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Preservice Science Teachers' Experiences of Food Garden Projects: Implications for Education for Sustainable Development (ESD) in Curriculum Transformation

Abstract: This paper examines preservice science teachers' (PSTs) experiences of agricultural garden projects to address education for sustainable development (ESD), specifically sustainable food resources. The main research question asks what PSTs' experiences of ESD are when taught through agricultural projects in science courses. Ninety-five PSTs, 3 PhD mentors and 2 academics were involved in this participatory action research project to engage PSTs in developing agricultural gardening skills. A second-year university physical science method course module was adapted to include the agricultural project. Firstly, data were collected through a questionnaire with a Likert-scale and followed-up with 10 interviews with PSTs using the questionnaire. Secondly, more interviews were conducted with 15 PSTs on the field using selected questions from the same questionnaire as a guideline. Thirdly, the data were also supplemented by field-notes and observations. Critical pedagogy (CP) and the United Nations Educational, Scientific and Cultural Organization (UNESCO) policy to implement ESD in the framework of the 2030 Agenda for Sustainable Development were used to analyse the data. The PSTs were positive about including ESD in their disciplines and acquired practical and integrated knowledge about agriculture. This study has implications for ESD in transforming PST education modules through sustainability projects to address UNESCO's Sustainable Development Goals (SDGs) as a matter of urgency and for school and community involvement.

Keywords: preservice teachers, education for sustainable development, agriculture, curriculum transformation

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Professional article

Introduction

Current global developments such as climatic change, global warming, poverty and unemployment raise serious concerns about the long-term sustainability of society, with science, technology and the environment prominent disciplines studied for the material welfare of humanity and for the preservation of earth resources (O'Neill et al. 2020). The ideas of sustainability, sustainable development (SD) and education for sustainable development (ESD) have emerged in the last few decades and face ongoing academic scrutiny with respect to their aims, terminology and value (Baker 2022). Beginning with Agenda 21, the product of the Earth Summit in Rio de Janeiro, Brazil in 1992, the United Nations (UN) stated that education plays a central role in SD for our future survival on Earth. To implement ESD in present education systems, the UN declared that the decade from 2005 to 2014 should focus on ESD (UNESCO 2014). Both the two UN World Summits, one held at Rio de Janeiro and the other at Johannesburg in 2002, accelerated ESD debates and action (Lafferty and Eckerberg, 2013). These debates emphasize that through education involving local citizens that we will be better able to understand the integrated nature of SD via the economic, ecological and societal changes that complex global society transforms. However, progress has been slow regarding Agenda 21. Accordingly, in 2015 the UN called for grass-roots-level action within the current global SD agenda, Agenda 2030. These goals are reflected in 17 Sustainable Development Goals (SDGs; see The 17 UN SDGs), with SDG 4 in particular focusing on quality education.

Quality science, technology, engineering and mathematics (STEM) teaching in teacher education is about studying the nature, concepts and pedagogy thereof, but it should also extend to social and human issues of survival due to drastic ecological changes and human factors. Moreover, it should address issues of sustainability with regards to the UN SDGs. While the role of the academy is to promote disciplinary knowledge production in a theoretical manner, it should also make this knowledge integrative and practical in its application; at present, these aspects are minimally considered. Of concern, the environment is still changing due to climatic change and human interference, and the education sector needs to

rapidly cope with the changing dynamics of the world, as well as ensure the development of professionals who possess the knowledge and skills to lead and manage increasingly complex ESD issues related to SDG outcomes. Educators, preservice science teachers (PSTs) and teachers are powerful agents of change who can deliver the educational response needed to achieve the SDGs. Thus, teacher education must meet this challenge swiftly by reorienting towards ESD and avoiding bureaucratic delays. Another contemporary crisis that ESD can resolve is unemployment and food security, which are dependent on the ability of countries to collect, preserve and disseminate knowledge of vegetables and animal husbandry. In this regard, there are calls to reduce total dependency on commercial farmers and to promote self-sustainability and food gardens.

While different countries strive to achieve different ESD goals depending on their resources and national policies, their implementation faces numerous challenges on the policy, execution and evaluation levels (Zguir et al. 2021). Lotz-Sisitka (2016) reports that after apartheid in South Africa in 1994, the new government aligned the social and environmental policy with the global ESD policy discourse. The conception of environmental and sustainable development within a neoliberal agenda shifted to a contradictory message of environment, sustainability and ESD under pressure from labour unions towards social justice discourse. However, there has been slow progress in accelerating ESD, as 17 years have passed since Agenda 21, though there is some research regarding ESD in South African higher education Lotz-Sisitka (2011). An interdisciplinary stance to approaching the teaching and learning of ESD via the 17 SDGs is thus crucial to explore phenomena that affect our everyday lives and to design and effect curricula through appropriate projects in seeking realistic solutions to the current crises. In this regard, the marginalized local subsistence agriculture sector has deep potential to contribute to knowledge and skills relating to ESD. Indeed, an educational curriculum that integrates ESD into its disciplines can develop a critical perspective and a systems-based approach to learning and teaching to solve the current problems.

This study explores how ESD knowledge and skills can be taught and experienced through agricultural garden projects as a practical way to learn about ESD and STEM. A physical science education method module was restructured to accommodate this ESD project, as there are no existing ESD modules. This study's objectives were to record and analyse PSTs' views and experiences of agricultural garden projects in addressing ESD, particularly employment and sustainable food resources. In this way, we anticipate that the experiential knowledge gained from this case study can be used to transform and provide fresh insights for ESD implementation in other curricula. STEM curricula will also become relevant to the everyday lives of PSTs. Furthermore, PSTs can share their ESD knowledge with learners and members of their community in this participatory process.

Literature review

Sustainable development and education for sustainable development

ESD must be understood in the context of SD terminology and policies. United Nations Conference on Environment and Development (UNCED) (Rio) outlines three dimensions of SD, the economic, social and environmental, which are all balanced and integrated (UN 2015). For Agenda 2030, SD is the sum of achieving the 17 SDGs and 169 targets measured by a set of globally agreed-upon indicators; if these targets are reached, then SD happens and the prospects of sustaining life on the planet are good (Hoffmann and Siege 2018). In this study, we define SD as »a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations« (Brundtland 1987, p.43). It is anticipated that ESD should empower PSTs and their learners with knowledge, skills, values and attitudes to make informed decisions and engage in responsible actions for the environment, economy and society. ESD must also promote problem solving in local and global contexts through sustainable thinking, decision making and acting. The global indicator from SDG Education 4.7.1 further calls for ESD to be mainstreamed in curricula, teacher education, assessment and education policy.

The *Curriculum Framework Education for Sustainable Development* (Schreiber and Siege 2016), drawn from the SDGs, lists 21 thematic areas, such as food and agriculture, poverty and social security that can be considered when discussing ESD. In the education process, ESD cannot provide answers to problems that arise in the 21 thematic areas and cannot prescribe specific solutions to sustainability problems or promote certain actions, but it is largely directed at promoting self-determined decision making among individuals or groups and problem solving in the contexts they find or will find themselves in.

Some researchers have raised issues concerning the policy and implementation of ESD in South Africa (SA). In a national case study, Lotz-Sisitka (2011) reported on the development of a national network, curriculum framework and resources for teacher education, with specific focus on the inclusion of environment and sustainability. She raised concerns that current undergraduate teacher education courses are more focused on STEM content and how to teach it (Pedagogical Content Knowledge), while postgraduate courses focus on problems and educational issues to raise awareness of social justice and gender equity. As such, undergraduate teacher courses fail to develop »deeper conceptual depth and understanding of environment and sustainability, as issues-based knowledge dominates« (ibid., p. 32). She further explicated that more support for social innovation and transformation is an urgent response to pressing environment and sustainability concerns. While there are some effective school-based ESD programmes and policies for the physical and life sciences in the *Curriculum Assessment Policy Statements* documents, Lotz-Sisitka (2011) lamented that there is a lack of a coordinated and integrated policy in South African teacher education for ESD and its

development. This reflects a common issue in most countries' higher education institutions, which despite being charged with integrating SD issues into teaching, research and service present little coordinated effort to achieve this goal.

Agriculture for learning about ESD in Africa

The New Economic Partnership for Africa's Development has documented that the harshness of the environmental problems in Africa, particularly climate change and global warming, are largely due to greenhouse gas emissions, resulting in major contributions to food insecurity, unemployment and poor economic performance (Brahmbhatt et al. 2016). Agriculture is the sector »worst affected by climate change, and rural populations are the most vulnerable to it. Agriculture, land use change and deforestation are also the largest source of greenhouse gas emissions« (Brahmbhatt et al. 2016). Climate change, as part of SDG 13, thus has to become an integral part of African ESD, national SD and poverty reduction strategies, as well as education curricula worldwide.

Studies on the beliefs and mental images that PSTs and teachers have about agriculture likely influence what and how they integrate ESD into agriculture and their instruction (Knobloch et al. 2007). In an action research study with 452 public school teachers in Illinois who integrate agriculture in their classrooms, the teachers believed that agriculture provided connectedness and authenticity as they teach their content areas. The teachers also shared agricultural integration topics and instructional resources that they wanted to know more about, especially how to draw from traditional content areas (Knobloch et al. 2007). Beginning with an agricultural project could thus be a beneficial and valuable introduction to ESD. Examples of an agricultural projects that is beneficial to ESD can focus on one or a multiple of resources such as land, water (from rain or lakes) and indigenous seeds that are easily accessible. The crops harvested from these projects can provide cash and food, hence solving the twin problem of unemployment and poverty. ESD driving principles are embedded in such projects as the SDGs goals to reduce poverty and hunger, improve health and well-being, and create sustainable production and consumption patterns, all while protecting biodiversity and ecosystem services.

Theoretical framework

There are two connected frameworks from which the data for this ESD study is analysed, namely, Critical pedagogy (CP) and UNESCO ESD Model. CP is closely linked with the UNESCO policy of implementing ESD (see Figure 1) as CP addresses both social concerns and transformations towards goals. The intent of CP is to contribute to a more socially just world where social justice is considered the attainment of equality in every aspect of society (Liboro 2015). CP is based on critical social theories, liberatory education, feminist pedagogy, post-structur-

alism and post-colonialism, all of which are linked to the SDGs, especially SDGs 5 and 10. CP has also been the focus of many studies involving curriculum transformation towards social justice including agriculture, among other topics (Govender 2019). The UNESCO ESD Model is embedded in the *2030 Agenda for Sustainable Development* and this Agenda is responsible for the overall implementation of ESD by 2030. UNESCO developed this ESD model for the 2030 toolbox to provide an evolving set of select resources to support member states in development activities (UNESCO 2021). In this UNESCO ESD model (Figure 1), ESD is holistic, transformational and encompasses learning content and outcomes, pedagogy and the learning environment itself. The agricultural project featured in this study is the driver and a suitable platform of this ESD model discussed under section »Pedagogy and learning environment«.

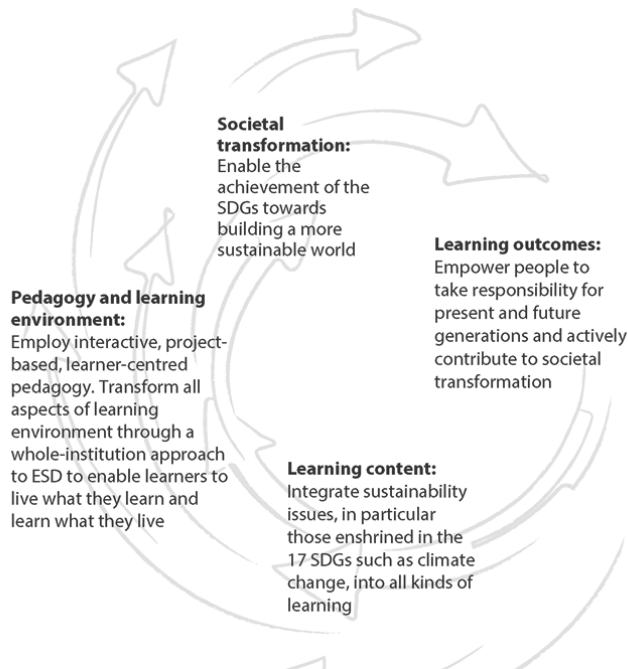


Figure 1: UNESCO ESD model

Methods

The problem in teacher education is that there are limited studies related to PSTs' experiences of ESD, science and agriculture, as this relationship is fairly new in PST education. It also involves a huge practical element at universities and lecturer time and resource commitments. Most science teacher education courses are theoretical, with a focus on science practicals, but hardly have any connect to agricultural science. The main research question in this study is therefore: What

are PSTs' experiences of ESD through agricultural food garden projects? Their experiences provide knowledge about how to integrate ESD into current disciplines and have implications for ESD's role in curriculum transformation.

Ninety-five students were purposefully selected for this qualitative participatory action research (PAR) project; additionally, 3 PhD mentors and 2 academics were involved in a over a 12-week semester. The students were drawn from the Physical Science Method module II class, the mentors were postgraduate students on campus and one academic was a Science Education visiting lecturer and the other, the researcher. All the participants were informed of the study and participated voluntarily. The mentors together with the academics supported and advised the students about sowing, soil etc while on the field engaging in the project and participating in validating the questionnaire used in the study. The data were stored on computer with security codes and paper documents in a locked cupboard. The instruments used to collect the data were a 15-item questionnaire on views of ESD inclusion in science education modules, with each item measured on a 5-point Likert scale, and 10 follow-up individual interviews for about 20 minutes for each student. Additional interviews after lectures and in the field were conducted with 15 PSTs using selected questions from the same questionnaire, and assessments and observation schedules, supported by field notes, triangulated the data, thus strengthening the study findings. The mentors also assisted in developing and collecting the data. The questionnaire was first tested with 3 PSTs for face and criterion validity and later they were also part of the sample. The instruments were assessed for face and criterion reference validity during team collaboration.

The Physical Science Method module II, featuring 2 lectures and 3 voluntary activity periods per week, was restructured to accommodate the ESD-focused agricultural project. The locations were University of KwaZulu-Natal lecture rooms and university open grounds, as demarcated by the university horticultural officer, with permission sought for their use. The module was used as a basis to develop the PSTs' theoretical and practical ESD experiences via an agricultural gardening project. Theoretical lectures incorporating ESD themes, such as chemistry, physics, climate change, environmental sustainability and basic agricultural principles, were presented to orientate the PSTs. Some lectures integrating science and agricultural gardening principles took place both on-site and in the lecture room. The PSTs and mentors used a Learning Management System (LMS) called Moodle to communicate and upload documents, together with WhatsApp and emails. The researcher and mentors also visited several local farms that grow traditional crops, such as spinach, amaranth, kale and lettuce, and tunnel farming innovations, where they observed and interviewed local farmers about their knowledge to share with the PSTs on campus. A young farmer was also invited to speak to students on campus. All the interviews were audio-recorded and transcribed. All the data collected were thematically coded and then analysed into categories which then formed distinct themes. The process was repeated to ensure consistency and validity of the emerging themes.

Results

Questionnaire

The 3 mentors and a visiting guest science education lecturer who joined us on the project jointly developed the 15-question questionnaire. This questionnaire was then given to 95 PSTs towards the end of the module. Seven of the 15 questions focus on agricultural and science curricula and ESD, as presented in Table 1 with responses recorded as percentages. All PSTs completed the questionnaire.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. Learners will enjoy a well-planned agriculture project in their science subjects that focuses on educational sustainable development (ESD).	78	20	0	1	1
2. Agriculture project-based teaching and learning of sciences in the field is as effective as the laboratory method in promoting ESD.	75	15	0	6	4
3. Agriculture projects focusing on ESD are better for primary school sciences rather than high school sciences.	60	25	1	2	12
4. Agriculture projects require integrated Science, Technology, Engineering and Mathematics (STEM) knowledge and skills related to science concepts.	95	5	0	0	0
5. Agriculture project-based teaching and learning is only for rural science learners, not urban learners.	2	3	2	8	85
6. Agriculture-based project teaching and learning has limited value for the sciences.	0	10	0	7	83
7. Learners will learn more everyday life skills from agriculture-based ESD teaching if it is included as part of their science learning.	90	10	0	0	0

Table 1: Agriculture project questionnaire questions focusing on ESD

Questionnaire analysis: The questionnaire was qualitatively analysed

through descriptive statistics, which revealed that most (78%) of the PSTs strongly agreed while 20% agreed with statement 1 (»Learners will enjoy a well-planned agriculture project in their science subjects that focuses on ESD«). For statement 2, while most PSTs (75%) strongly agreed, 15% agreed, and felt that agricultural projects are as effective as science laboratories in teaching ESD skills, only 10% felt that they are not effective. For statement 3, 60% strongly agreed while 25% agreed, and felt that agricultural education is better in primary schools than secondary, though some (12%) strongly disagreed. For statement 4, most (95%) PSTs strongly agreed that STEM inclusion is important in agriculture while 5% agreed. In statement 5, only 2% of the PSTs strongly agreed, while 3 % agreed that only rural learners should be involved in agricultural projects, with 85% strongly disagreed indicating that it is for all learners, whether urban or rural. For statement 6, 83% strongly disagreed that agricultural projects have limited value for sciences, while only 10% agreed. In statement 7, 90% of the PSTs strongly agreed with 10% agreeing that that learners would learn more everyday life skills from agriculture-based ESD teaching if it was included in their sciences learning.

Follow-up interviews

The following excerpts provide the in-depth views of 10 PSTs randomly selected from the sample, as taken from follow-up interviews conducted using the questionnaire. During the interviews, 2 PSTs felt that sciences should not be diluted with agricultural projects but they can include ESD principles. Teacher Shreya said, »I am of the view that pure sciences must be taught like the way it is now with topics in the discipline and not be diluted, as the agricultural projects take too much time and effort and we need this time for science concepts and laboratory work.« Teacher Dlomo said, »Yes [...] we cannot waste time and agriculture must be taught separately, but we have the ideas of sustainability and environmental issues in agriculture. It can help me in my community and school garden projects.« Four of the PSTs agreed that learners can learn ESD knowledge and skills by participating in well-planned agricultural project-based tasks, which are valuable to integrate with the sciences. However, they felt that time and resources are constraints that need to be addressed. For example, Teacher Daisy said, »I need to learn more about how to integrate the sciences and ESD into gardening activities but what we are doing now is helpful, as we [are] learning about soil, weather and [the] wise use of resources [...]« Teacher Nad said, »We need more time, but it helped me to understand how the concepts in chemistry are linked practically, like measuring pH of the soil and taking soil temperatures and testing for acidity.« Teacher Andy said, »Looking at it from ESD, it is the perspective of fighting climate change. To understand everything in the atmosphere, greenhouse gases, you need to understand physical sciences, then the agriculture aspect helps us to know how plants are affected by gases, and combining the two brings a richer understanding of climate change and the world [as] a whole, which helps bring a solution to climate change.«

Field observations and support: Data were also collected from field observations, with the team spending many hours supporting, guiding and asking questions related to agriculture, sciences and ESD. The PST teachers were given equipment and implements such as seeds and seedlings to capture their dialogue with the PSTs. Pictures and videos were taken over the term to observe the PSTs' progress in their field tasks. As some assessments, both formative and summative, were included in this project and needed for the module outcomes, the team developed assessment rubrics and used them in the field to gather scores, but they did not interfere with the goals of the project. The analysis of field notes, pictures and video recording produced six themes that demonstrated that the PSTs were engaging with agriculture, sciences and ESD. These are recycling; multi-cropping; field observations and assessment; diseases, chemicals and insects; mulching and bolting; and security and theft, elaborated as follows:

- Recycling: From the scrap bin near the university site, the PSTs collected recycled materials like old plastic piping, bricks and glass bottles to build raised garden beds that were divided into sections, making all sides from the bed accessible. The team asked questions about the value of re-using and recycling. The PSTs reported that while it might not be aesthetically pleasing, the materials came at no cost, served to border and frame their planting beds, protect the plants from harmful insects and contained the sand during heavy rains, thus preventing soil erosion.
- Multi-cropping: The PSTs grew several different food plants, such as spinach, beetroot and tomatoes, in one bed, divided in parts, but when asked why, they had little knowledge of which plants to mix based on plant symbiosis (companion planting). They did not know that some vegetables, herbs and flowers benefit each other by improving soil, while others deter pests from one another to ensure a higher yield and disease-resistant plants; equally, some can stunt the growth of their companion plants. The agricultural advisors mentored them on this aspect.
- Field observations and assessments: As part of the agricultural project required an assessment of the PSTs' agricultural garden project, both the mentors and PSTs participated in the rubric development, which was part of the learning outcomes. The mentors kept copious scores of the group projects, as the PSTs were advised in a formative way. Then, a summative assessment was done of the PSTs' knowledge of the environment, seeds, plants, ESD food, sustainable food garden development and science lesson planning in an integrative STEM way. The mentors also examined how the plants and beds were spaced for good air circulation, as well as wise water use (e.g. if the PSTs avoided wetting the leaves, and used as little water as possible for maximum plant growth).
- Diseases, chemicals and insects: The mentors guided the PSTs through some common plant pests and diseases. The PSTs also used the internet to search for information on pests and diseases, as well as their chemical and indigenous remedies. For example, sulphur (S) can be used to address white rust fungal disease on leaves. The PSTs learnt about S but were surprised about

its use in agriculture. For example, Bongi said, »I only know about its chemical reactions with oxygen in grade 10 practicals but [this is] so interesting now. I now know from my internet search that by dusting the plants with sulphur early in the season, we can prevent mild infections from spreading. For example, this spinach leave is planted in soil that maybe [is] deficient in sulphur, as it looks short with yellowish veins on their leaves. I found that in the soil, sulphur interact[s] with plant roots and [is] converted by bacteria to sulphuric acid, lowering the soil pH, and it also increases plant root access to many nutrients.« Zondo similarly said, »Also I found from [the] internet that possible causes of yellow spinach leaves include poor drainage and high soil pH. I observed that the leaves sometimes have pitted areas. The insects are so tiny that you may not see them.«

- Mulching and bolting: The PSTs were taught about composting and mulching and how to retain moisture in plants. Some PSTs already had indigenous knowledge of these methods, such as piling leaves and adding chicken droppings to make manure. For one plant the PSTs asked, »What is the problem?« Nyla remarked that »too much heat caused the plant to bolt into seeds«. One mentor, Susan, helped their understanding in stating that »bolting is a response to plant stress – increased day length, high soil temperatures and root stress – which then starts the reproduction process, where flowers and seeds are reproduced«.
- Security and theft: All PSTs highlighted theft as a major problem, for even though the campus has security, students and cleaners are likely to take plants. When asked how to resolve this issue, Phil said, »We need a sign and a fenced yard so it will not be easily stolen.« Students who lived near the hostel where the garden is located could also supervise and protect it, thereby partaking in the project. »What about the monkeys?« asked the researcher. Here, the PSTs were boisterous; some said they could chase them away, others said to grow plants that monkeys do not eat and more recommended building a greenhouse or covering the garden with shade netting material. One innovative PST said, »Use physics and technology to build a sound meter, as it might frighten them.«

Field interviews conducted with individual PSTs on selected question from questionnaire

The mentors conducted in-depth interviews in the garden fields featuring 4 selected questions from the questionnaire with 15 PSTs who volunteered after their lectures. All interviews were recorded, transcribed and grouped together per question, and then classified into 4 major themes that were validated by another colleague. Due to limited space, some responses are not reflected. An analysis of these questions in relation to SD and ESD is discussed below per theme.

The role of science in understanding ESD

The PSTs were asked about their understanding of the role of science in understanding ESD using questionnaire question 1 (what is your understanding of science in terms of ESD?). One PST said that since science is about understanding the world, it must be applied to effect ESD actions. Similarly, student 3 said that science needs to be applied to everyday life to effect ESD. ECD promotes good knowledge and understanding of the world, environment, atmosphere and skills. Student 4 highlighted that science »is about relational understanding of the subjects and applying the knowledge to whatever we are doing«. In this case, the student implies that we must seek significant relationships in ESD, and use scientific knowledge to solve SD problems. One PST also stated, »Science is not only about application and calculation; there are some other projects that can be added. For example, you can ask learners to check the growth of certain plants in previous years from the internet, then plant them now and check the effect of climate change. It needs to be applied to everyday life in ESD.« Here, the student emphasized project work, technology and practical values, as well as use of the scientific process, to learn about SD and the impact of climatic change. They also felt that science is abstract by nature and an everyday phenomenon that engages problem solving, so it can be used to develop concepts that explore SD through education.

In summary, PSTs are of the view that science and scientific processes are important to understanding and taking action against SD issues through ESD.

Agricultural knowledge as a basis of teaching and learning sciences for SD

The project aim was to integrate the PSTs' scientific understanding from their disciplines into real-life contexts, such as agriculture, farming and food gardening tasks. In this regard, the PSTs were asked in question 2 what they felt were the benefits of introducing agriculture-based teaching and learning of sciences for SD. Their responses included the importance of land as soil for growing crops and minimizing pollution. For example, student 2 said, »Science research makes me aware of taking good care of the land [and limiting] land pollution, which contributes to climate change. If we don't take care of our land, we will run out of certain crops, because they don't grow under certain conditions.« The PSTs also understood the climatic change factors that affect plants/crops growth and also their production, as »it makes me understand the growth of plant[s] is different using compost, mulching or not using it«. The PSTs realized that soil testing is important for different varieties of food production as well. One PST commented, »It can look deeply at chemistry, whereby we test the soil for nutrients and minerals we get from plants so as to know the nutrient we can get from each type of food. You then test for nutrients in the soil, as each plant needs different minerals.« Another PST added, »Most of the learners will use agriculture to learn more [about] physical sciences. Some of the things we did in agriculture also appear in physical sciences. My school had no garden, so I was not exposed to it and doing it

here makes it very important. Types of soil determines the plant you use in that soil; the project helps to understand that.«

The PSTs felt that by learning about agriculture using the scientific process and skills, such as observation, they can now engage in practical actions for self-sustainable food gardens. For example, student 4 said, »I can do my own garden at home, harvest and have food to eat. I gained gardening skills and knowing the conditions and times for gardening.« The PSTs also knew the importance of scientific facts and relational knowledge for SD in learning about ESD and climatic change. One PST claimed, «Looking at it in the perspective of fighting climate change, to understand everything in the atmosphere, greenhouse gases, you need to understand the physical sciences part. Then the agriculture aspect helps us to know how plants are affected by gases. Combining the two brings a richer understanding of climate change and the world [as] a whole, which helps bring a solution to climate change.«

In summary, the PSTs acknowledged that agricultural and scientific knowledge can be used as a basis of teaching and learning for SD in ESD.

Challenges in using agriculture-based projects in teaching and learning physical sciences

The challenges that PSTs foresee in ESD using agriculture-based projects for the teaching and learning of physical sciences and SD are elaborated in this paragraph. »Getting the seeds might be a problem because there might be no money. Learners [could want] to plant crops that don't grow well in that location or area [and there could be] limited space for planting«. The PSTs also complained about the brevity of the course, which is only allocated 90 minutes. In this module, they spent another 90 minutes outside lecture time in the field. The PSTs added that »combining agriculture and physical sciences makes time management a big problem«. Additionally, while they agreed that physical sciences is largely theoretical and agriculture mostly practical, they were primarily concerned with the practical part, as some learners »might not want to touch compost and they don't want to be smelling of cheap compost like dung«. One PST was very critical and forthright that learners, possibly due to technology and lack of direction in their home environment, have become physically inactive and do not want to spent time outdoors or in the garden. She stated, »Basically, most learners are lazy – they are becoming lazy, you can tell them to go to the garden and they will not go there.«

In summary, the challenges and limitations to agricultural projects included resources, both human and physical, such as infrastructure and equipment, time, attitude and motivation to work outdoors in the natural environment. These all pose concerns for implementing ESD in current science curricula, which can be problematic unless more time and an integrative structure is formalized.

Questioning the relevance of agriculture-based projects to achieve physical science goals

PST were asked about their views about the relevance of agriculture-based projects in physical sciences. Most PSTs found relevance in the chemistry aspects of agriculture, such as the chemicals in fertilizers, which proved informative and could be linked directly to physical sciences curricula. However, it remained unclear how to integrate physics. One PST reported in this regard that »it makes learning of fertilizers easy for students by asking them to identify the nutrient needed by the plant. I'm not really sure [about] the relevance to physics though«. The PSTs felt that the goals of agriculture, ESD and physical sciences are similar in that all focus on important skills, which »helps students to gain life and problem-solving skills«. Some PSTs believed that it is partly relevant, as »physical sciences is not all about chemistry or plants, it can also involve other things than plants«. Another said, »At least in fifty percent of the content in the Agricultural Sciences includes some chemistry. Physical sciences involves engineering which is used in agriculture, [such as] machines [heavy and simple]. There's [a] technology part in agriculture and [it] is used in physical sciences too.« One other PST indicated that physical sciences is about understanding chemicals, which can help in understanding the composition of compost and suitable chemicals to maximize crop growth.

In summary, the PSTs agreed that there are some outcomes of agriculture and garden projects that match the physical sciences curricula, though they are largely related to chemistry and technology.

Discussion

The project aim was to integrate the PSTs' scientific understanding from their disciplines into real-life contexts, such as agriculture, farming and food gardening tasks and to obtain their experiences on ESD and whether integration of agricultural projects into the physical science method course was beneficial. From the data of a questionnaire that asked for their experiences on integrating ESD projects into science education and method modules, most PSTs indicated that agricultural activities are important and should be integrated with STEM knowledge and skills for the enhancement of global ESD goals. However, a few felt that the disciplines should stand alone. They found it difficult to understand the importance of ESD as an integrated whole, as per UNESCO toolbox guidelines for PSTs, as they are used to learning traditional disciplines. They added that efforts to prepare teachers to implement ESD have not sufficiently advanced and more work still needs to be done. They also claimed that ESD must not be seen as a separate discipline but integrated into others, using SDGs as key cross-cutting strategies for sustainability. Some PSTs also described that practical projects pertaining to agriculture are mostly for rural and primary school learners. It thus seems that these PSTs perceived agricultural education to be of a lower status, and hence they were not likely to »get their hands dirty«.

From the interviews following the questionnaire, the PSTs cited time and resources as constraints that need to be addressed to integrate ESD into science learning. Some felt that they need more help in seeing the connections between ESD, STEM and agriculture, as it was quite challenging, but in some cases they did see the value of these connections, such as testing soil pH relating to chemistry and how that in turn links to plant growth and the nature of soils. Most PSTs reported that the agricultural garden project was beneficial to learning, as they could now begin gardens in their home communities. As there are still many in-service teachers and PSTs who have not learned about ESD and how to integrate SDGs in their classrooms, there now has to be a coordinated effort in how to approach ESD in teacher education and who in education takes the responsibility to lead the process. Often this is the science/geography education sectors. For all teachers to be prepared to facilitate ESD, they must develop key sustainability competencies, such as knowledge, skills, attitudes, values, motivation and commitment, but they should also be able to train others to be innovative. To facilitate the development of ESD competencies in teacher education, changes in the content and structure of pre- and in-service teacher education are necessary. Hence, ESD should provide the fundamental orientation for teacher education programmes for all PSTs. Currently, the *Minimum Requirements for Teacher Education Qualifications* (MRTEQ) (DHET 2015) is the policy driver for teacher education in SA; its »mix knowledge« category allows for more related content, pedagogy and time. For example, method modules are now allocated from 2 to 6 periods per week, making them ideal platforms to integrate ESD.

The field experiences of the PSTs and their reflection of their learning were documented and these are reported next. Data from the field observations, field notes and field/post-lecture interviews were analysed per the following categories all related to agriculture, sciences and ESD: recycling; multi-cropping; field observations and assessment; diseases, chemicals and insects; mulching and bolting; and security and theft. The field observations and interviews confirmed that the PSTs had opportunities to grow seedlings and plants, study the soil and weather, and take care of the plants in terms of pests and their needs over several months. The PSTs also examined and reflected on their learning in terms of the sciences, ESD and SDGs through collaborative groups, which the mentor team supported, questioned and assessed for their experiences. From the interview data, only when chemistry knowledge like that of sulphur and soil pH emerged in agricultural practices did the PSTs make connections to other disciplines.

Analysis of the interviews from the questionnaire also indicated that many PSTs could define science and knew its applications, as well as could describe ESD very generally. One PST said that »science needs to be applied to everyday life in effecting ESD«. This confirms that they value knowledge of their discipline. Another PST stated, »Science promotes good knowledge and understanding of the world, environment, atmosphere and skills«, clearly linking to ESD. On the question of the benefits of introducing agriculture-based teaching and learning to the sciences, one PST replied positively about the link between the sciences and agriculture. For example, »It makes me aware of taking good care of the land [and]

limit[ing] land pollution, which contributes to climate change. If we don't take care of our land, we will run out of certain crops, because they don't grow under certain conditions.« Additionally, another PST added that, »Agriculture provides food, as we can survive from plants in our garden. We are using physical sciences knowledge/ideas to see how we can use our environment to benefit us.« There is also explicit evidence of the PSTs connecting ESD to their disciplines as »taking care of environment«. On the question of challenges in using agriculture-based projects to teach and learn physical sciences, the PSTs said that when they teach at schools, there are several resources, like land space, fertility of the soil, finance, lack of special knowledge or experience with growing plants, and negative learner attitudes towards practical hands-on activities, that pose challenges for them.

On the question from the questionnaire of how relevant agriculture-based project teaching and learning is to achieving physical science goals, some PSTs said that »it gives an opportunity [where] physical sciences does not rely on the sciences alone, but it is broad and can be applied in agriculture, thus getting better results than the agricultural people«. Another said, »It exposes students to [the] practical aspect of learning rather than theory. You find ways to improve agriculture.« A third PST stated, »It is important to use agriculture to teach physical sciences. I wonder why it's not part of [the] education department. People will teach agriculture in schools, so we need agriculture. Agriculture can be the best strategy to eradicate poverty. The observation skills of learners will be developed. You learn more physics from observing the plants.« Only a few PSTs said that physical sciences is not that relevant to plants and is an independent discipline.

The integrated role of science, ESD and Agriculture must be explored further. Science educators can play a pivotal role in networking with PSTs, farmers, scientists and others, as their students may come from impoverished communities, and the science educators and PSTs can share their scientific and biological knowledge in the process of development. Through science educators, PSTs can, for instance, learn from local farmers to enhance their own agricultural experiences and follow SD practices, such as using ash, select grasses and manure to make their own organic fertilisers, thus preventing harmful damage caused by industrialized fertilizers and chemical runoffs. Other SD projects may depend on other agricultural income sources, such as chicken runs, manufacturing pickles and growing local indigenous crops. Already educators are facilitating trial projects for PSTs to engage with on campuses across South Africa (Govender 2019). While this and other studies show the positive attitudes of PSTs towards ESD such as personal responsibility, willingness to promote SD, taking action to sustain the soil, and to care for growing vegetation (Andersson et al. 2013), there must be more focus on ESD in all disciplines in teacher education, including ESD pedagogy (Evans and Ferreira 2020).

Conclusion

This study reports on an agricultural garden project that was used as a plat-

form for PSTs to learn about ESD. The study had a main research question – what are PSTs' experiences of ESD? The findings confirm that most of the 95 PSTs involved were positive about ESD's integration into their discipline modules, with only a few still wanting traditional discipline topics. The study concludes that all PSTs gained valuable integrated ESD experiences from trained agricultural mentors while embarking on the agricultural garden project, which exposed them to cross-cutting SDG outcomes. However, the PSTs indicated that they required more support about how to go about integrating ESD into their individual disciplines, which requires deeper gardening knowledge and skills. The study also confirms that in spite of time and limited resources, one of the more practical ways to introduce ESD to PSTs is through agricultural or other environmental projects within discipline modules. As in this study, identifying ESD knowledge and skills in agricultural projects can result in PSTs' newly produced integrated knowledge, as drawn from the traditional science disciplines, resulting in interdisciplinary approaches to meet the UN's 17 SDGs. The PSTs concurred that ESD is dynamic and complex, and thus requires some theoretical understanding, together with practical activities and great effort, resources and time. To maximize ESD within disciplines, it is essential that PSTs develop necessary integrated STEM knowledge, skills and competences, as well as pedagogical, open-ended and innovative ways to teach their learners for society, now and in the future.

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IZKUŠNJE BODOČIH UČITELJEV NARAVOSLOVJA PRI PROJEKTIH PREHRANSKIH VRTOV: POMEN ZA VZGOJO IN IZOBRAŽEVANJE ZA TRAJNOSTNI RAZVOJ IN PREOBLIKOVANJE UČNIH NAČRTOV

Povzetek: Prispevek proučuje izkušnje bodočih učiteljev naravoslovja (BUN) pri projektih poljedelskih vrtov v kontekstu vzgoje in izobraževanja za trajnostni razvoj (VITR), zlasti trajnostnih prehranskih virov. Glavno raziskovalno vprašanje je, kakšne so izkušnje BUN z VITR, kadar poučevanje pri naravoslovnih predmetih poteka prek kmetijskih projektov. V tem participativnem akcijskem raziskovalnem projektu vključevanja BUN v razvijanje poljedelsko-vrtnarskih spretnosti je sodelovalo petindevetdeset BUN, trije doktorski mentorji in dva akademska profesorja. Projekt je bil del prilagojenega naravoslovnega modula drugega letnika univerzitetnega študijskega programa. Najprej smo zbrali podatke z vprašalnikom z Likertovo lestvico, nato pa je sledilo 10 intervjujev z BUN na podlagi tega vprašalnika. Drugič, na terenu smo opravili dodatne intervjuje s petnajstimi BUN s pomočjo izbranih vprašanj iz istega vprašalnika. Tretjič, podatke smo dopolnili s terenskimi opombami in opažanji. Pri analizi podatkov smo se sklicevali na kritično pedagogiko in politiko Organizacije Združenih narodov za izobraževanje, znanost in kulturo (UNESCO) za izvajanje VITR v okviru Agende za trajnostni razvoj do leta 2030. BUN so pozitivno ocenili vključevanje VITR v svoje discipline ter pridobili praktično in celovito znanje o kmetovanju. Raziskava lahko vpliva na VITR pri vprašanju preoblikovanja izobraževalnih modulov BUN s trajnostnimi projekti in na nepotrebno uveljavljanje UNESCO-vih ciljev trajnostnega razvoja ter povezovanje šol in skupnosti.

Ključne besede: bodoči učitelji, izobraževanje za trajnostni razvoj, kmetijstvo, preoblikovanje učnih načrtov

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