teachers and 20 female science teachers enrolled in the course.

Procedure

Reoriented course on ESD

The course was reoriented towards sustainability where the author made crucial decisions as to what to teach and how to teach. The purpose was to reorient the existing course 'Teaching Strategies' by adding content on ESD and mainly adopt teaching methodologies and assignments that address issues which are pertinent to ESD. The main method in revising the course was by the 'infusion approach' that permits to address sustainability by teaching the course with a different perspective and philosophy without changing the meaning and aim of the original version. Therefore, the course was guided by the author's philosophy to change and reflect, taking into consideration that sustainability demands individual and social transformation, which involves a radical shift of awareness and worldview (Reason, 2007) or transformative changes in our frames of reference (Mezirow, 2000). To make sure that the reoriented course followed an acceptable structure in terms of course design, course objectives and description were then stated. There was a particular emphasis on the types of learning that ESD promotes within Delors' (1996) report. In general, the course was based on the 'ExConTra' model where the author's main philosophy was to get science teachers involved in reflective activities that could allow them to change and transform. The course was a four-hour weekly course offered in the spring semester in the academic year 2011/2012.

Science teachers were asked throughout the study to reflect on their perceptions towards SD and the critical issues that are witnessed in the local community and education system, particularly as aspects of ESD relate directly to science education and science literacy in addition to the social and ethical context of science in schools or what is termed as socio-scientific issues (SSI). Teachers were also asked to reflect on their classroom teaching practices and then develop action research projects to incorporate the main issues of SD in their daily pedagogical teaching. This was done purposely to provide teachers with opportunities for transformative learning as 'agents of change'. As for the action research, this was done collectively through the use of Wikis as a tool for online communication and collaborative discussion. In general, technology can provide opportunities for learners to construct meaningful learning environments which can be applied to ESD such as: a) engaging and challenging learners; b) stimulating dialogue and social negotiation through new modes of social interaction; c) learning by exploring and discovering; d) doing and reflecting; e) constructing personal and collective representations of meaning; f) supporting discourse in dealing with real-life problems (Makrakis, 2011). Science teachers in this study developed research projects that started by identifying a focus of an ESD problem then going through developing action plans, data collection and finally reaching results, suggestions and final reflections. The whole process of the study consisted on the six components of the ExConTra learning model. The action research projects were analysed qualitatively according to rubrics developed by the author of the study. Pre- and post-test data were also collected in terms of their perspectives of the concept of SD and their teaching practices in regards to ESD. Quantitative data were analysed using Statistical Package for the Social Sciences (SPSS). Figure 2 shows the procedure of the study.

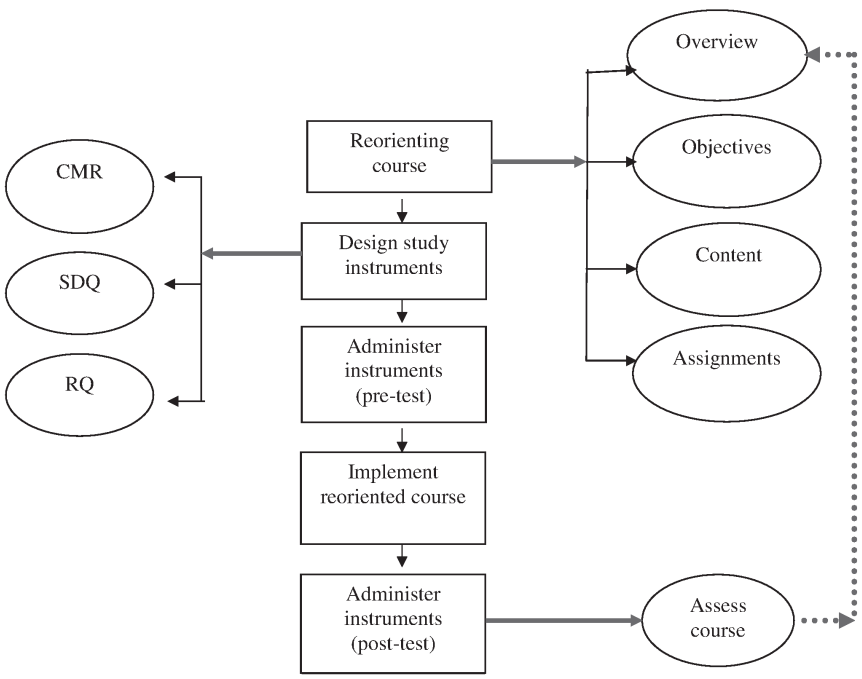

Figure 2. Procedure of the study

Instruments

Concept Mapping Rubric (CMR)

Participants were asked to construct a concept map of SD before engaging in the action research as a pre-test and at the end as a post-test. The concept maps were structured according to each participant's chosen concepts and connections. The aim of this was to probe for the cognitive organisation that the participants had before and after developing the action research projects. Although there is extensive work on concept mapping such as that developed by Novak and Gowin (1984) and Cronin, Dekker and Dunn (1982), specific work on ESD by Ahlberg (2004), the author decided to use a grading system which analyses concepts under SD dimensions that are stated in the literature. The rubric also analysed the number of valid cross-links among concepts and the number of hierarchal levels. The reliability and validity of the rubric were determined by having a second rater. The raters scored concept maps and discrepancies between raters were discussed until near consensus was reached. As for the validity, this was determined by experts who helped decide on the construct validy. The lowest total score on the concept map was three while the highest was 12.

Sustainable Development Questionnaire (SDQ)

The SDQ was developed in light of previous studies, both inside and outside the Arab context. These studies were numerous: Summers, Corney and Childs (2004), Azapagic, Perdan and Shallcross (2005), Summers, Childs and Corney (2005), Kagawa (2007), Spiropoulou, Antonakaki, Kontaxaki & Sarantis (2007), Qablan, Abu Al-Ruz, Khasawneh and Al-Omari (2009). The questionnaire was divided into two scales. The first scale was developed in order to identify the participants' attitudes towards teaching for ESD, while the second aimed to identify the participants' classroom pedagogical practices. The former scale of the SDQ asked participants to respond to each statement by selecting one of five Likert style responses: strongly agree, agree, undecided, disagree and strongly disagree. There were both negative and positive statements that were placed randomly, where scores can range between 10–50. The participants were asked to select their responses according to the frequency of their classroom practices on a three-point scale: never, seldom, or frequently, where score ranged between 10–30. Content validity was determined by a panel of experts consisting of four science educators and two psychologists. Reliability coefficients of the attitude scale and ESD teaching practices were determined by 16 science in-service teachers where a reliability coefficients 'item-total statistics' were calculated, alpha = 0.87 and = 0.73 respectively. The author investigated the participants' attitudes as studies in the literature identified the influence of science teachers' beliefs and attitudes on their teaching practices (Pajares, 1992; Haney, Czerniak, & Lumpe, 1996). As it is presumed that teachers apply ESD teaching practices in their own classes, attitudes and beliefs were therefore a concern of this study.

Reflective Questionnaire (RQ)

Open-ended questions were developed to document the participants' views on how they perceived their experience in developing action research in ESD. Responses to the questions were analysed qualitatively in order to identify the underlying themes. The questions were as follows: *How do you view the collaborative action research experience that you were involved in? How did your engagement in action research impact you personally? How did your engagement in action research impact you professionally?*

Results and discussion

The results are presented under four subtitles that reflect the four research questions.

Research question one

The first research question: *What are science teachers' perceptions of SD?* A blank sheet was given to participants to construct their concept maps of SD in a time limit of twenty minutes before developing their action research projects. The same task was done again after developing the action projects. Participants were graded using the proposed grading system in this study. A dependent t-test analysis with 95 per cent confidence using SPSS version 19 shows that the final mean is greater than the initial mean. This entails that the participants' involvement in the action research had a positive impact on the conceptual knowledge construction on SD which was better at the end of the research than at the beginning in terms of the number of concepts and the dimensions it represents. This reflects the theoretical framework ExConTra as it particularly emphasis the conceptualising and constructing components of the model. The mean and standard deviation of the pre- and post-concept mapping are as follows (Table 1).

Table 1. T-test analysis on pre/post data from participants' concept mapping for SD (n = 29)

	Mean	SD	t	p
Pre-test	4.4483	1.50205	-9.495	< 0.05
Post-test	7.9310	1.86951		

Statistical analysis shows that there is a statistically significant difference between the participants' pre- and post-data on the SD concept mapping in favour of the post-data. In the pre-concept mapping analyses, the concepts that the participants related to SD were mainly in the environmental dimension, while in the post-analysis this changed rapidly into other additional dimensions. This finding is in line with that from studies such as Summers and Childs (2007) and Summers, Corney and Childs (2004). Social, cultural and economic dimensions were included in the participants' post-concept mappings alongside the environmental. From the examples found were equality, democracy, freedom of speech, social responsibility, human right, green schools. Nonetheless, the significant increase in teachers' perspectives on SD in the post-data can be due to the effect of the independent variable of the study, namely, the reoriented course and the action research that teachers were engaged in that provided for meaningful experiential learning, as part of the ExConTra model, on the key concepts and values of various SD dimensions. This finding aligns with what a study indicated that when professional

development is content-focused, connected to other aspects of teachers' lives and coherent, it is more likely to have positive impact on teachers' knowledge and skills than less coherent experiences (Garret, Porter, Desimone, Birman, & Yoon, 2001). This is what the action research projects seemed to advocate as it added meaning to science teachers responsibilities and roles. According to Makrakis and Kostoulas-Makrakis (2012) in their ExConTra model, for learners to make meaning, either individually and/or shared, they need to reflect on their own experiences, leading them to develop more abstract understandings of their experiences (*conceptualising*). Arriving at individual and shared meaning (*constructing*), learners need to get involved in a shared inquiry enriched through continuous reflection, re-conceptualisation and active experimentation. Other studies also acknowledged the role of action research in developing their participants' SD knowledge (for instance, Corney, 2006). It is important to develop participants' perspective of SD if they are expected to act as 'agents of change' in their schools and classroom contexts, hence the growth of research in studying teachers and lecturers' perceptions of ESD (Reid & Petocz, 2006; Cotton, Warren, Maiboroda, & Bailey, 2007; Jones, Trier, & Richards, 2008). To conclude this point, Smith (2009) emphasised the importance of the way teachers interpret ESD and how it will affect the way that they teach it.

Research question two

The second research question: *What are science teachers' attitudes towards teaching for ESD?* The quantitative data collected from all participants were analysed using SPSS version 19.0 software. Prior to analysis, descriptive statistics of all variables in the study were examined using frequencies and the minimum and maximum values for each variable were examined for the accuracy of data entry by inspecting out of range values, which did not show any outliers. Statistical analysis shows that there is a significant difference between participants' pre- and post-data on the attitudes towards teaching for ESD scale in favour of the post-data (Table 2). It is important to develop positive attitudes, especially if teachers are expected to transfer their experiences in classroom and school contexts. In this case, if teachers are convinced about the importance of ESD practices, they can become 'agents of change' in their schools for an educational and political reform. They can also try to overcome the factors that inhibit the facilitation of ESD practices in schools and local communities. Acting as change agents, learners are empowered to transforming experience through critical reflection and active experimentation. When critical reflection is transformed into an action, it becomes praxis that turns learners able to function as agents of change (Makrakis & Kostoulas-Makrakis, 2012). By this role teachers are applying components of the ExConTra learning model specifically the acting and transforming components.

Nonetheless, the significant increase in teachers' attitudes in the post-data can be due to their experiential involvement in the action research projects that link directly to science teaching. This finding supports what Cotton et al. (2007) found when 55% of their respondents agreed or strongly agreed that sustainable development was central to their teaching interests as respondents suggested imaginative and diverse teaching strategies that reflected the contested and exploratory nature of sustainable development. Qablan et al. (2009) in a Jordanian study also found that university teachers developed attitudes towards ESD teaching. In general, this study claims that a change in attitudes would seem essential for teachers to become agents of change.

Table 2. T-test analysis on pre/post data from participants' attitudes towards teaching for ESD (n = 29)

	Mean	SD	t	p
Pre-test	31.7586	7.47689	-6.524	< 0.05
Post-test	40.7931	4.12639		

Research question three

The third research question: *What are science teachers' pedagogical practices for ESD?* Although teachers were not actually observed in the classroom, which is considered a limitation to this study, practices were indicated through teachers' responses to the SDQ. Statistical analysis shows that there is a significant difference between participants' pre- and post-data on their ESD classroom practices according to responses from the second scale in the SDQ (Table 3). This result emphasises the components of the ExConTra learning model as teachers seem to be interested in experiencing, acting and transforming ESD in their science classroom teaching practices. By referring back to the literature, vitality of teaching for sustainability is supported by Posch and Steiner (2006) and Filho and Santos (2005) who stated the importance of initiating and applying new approaches in teaching for sustainable development. The main emphasis in ESD practices lies in a paradigm shift from teacher-centred approaches that seem to dominate science classes to those which encourage active and participatory learning as stated by Tilbury (2011).

Table 3. T-test analysis on pre/post data from participants' ESD teaching practices (n = 29)

	Mean	SD	t	p
Pre-test	20.8621	4.24873	-7.093	< 0.05
Post-test	26.2759	1.77073		

Research question four

The forth research question was: *How do science teachers perceive their experiences through developing action research projects in ESD?* A reflective questionnaire with open-ended questions was designed to investigate science teachers' experiences while developing their action research projects. Analysis of teachers' responses required a coding process based on the qualitative findings. The main purpose of the analysis was not to quantify data but to find themes and patterns across teachers' responses. In general, the projects that the science teachers developed emphasised the key aspects related to ESD. The teachers developed seven projects in total, where four teachers were involved in each group except for one group that had five teachers. Wikis was used as a means for communicating, discussing, decision making and developing the action research projects. It was also a means to uploading and sharing material related to their ESD projects whether it were text or videos. The process of developing the ESD action plans and the use of technology where based on all six components of the ExConTra learning model: experiencing, reflecting, conceptualising, constructing, acting and transforming.

Two main themes were identified in relation to the analysis of responses to the question: *How do you view the collaborative action research experience that you were involved in?* These were identified as the 'social theme' and the 'change theme'.

Social

The social theme that emerged from the data was the benefits of collaborating with colleagues in developing their action research projects. The science teachers in their group collectively determined the focus of the research and collaboratively shared and discussed aspects via online Wikis. By the end of the course, all groups completed their ESD research and presented their projects to the rest of the cohort. All teachers indicated that they had valuable learning opportunities by sharing ideas throughout the process. They repeatedly mentioned that they learned from each other about various aspects of teaching and how to infuse ESD in their practices and schools. In particular, the teachers found that each one felt a spirit of community. The point on collegial support echoes findings from previous studies such as Briscoe and Wells (2002), Burbank and Kauchak (2003) and Kraft (2002) and seems an essential component for supporting teachers' learning and professional development. One teacher, for instance, mentioned, "I really enjoyed and learned from everyone in the course." The other teacher said, "The interaction that we had was valuable. We shared ideas that we could use in the classroom and how to bring sustainable development into reality." However, another teacher mentioned the difficulty of working in groups at first, then showed how this soon disappeared throughout the work, "It was really difficult at first, then soon we started to cope and understand each other and commit to our task."

Change

In the literature, there is documented evidence that 'change' is difficult to achieve with teachers as they seem to resist it quite often. However, teachers need to be persuaded of the need to change their teaching practice and be allowed the chance to acquire the knowledge so that the idea of change and transformation matures in them and motivates a change of attitudes (Connelly & Clandinin, 1988). An indication that this had happened to participants in this study is that 'change' was a key finding in the analysed data, as teachers stated that they had 'changed' or will continue to 'change' in one way or another. Data revealed that as the teachers' knowledge changed, so did their teaching practices. Some of the teachers linked 'change' to their practices and professional development while others referred to 'change' in terms of their skills and values especially towards ESD as a new topic to their repertoire. However, most teachers not only recognised their 'change' but also discussed the struggle it took in order to change. Others felt good about the 'change' they made but felt they could have done more, given the time and energy. Examples of teachers' responses are: *Action research and the logical thinking needed for it changed my professional practices by changing my thoughts from just theoretical ideas on paper to concrete practices applicable in the real world; I also have more confidence to make positive change; Since action research works in cycles, modifications are necessary, as well as encouraged. There is no fear of not getting it right the first time; I know that my actions can bring about change, not only to myself, but to my school, too; I developed reflective skills necessary for my work as a*

revolutionary teacher who wants to change for the better; I have to be positive to make change for the better and not to give up.

How did your engagement in action research impact you personally?

Three themes were identified through analysing responses to this reflective question. Science teachers indicated that the action research helped develop 1) knowledge; 2) skills and 3) values and dispositions that were beneficial on the personal level. In the knowledge theme, teachers developed concepts such as: democracy, social responsibility, equity, fair trade, citizenship, economic satisfaction and consumer right. In the skills theme, teachers' responses were mainly about the skills they developed and dispositions towards aspects related to ESD. It seemed that the process of going through action research helped to develop thinking skills such as positive thinking, scientific thinking, critical thinking, creative thinking, research skills, future planning and reflective thinking. Other skills were also developed such as communication skills, organisation skills, internet search skills, decision making, problem solving, freedom of speech and self-assessment. From the values and dispositions that were commonly identified as being developed: a better acceptance of the other, appreciation of human rights, tolerance and appreciation of community service. The following are examples from teachers' quotes from the identified themes: *I am more aware of my actions and the effects they have on my environment and others while engaged in action research; Acknowledging the importance of biodiversity and behaviours positive to the environment; This project has made me change even at home; I am aware and concerned about resources so I am trying to manage and consume water, energy and food better; Involvement in action research made me apply reflective thinking in my daily life.*

How did your engagement in action research impact you professionally?

Three themes were also identified through analysing responses to this reflective question: 1) knowledge; 2) skills and 3) values. Knowledge related to sustainable development and relevant research that could be applied with students at various stages in addition to the experiences of other countries in ESD in order to identify what could be done in Egypt, if applicable. Identify ways of making use of all resources, especially material for everyday use that could be designed for teacher aids in the classroom. Through the developed projects, teachers realised that there is a great need to establish a link between school administrators and the local community. One teacher stated, "I have now updated knowledge in my field that can help develop myself and my students." Another teacher mentioned, "I can change students' behaviour, especially in aspects of sustainable development and everyday practices." One more teacher stated, "Increase the effectiveness of science teaching and therefore the achievement levels of my students."

In terms of the values and dispositions that were developed by the teachers, these were accepting students' individual differences, development of positive relations with students and appreciation of a respectful learning environment. Teachers went on to developing through their proposed projects students' ESD awareness and behaviour and disseminating this to the local community. They even valued the use of technology in their teaching. An example of this theme was what one teacher stated, "Accept students comments and ideas wilfully."

The skills varied from lifelong learning skills that relate to the 'change' teachers had identified before and hands-on application of action research that helped link theory

to practice in a realistic way. Also teachers mentioned the use of Wiki and how it helped in formalising their ideas and suggestions for providing for ESD in their own schools. Examples from teachers' quotes are as follows: *I have learnt to review and assess my own teaching; I have learnt how to infuse ESD in terms of its teaching practices and the application of reflective thinking; I have learnt how to manage waste in the school; I now understand that action research is a valid means to solving educational problems in schools and providing for concrete suggestions through action plans that are realistic and hands-on; I see myself as responsible for solving everyday problems in the class, as I have a positive role in the profession.*

Emphasis on developing reflective practices in teaching was the highlight of several responses. The process of action research encouraged the teacher researchers to reflect about the art and science of teaching. Sagor (2000) believes that an important purpose for action research is "building the reflective practitioner" (p. 7). Danielson and McGreal (2000) view reflection as a critical aspect of professional growth. Teachers described the introduction of new teaching strategies as they responded that their teaching practices had changed through involvement in the action research projects. Many said that the research project helped them to develop new strengths in teaching and add to their existing repertoire of instructional methods. This was based on their understanding and appreciation of the Earth Summit that advocates for student-centred teaching and respecting the five pillars of learning identified by (Delors, 1996). One teacher wrote, "Yes, my teaching has changed as a result of the action research. My science teaching will surely not be the same as before as now I will link science with sustainable development issues." Teachers also mentioned that the action research process made them more confident to try these new strategies. Ferrance (2000) and Sax and Fisher (2001) found similar results; action research gives teachers more confidence in their own work. Teachers appeared empowered and confident with regards to daily and future pedagogical practices and decisions.

Conclusion

The significance of this study hinges upon the voices, viewpoints and experiences of science teachers' engagement in action research. The research empowered the teachers to take the role of active participants in the research process and helped them develop and critically analyse and reflect on their own knowledge about teaching and ESD in their schools and subject areas. While engaging in this work, teachers came to trust their own ability to construct knowledge, improve their practice and feel that they have a positive impact as agents of change in their school context and with classroom teaching practices in relation to ESD. Findings from this study suggest that for collaborative action research to be effective at empowering teachers, teachers need to join with other passionate teachers to explore ways to voice freely their concerns, develop action plans and enact their plans for change. Action research was a valid means to experiencing, reflecting, conceptualising, constructing, acting and transforming science teachers in ESD. Through action research, science teachers' conceptual organisation of the SD developed further, and teachers' attitudes towards ESD in addition to their classroom pedagogical practices improved in the post-test. The author therefore recommends including action research in teacher education programmes, particularly where teachers work collaboratively together and where the six components of the ExConTra learning

model can be applied. With such a view on action research, teacher education programmes will fulfil their accountability for transforming teaching practices for successful educational reform.

The true change factor that influenced science teachers in this study was the philosophy and methodology of the course rather than its content, where the assignments and action research provided opportunities for active engagement in learning that changed their attitudes and values towards SD, their teaching for ESD and therefore was a transformative experience.

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