Araştırma Temelli Etkinlik Dergisi (ATED) / Journal of Inquiry Based Activities (JIBA)
Vol 15, Special Issue, p. 172-185, 2025

Exploring Life Sciences Pre-Service Teachers' Competences in Education for Sustainable Development

Gaseitsekgosi Dimakatso[1] & Glen Legodu[2]

ABSTRACT

This paper explores the competencies of Life Sciences pre-service teachers in Education for Sustainable Development (ESD), following UNESCO's 2030 call to address global sustainability challenges. Effective ESD integration requires teachers to be adequately prepared, yet higher education often falls short in equipping future educators with essential ESD competencies. Using a qualitative, interpretivist approach, the study analyzed semi-structured interviews and micro-lesson observations of four South African pre-service teachers. Thematic analysis revealed two main themes: perspectives on ESD and the facilitation of ESD in Life Sciences through Pedagogical Content Knowledge (PCK). To enhance the trustworthiness of the findings, data triangulation and member checking were employed. Findings indicate limited awareness and pedagogical application of ESD principles among participants, underscoring the need for targeted training and enhanced alignment of teaching practices.

Keywords: Education for sustainable development; pedagogical content knowledge; pre-service teacher; life sciences.

Journal Information
Submitted: October 31, 2024 Revised: May 2, 2025 Accepted: May 8, 2025

[1] University of the Free State, Department of Mathematics, Natural Sciences and Technology Education, Bloemfontein, South Africa, ORCID: 0000-0009-5926-1474, E-mail: masegaseitsikgosi@gmail.com
[2] ***Corresponding Author***, University of the Free State, Department of Mathematics, Natural Sciences and Technology Education, Bloemfontein, South Africa ORCID: 0000-0001-7118-6787, E-mail: legodugl@ufs.ac.za

INTRODUCTION

The world is facing urgent sustainability crises from climate change and biodiversity loss to food insecurity and resource depletion that threaten human well-being and planetary health. These challenges demand education systems that empower learners to think critically, act responsibly, and contribute meaningfully to sustainable futures. As such, Education for Sustainable Development (ESD) has become a global priority. Introduced by the United Nations in 1987, sustainable development aims to meet current needs without compromising those of future generations (Kurnia et al., 2022). At the 1992 UN Conference on Environment and Development, education was identified as a key vehicle for achieving this vision (United Nations, 2017). UNESCO has since taken the lead in helping countries integrate ESD into national education policies and curricula (UNESCO, 2017). Despite these efforts, UNESCO (2014) warns that not all education promotes sustainability. When education focuses narrowly on one pillar (environmental, social, or economic) it can unintentionally undermine the others (Ssosse et al., 2021). This raises a critical question: Are higher education institutions preparing Life Sciences pre-service teachers with the competencies needed to meaningfully implement ESD in schools? This study explores that question by examining how Life Sciences pre-service teachers in South Africa understand and apply ESD principles in their teaching, with a focus on their pedagogical content knowledge (PCK) and preparedness to support sustainability learning in classrooms.

Competences of ESD

Agbedahin (2019) defines Education for Sustainable Development (ESD) as a framework of creating curriculum formats that promote teaching and learning for sustainable development, and above all, a sustainable world. Similarly, UNESCO (2019) points out that to achieve a sustainable society, every person should be capable of working together and respond positively to developments in the planet. Therefore, teachers need to be competent to work with the concept of ESD (Vilmala, 2022). Pedagogical practices in Life Sciences promote critical thinking and systems thinking, which are core ESD competencies. Engaging learners in inquiry-based learning about ecological and human impacts, these practices foster holistic understanding and responsible decision-making. This way, they will be able to align their pedagogical practices with ESD. For example, in Life Sciences, learners are taught about how deforestation can affect the biodiversity, local communities and climate, which aligns with ESD's emphasis on comprehending the interdependence of environmental, social and economic systems. According to UNECE (2013) there are three key characteristics that are used to categorize teacher's competences for ESD which are: a holistic approach, envisioning change and achieving transformation. Additionally, the organization further elaborates that these characteristics provide a logical manner to classroom practices that guide the importance of tackling sustainable issues. Also, it is important to mention that these competences give teachers the opportunity to understand the challenges society is facing both locally and globally and develop the knowledge and skills regarding ESD (UNESCO, 2020). Consequently, teachers will have increased independence to facilitate students' involvement in a sustainable society environmentally, socially and economically.

Perspectives of Life Sciences teachers towards ESD integration

Teachers serve as role models to their learners and that is why their perspectives towards ESD influence how they facilitate learning to help learners prepare for the future. Vukic (2019) suggests that if education aims to encourage learners to change their lifestyle choices towards sustainable development. For instance, how to use what they learn to make informed decisions on reducing waste, saving energy and choosing sustainable food options. Then there is a need to concentrate on teachers' perspectives and behaviors as they influence learners. Conversely, Kioupi and Volvoulis (2019) argue that teachers frequently feel overwhelmed by the concepts of sustainability, and that makes it hard for them to relate the goals of sustainable development into their learning objectives.

Dimenas and Alexandersson (2012) found that teachers often assumed that the responsibility for teaching sustainable development lay with colleagues in other subjects. However, when interviewed, those colleagues expressed the same belief that someone else was covering the topic. This revealed a shared misconception among teachers that ESD is not part of their own

teaching responsibility, highlighting a gap in ownership and integration of sustainability principles across the curriculum. Furthermore, Vukic (2019) found that the majority of teachers, including Life Sciences teachers, are unfamiliar with the notion of sustainable development and were not aware of key documents of sustainable development such as Agenda 2030. Thus, this ultimately becomes a problem, as learners end up missing the opportunity to be aware of what sustainable development is about and how it affects them (Ferguson et al., 2021).

Research by Nousheen et al. (2019) indicates that pre-service teachers enrolled for Masters Education at the University of Education Lahore were offered a course on ESD that aimed to prepare teachers for the current and future sustainability issues. Findings of research show that the pre-service teachers showed a positive attitude towards ESD. However, they initially thought that it was only related to environmental aspects and not economic and social aspects. Moreover, the authors suggest that preservice teachers are interested in including concepts of ESD into their teaching and learning, but they need adequate training to achieve that (Nousheen et al., 2019). Furthermore, teachers believe that knowledge and skills relating to sustainable development are not effectively addressed in science subjects (Qablan, 2018). In summary, pre-service teachers' education is important to achieve socio-economic changes and a more sustainable environment.

Dimenas and Alexandersson (2012) found that teachers often assumed that the responsibility for teaching sustainable development lay with colleagues in other subjects. However, when interviewed, those colleagues expressed the same belief—that someone else was covering the topic. This revealed a shared misconception among teachers that ESD is not part of their own teaching responsibility, highlighting a gap in ownership and integration of sustainability principles across the curriculum.

ESD integration in Life Sciences

Tackling sustainability issues is now seen ~~as~~ a vital part of science education and is being integrated into science curricula more (Vesterinen, 2016). Moreover, when incorporating ESD into Life Sciences teaching and learning, it is important to show the interconnection between ESD three pillars of sustainable development. In addition, Ssosse et al. (2021) point out that focusing only on one pillar can lead to unsustainability for the other two pillars. Therefore, teachers should be able to integrate various viewpoints on the three pillars of SD, while highlighting their interrelationships and limitations at local and global levels. However, Maidou et al. (2019) argues that science educators lack the necessary knowledge and training about ESD concepts in pre-service learning. Thus, leading to incompetent teachers who are unable to teach learners about the importance of sustainability in the environment.

Teachers have the responsibility to ensure that ESD is featured when they teach. In Hogan & O'Flaherty's (2021) view, teachers must make sure that science curricula allow learners to think critically about sustainability concerns scientifically, with an emphasis on evidence-based learning, scientific inquiry, and participation in socioscientific discussions. Consequently, the idea is for learners to recognize that they can integrate different ways to effectively address the issues of the present and the future (UNESCO 2020; Vilmala et al., 2022).

When integrating ESD into Life Sciences, it is imperative to help learners to see the connections between topics in order to provide them with a thorough understanding of the nature and connections of life. Leicht et al. (2018) point out that learner-centered approaches are appropriate for ESD as they allow learners to build on their personal life events and social situations to improve their understanding on sustainability. For example, a teacher has to create an opportunity for learners to share ideas by doing group work and experiments so that they can engage with each other and their environment to respond to SD challenges and raise awareness about how changes made in one part of the world can have an impact elsewhere (UNESCO, 2019). As a result, learners integrative thinking skills are promoted as collective wisdom of different learners' ideas is encouraged during the meaning-making process of knowledge development.

Transformative learning is another strategy teachers can use to integrate ESD into Life Sciences classrooms. According to UNESCO

(2020), this strategy influences learners to ask questions, the teacher is also able to push learners to dig into their worldview and think of the future. Thereby preparing learners to be critical thinkers who will build on sustainable development to produce more sustainable knowledge. Furthermore, the teacher should be able to envision change by using historical events to bring awareness of sustainability in classroom interactions. Consequently, reflecting on the past enables the teacher and the learners to identify common threads that we can use to inspire new ideas for the future (Eikenberry, 2021).

Challenges faced by teachers when integrating ESD in Life Sciences classrooms

Research shows that lack of understanding of ESD is one of the major factors that is inhibiting pre-service teachers from effectively integrating sustainability in schools (Sinakou et al., Vukic, 2019; Ferguson et al., 2021). According Mandikonza & Kavai (2023) Life Sciences teachers do not acknowledge that they should integrate ESD into every topic, and they are more biased towards environmental education, overlooking the social and economic pillars of sustainability. This shows that teachers are not recognizing the other pillars of sustainability and other Sustainable Development Goals.

Burgener & Barth (2018) argue that teachers face challenges when they have to address all aspects of sustainability and which ESD teaching strategies to choose. In addition, Howard (2019) states that teachers avoid covering ESD in their teaching and learning because they think that discussions and incorporating different ideas is time consuming and challenging to tackle. As a result, they end up using rote learning which robs learners a chance to develop awareness of what it means to be a responsible citizen as stipulated in the CAPS document (DoE, 2011). Furthermore, Khadim et al. (2022) argues that lack of interest among learners is also a factor, learners prefer to only learn about the subject content which contributes to their assessment marks. It can be concluded that to successfully implement ESD in classroom practices, there must be a change in both the teachers and learners' view towards the concept.

THEORETICAL FRAMEWORK

This study used Pedagogical Content Knowledge (PCK) as a framework to enable the study to assess pre-service teachers' competences for ESD in Life Sciences teaching and learning. PCK was introduced by Shulman in 1986 in the field of teacher education. In his article of Educational Researcher, Shulman suggested that it is imperative to differentiate between the three categories of teacher's content knowledge, namely, subject content knowledge, pedagogical content knowledge, and curricular knowledge (Star, 2023). Moreover, one significant part of a teacher's professional competency is pedagogical content knowledge. Better teacher's PCK results in more effective teaching, hence it is necessary for a teacher to have a competent PCK to teach ESD as well (Handtke et al., 2022). Moreover, Brandt et al. (2019) adds on that to effectively teach ESD in science, teachers are required to be knowledgeable about how to cover sustainability challenges and engage learners in meaningful discussions. Furthermore, they need to be able to break down complex sustainability topics in accordance with learner's level of understanding (Brandt et al., 2019) and know how to deal with the development of sustainability and their overall importance.

The components of PCK in science were used to explore how pre-service educators teach ESD in their Life Science classroom, the skills they have towards ESD and the type of assessments they give to learners. The aim is to show how pre-service teachers' PCK influences their perspective towards ESD and how their teacher knowledge influences their teaching in the Life Sciences Classroom. The following model show the components of PCK in science integrated.

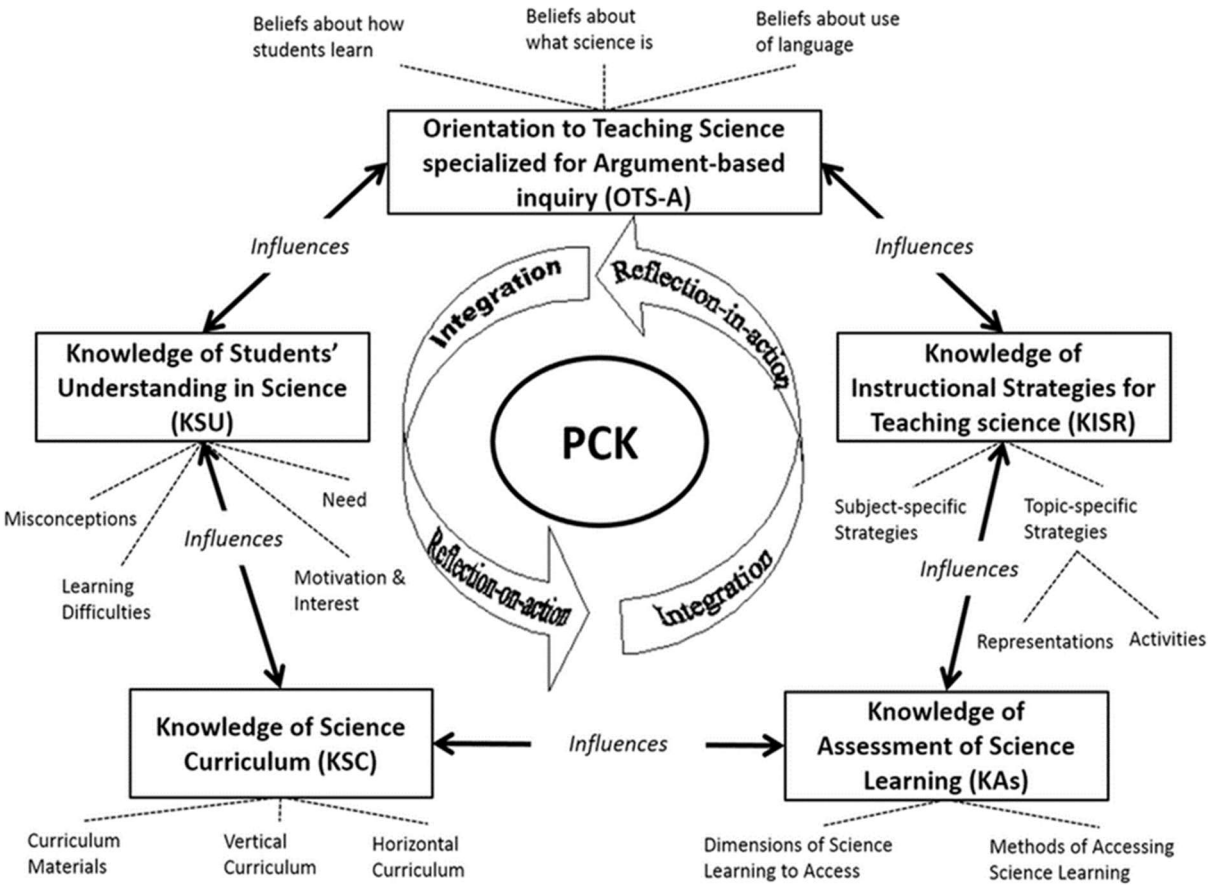

Figure 1: *Pentagon model of PCK for teaching science (Park & Oliver, 2008)*

Ethical Statement

This study was approved by one of South African the University. Four Life Sciences pre-service teachers participated in this study, and they were informed about the study via a written consent form that they all approved and ethical clearance was granted (HSD2023/1425/24). To protect the identity of the participants, they are labelled using letters of the alphabet and not their names.

ACTIVITY IMPLEMENTATION

The study was conducted in one of the South African public universities with four Life Sciences pre-service teachers in 2024 to conduct classroom observations and semi-structured interviews. This is because they represent an information-rich case, providing a deeper comprehension of the competences they need to acquire to successfully integrate ESD into their classroom teaching and learning. The researchers met with the participants once a week for four weeks in their classroom simulations that took place as part of their teacher training in one of the Life science didactics modules third years. The researchers firstly observed the presentations of the participants which occurred for a period of 30 minutes each, where the participants presented their lessons to the rest of the class and received feedback from the lecturer afterwards. In addition to the observations, the participants were interviewed after their lessons to see how much they know about ESD.

Stages of implementation

This study was completed in two stages. The first stage was the observations that took place among the participants where they presented their lesson in their classroom simulations with their lecturer giving them feedback. Following the observations, the second stage involved semi-structured interviews with the participants to unfold how much pre-service teachers know about ESD, how they incorporate it into their teaching and learning while promoting critical thinking and problem-solving skills in learners. The study utilized the ESD competencies

framework developed by UNECE (2013) to understand and assess pre-service teachers' competencies in teaching Life Sciences. Adopting five key competencies, the framework provides a comprehensive set of categories that encompass diverse learning experiences.

(a) Learning to know, which refers to understanding the challenges that the society faces both locally and globally and the potential role of teachers and learners.

(b) Learning to do, which refers to developing practical skills and action competence in relating to education for sustainable development.

(c) Learning to be, which addresses the development of one's personal attributes and ability to act with greater autonomy, judgement and personal responsibility in relation to sustainable development

(d) Learning to live together, which contributes to the development of partnership and an appreciation of interdependence, pluralism, mutual understanding and peace.

(e) Learning to transform oneself and society, which addresses the knowledge, values and skills for transforming attitudes and lifestyles.

Using the ESD competencies framework alongside PCK competencies (subject content knowledge, pedagogical content knowledge, and curricular knowledge) enhanced our research by providing a deeper understanding of pre-service teachers' approaches to education for sustainable development (ESD). Through two key stages, lesson facilitation observations (stage 1) and semi-structured interviews (stage 2), we examined the extent to which pre-service teachers integrate ESD principles into their teaching practices. The ESD framework offered a structured lens for assessing broad sustainability competencies, while the PCK framework allowed us to evaluate teachers' grasp of content, pedagogy, and curriculum. Together, these frameworks helped identify how effectively pre-service teachers were fostering critical, inquiry-based learning aligned with sustainable development goals in their Life Sciences lessons.

Stage 1: Observations (30 Minutes)

Four pre-service teachers were purposefully selected to present to their classmates in a simulated learning environment. This setup allowed for close observation of each participant to gain a deeper understanding of their subject knowledge and assess their ESD competencies in the Life Sciences didactics module. Each participant delivered a comprehensive lesson, incorporating educational teaching media and innovative practices to demonstrate their ability to facilitate engaging lessons. During these simulations, they showcased their approaches to integrating sustainability themes, utilizing diverse teaching aids, and fostering interactive, inquiry-based learning among peers. This immersive environment enabled detailed observation of their pedagogical techniques, content delivery, and alignment with ESD goals, providing valuable insights into their competency development.

In a lesson of human impact to the environment, participant C introduced the lesson by asking learners about their thoughts on deforestation. The participant further touched on how climate change affects the environment, how these issues affect the communities and how they can be lowered. The observation made here is that the participant introduced the topic in a way that informs them about the learners' knowledge on the topic and the participant was able to relate the topic to real-world settings. However, the participant did not interconnect every component of PCK to scaffold student learning (Park & Chen, 2012). It was also evident that the participant was not familiar that in some aspects of their lesson, they integrated ESD. This supports Thomas et al. (2017) argument that with lack of ESD integration in teacher training, it causes teachers to lack understanding of the concept, ultimately causing a disconnect between instructional applications in ESD literature and experiences of teachers.

From the observations conducted, when participants taught Life Sciences, they were able to create opportunities for learners to share ideas, to meet new challenges and also engage them in real world issues. However, most of them failed to connect learners to their local and global spheres and to help them see a sense of urgency for change in the challenges we face. This indicates that the participants are unable to

link the content information with the issues of SD as PCK in science suggests. Ultimately, showing that participants don't have knowledge about SD issues, leading to them not knowing the appropriate strategies to in ESD.

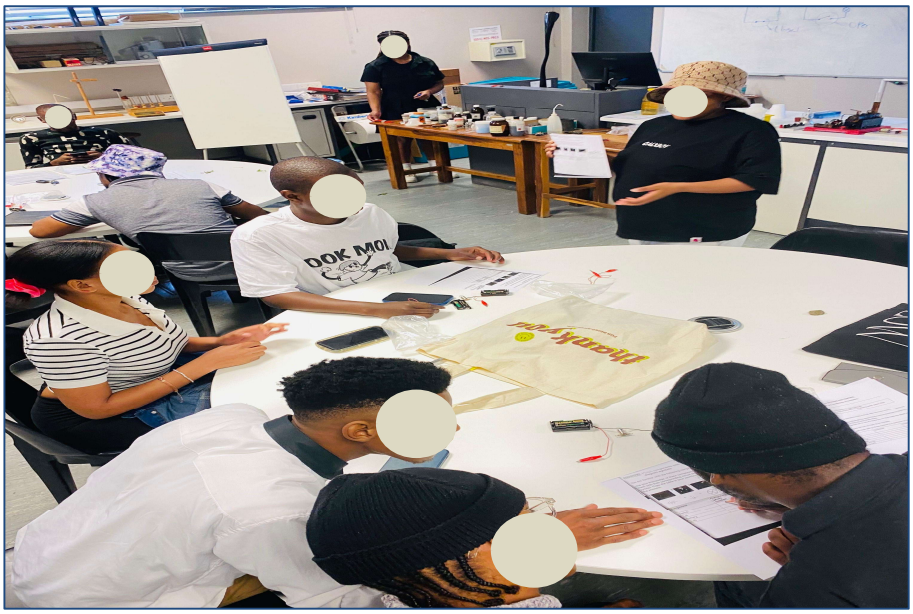

Image 1: *Hands-On Pedagogy: Developing ESD Competencies through PCK*

Image 2: *ESD in Action: Pre-Service Teachers Shaping PCK Competence*

The observations showed that participants used learner-centred methods such as collaborative learning to keep learners engaged and allow them to come to the answers themselves. Moreover, participants were able to regulate and facilitate class interactions to give each student a chance to engage with the teacher and their peers. Ultimately, supporting PCK, that instructional methods should be learner-centred, to allow learners the opportunity to make knowledgeable decisions concerning problems (Bremner et al., 2022)

When introducing the topic of genetics, participant A used direct instruction and gave learners a presentation on Mendel's experiment with pea plants, she further proceeded to play a video demonstrating the punnet square while interacting with the learners. She then gave them a peer activity to complete the punnet square and discussed their responses after. The observation indicated that no pillars of ESD were incorporated in the lesson, the participant was solely focused on the scientific aspect of genetic crossing with no reference to

sustainability. The participant failed to bring the real-life application of genetics to the learners. Which does not correspond with UNECE (2013) that a teacher should be able to achieve transformation by engaging learners in real-world issues, helping learners to make a difference in practice.

Stage 2: Semi-Structured interviews

Semi-structured interviews were adopted as the second data collection tool following the researcher's observations of participants' presentations, ensuring triangulation by combining multiple data sources for a more comprehensive understanding of pre-service teachers ESD competencies. Semi-structured interviews were particularly valuable in this study, as they allow for flexibility and depth, enabling the researcher to explore participants' perspectives on their strengths, weaknesses, and opportunities when using the ESD framework in their classroom practice. This approach is advantageous in qualitative research, as it provides a structured guide of questions while allowing participants to express their thoughts in their own words, encouraging authentic, reflective responses (Creswell, 2014). Conducting these interviews after the observations, the researcher could move into the participants' views on their teaching practices (PCK) and approaches to ESD, facilitating a richer understanding of their competencies and areas for growth. Thematic analysis, following Clarke and Braun's (2013) approach, was used to identify key themes emerging from the data. The study produced two themes and their categories as stipulated on below table.

Table 1: *Themes and Categories*

Theme 1	**Categories**
Perspectives of pre-service teachers' towards ESD	a. Experiences of ESD integration in teaching programs b. Connecting learning to life c. Support for integrating ESD in teacher training
Theme 2	categories
Facilitating ESD in Life Sciences using Pedagogical Content Knowledge	a ESD integration using PCK for effective instruction and assessment. b. Competences for Life Sciences teachers to integrate ESD c. Challenges implementing ESD in classrooms

Theme 1: Perspectives of pre-service teachers' towards ESD

Experiences of ESD integration in teaching programs

The potential of education to help change the world through learners cannot be realized unless higher institution teaching programs embrace SD and start equipping pre-service teachers with sufficient training to successfully integrate ESD. When participants were asked if they have been taught how to incorporate ESD in their teaching, they had mixed experiences that they shared.

Student D pointed out that:

> *As Life Sciences student teachers, we do teaching simulations where we get to practice on how to be effective teachers, and we are often encouraged to make examples of real life environment experiences on the topics we do, so that learners can relate it to what they go through every day, I think that is the university trying to incorporate ESD.*

Similarly, Student B said:

> *We are currently making posters to make students aware of the environmental issues that we face. So, I would say yes.*

These comments made by participants suggest that their understanding of ESD has to do with the environment, which states that they confuse Environmental Education with ESD. The environmental pillar is the one that is most recognized and employed, however, UNESCO (2018) reminds us that if education is only directed towards enhancing one pillar, it will lead to the other two pillars to become less sustainable.

Conversely, other participants expressed that ESD in teaching programs is not really emphasized. Making it hard for pre-service teachers to notice it or even show interest in educating themselves about it.

Student C had this to say that:

> *If it was integrated, then it was not clarified that it was ESD where I can point out and say in Life Sciences that this is sustainable development. They were just teaching me to apply pedagogical knowledge in classrooms.*

Connecting learning ESD to life

In order to understand if pre-service teachers acknowledge the significance of ESD, I asked them to share the importance of ESD being incorporated in Life Sciences and how it benefits learners. Despite the lack of supporting guidelines in teacher training, pre-service teachers found ESD to be beneficial to learners in Life Sciences. They recognize that life sciences is connected to ESD as it provides the primary knowledge and understanding of the natural world.

Student B stated that:

> *It is important to inform learners about ESD to show them that the content they learn does not end up in the classroom, but they can apply it in real-life. Allowing them to make connections with what they learn and the real world.*

In a similar vein, Student D postulated that:

> *Life Sciences is really an interesting subject that speaks for itself, it is so self-explanatory. And that is what makes it important for ESD to be incorporated in it. Life Sciences teaches learners about things that they experience on their daily lives and incorporating ESD in the subject will make it an easy thing for them to acquire the knowledge they need to not only sustain themselves but the community too.*

Student A also said:

> *Learners are the future of tomorrow, so we need to use Life Sciences to teach them how they can sustain the environment. Learners are not well informed about the current issues, so we need to ensure that the education they get teaches them how to approach these challenges.*

Student C had this to say:

> *I think it will make them critical thinkers and problem solvers, yes. This subject will equip them with the necessary skills to tackle ESD problems.*

This is also highlighted by Gresch et al. (2013) that the main goal of science education is to teach learners to be critical thinkers and engaged citizens who can make systematic and well-informed decisions. This aligns with the purpose of Education for Sustainable Development to encourage the development skills, attitudes and knowledge that enables learners to make informed decisions and address local and global challenges to create a more and just sustainable society (UNESCO, 2018).

Support for integrating ESD in teacher training

The higher education institutions have the advantage of accomplishing ESD as they have a history of in-depth research, they are able to form collaborative efforts into supporting students to find solutions for SD problems (El-Jardali et al., 2018). When participants were asked if the University was doing enough to support them with enough professional support and resources to integrate ESD in schools, they all had different opinions.

Student A mentioned that:

> *I think they are doing enough. They are exposing us to teach in a way that we can sustain what we have.*

Concurring with Student A was Student B who said:

> *Yes, they are doing enough. Student teachers go to teaching practical where they get to teach Life Sciences and relate it to real life experiences …ummm I feel*

> *like that is something that is sustainable, I will be able to pass the knowledge I received in my training on to my learners.*

This correlates to the argument by Finnvedene et al. (2019) that higher education institutions foster sustainability by developing strategies that help students to address sustainability issues so that they are able to contribute knowledge to society, not only within the university but with their daily tasks.

However, Student D had a different opinion:

No, the support is not specifically focused on student teachers, but it is generalized. They are focusing generally on everything that is happening, it is not adapted to pre-service teachers' teacher training curriculum. The university might have generalized workshops about sustainable development but that might hinder our knowledge as we might not be interested as pre-service teachers to go to those workshops because they are not particularly related to our course.

Student C further added that:

> *Not really, they are focused on us knowing the content, they do not focus on ESD as a whole. They should be making ESD a part of our objectives, it should be a core focus within the modules of teacher training.*

This supports the findings on (Mula et al., 2017; Filho et al., 2018) that South African's higher education does not put enough funding into supporting the implementation of sustainability into teacher training and they lack capacity to effectively integrate ESD into mainstream teaching practices programs. Moreover, there are no policy guidelines on ESD in teacher education curricula.

Theme2: Facilitating ESD in Life Sciences using Pedagogical Content Knowledge

Competences for Life Sciences teachers to integrate ESD

To successfully incorporate ESD in Life Sciences, the teachers are required to have specific set of competences which enable them to connect scientific topics to real-world sustainability challenges. To see if the participants are aware of these competences, we asked them to name the competences they are familiar with.

Student C shared that:

> *They should be masters of the content, see its applicability in the real world, then be able to align your objectives to the requirements of Sustainable Development.*

Student C further mentioned that:

> *Be able to give learners curiosity, promote creativity among the learners so that they see the importance of ESD in society and know your learners so that you can be creative in your teaching.*

Student B also pointed out that:

> *They should be computer literate and be researchers, be aware of their surroundings, volunteer and be hands-on.*

However, one participant did not have an idea of the competences required by teachers to successfully incorporate ESD.

Student D did not have much to say and only mentioned that:

> *I don't have much knowledge about this concept so I don't know which competences would be relevant.*

These responses do not align with the competences for educators in ESD set by UNECE (2013), showing how much little knowledge pre-service teachers have about the effective competences required to incorporate ESD in Life Sciences.

ESD integration using PCK for effective instruction

To successfully teach ESD in Life Sciences, pre-service teachers require more than just subject knowledge, they also require adequate pedagogical content knowledge. PCK is a content-specific knowledge that teachers should use to promote learners' learning of a specific subject matter (Chan, 2022:487). They need to be equipped about lesson planning, how to engage learners on important issues and addressing sustainability challenges. When participants were questioned about teaching methods that they think are more effective in ESD integration, they revealed various teaching techniques that they use in their teaching and learning.

Student A shared that:

> *Collaborative learning would be best because learners would be engaging and sharing experiences and ideas on how to address complex sustainability issues that we face.*

Student B also shared that:

> *I think problem-based learning is a good method. This method makes learners aware of the real life challenges that we face on a daily basis and how they can change their behaviors to help achieve sustainability.*

Student D had a few words to say and said:

> *Scaffolding is a great method to use and it is one of my favorite methods to use.*

Challenges implementing ESD in classrooms

ESD plays a significant role in fostering skills and knowledge needed by learners and teachers to promote sustainability. However, pre-service teachers may encounter challenges when implementing it in their future teaching. It is necessary to address these challenges in order to cultivate a generation of teachers equipped to tackle environmental, social and economic issues for the future. When participant were asked what challenges do they think they could encounter in their future teaching in schools, they responded as follows.

Student C shared that:

> *Because ESD is not part of the Annual Teaching Plan at schools, I might not have time to integrate it as we are given specific objectives that need to be met so that learners finish the content on time. If it is not part of the curriculum, I might shy away from it completely because it is not included in the bigger picture.*

Student C further mentioned that:

> *Resistance from leadership could also be a challenge, this concept is not done by a lot of teachers in schools. For instance, as a new teacher, I might want to take learners to the fields to give them first-hand experience of the environment, but I would be met by resistance from the management to say that we do not have time on our hands, learners need to focus on the content.*

This is supported by findings on (kandangama, 2018) which states that time constraints are one of the major barriers of implementing ESD, with lack of dedicated time in school timetables for ESD programs. Sustainable Development is not considered as a critical concept in schools, which ultimately makes teachers to not include it in their lesson planning. Participants also believe that another challenge that could hinder the implementation of SD is the lack of resources in some of the schools. Student A pointed out that:

> *Schools in rural areas lack resources, they are not adapted to incorporate ESD. Already there are lack of textbooks in those schools, so bringing in a new concept could be challenging.*

This is shown in the study of Kandangama (2018) that key barriers such as time constraints, insufficient funding and shortage of trained personnel are some of the reasons for ineffective integration of ESD in schools. Participants also expressed that they have little knowledge about the concept, which will make it hard to get learners to be motivated and excited to learn about SD. They believe that if they are given training and enough resources to implement ESD, there would be much progress in ensuring that they prepare learners for a sustainable future.

DISCUSSION

This study highlights the essential competencies required for pre-service teachers to effectively integrate Education for Sustainable Development (ESD) in Life Sciences. The findings indicate a varied understanding among pre-service teachers regarding ESD's role, with many participants associating it primarily with environmental education. This limited view reveals a gap in understanding ESD's broader dimensions, and its foundational pillars (environmental, social and economic) grounded on ESD framework components learning to know, learning to do, learning to live together, and learning to be (UNECE, 2013). Participants' associations of ESD with environmental themes alone, while meaningful, reflect a narrow scope of its potential for fostering a more holistic and sustainable worldview.

Moreover, observations and semi-structured interviews suggest a disparity in how pre-service teachers incorporate ESD competencies in their lesson planning and facilitation. While

some participants recognized the value of connecting Life Sciences content with real-life sustainability issues, they struggled to extend this connection to ESD's social and economic dimensions. This gap suggests the need for strengthened subject content knowledge within the Pedagogical Content Knowledge (PCK) framework, as teachers must possess both a solid foundation in Life Sciences and an awareness of broader sustainability themes to facilitate holistic learning (Shulman, 1987). The research revealed that pre-service teachers, while adopt at employing learner-centered methods such as group work and discussions, often lacked depth in implementing learning to do and learning to live together competencies in their classrooms. These competencies are essential for encouraging critical thinking, collaboration, and social responsibility among learners, skills that are integral to ESD (UNECE, 2013). As highlighted by Darling-Hammond et al. (2017), developing such skills requires that teachers are well-versed in curricular knowledge to make intentional choices about content integration, further pointing to the necessity for structured support within teacher preparation programs.

An additional challenge uncovered was the participants' limited familiarity with ESD resources and frameworks, underscoring the critical role of institutional support. Many participants felt they lacked access to resources that would help them integrate ESD more thoroughly, reflecting a gap in pedagogical content knowledge and curricular knowledge that is vital for contextualizing ESD within Life Sciences. This finding aligns with Schleicher (2018), who emphasizes the need for institutional support and professional resources to empower educators to incorporate complex, interdisciplinary competencies like ESD effectively.

Implications For Teacher Education

The observations and participant responses indicate that while pre-service teachers understand the importance of ESD in theory, they require a clearer framework to align their practice with ESD principles. Targeted PCK training focusing on ESD competencies would enhance their ability to bridge theory with practical applications, ultimately preparing them to foster learning to be in students—a competency that emphasizes personal growth, ethical values, and responsibility toward sustainability (UNECE, 2013). Strengthening these areas in teacher education programs would help future educators build a comprehensive approach to sustainability, enabling them to design learning experiences that connect scientific content to pressing real-world issues.

CONCLUSION AND RECOMMENDATIONS

This study highlighted the importance of equipping Life Sciences pre-service teachers with both Education for Sustainable Development (ESD) and Pedagogical Content Knowledge (PCK) to effectively implement sustainable development principles in their teaching. Although participants demonstrated a basic awareness of ESD's environmental dimension, their limited understanding of its social and economic dimensions underscores the need for more comprehensive training. Specifically, the study recommends that teacher education programs strengthen competencies aligned with UNECE's (2013) four pillars of ESD learning: learning to know, learning to do, learning to live together, and learning to be.

Integrating ESD into core teacher education curricula rather than treating it as an isolated module will enable pre-service teachers to develop the knowledge, skills, and values necessary to prepare learners for sustainability challenges. Life Sciences educators must be equipped with strong subject content knowledge, PCK, and curricular knowledge to create classrooms that foster sustainability-oriented thinking and action. To support these efforts, institutions should provide quality teaching resources such as UNESCO's Education for Sustainable Development Goals: Learning Objectives (2017), the UNECE Teacher Competence Framework for ESD (2013), and localized sustainability case studies relevant to South African contexts. These tools can help teacher educators develop targeted interventions and enhance ESD integration in Life Sciences education.

This study was limited to a small, once-off qualitative sample of four pre-service teachers, which restricts the generalizability of the findings. Additionally, the study was conducted at a single institution, which may not reflect the broader state of ESD integration across other South African teacher education programs.

Furthermore, due to time and resource constraints, the study did not explore long-term impacts on teaching practice or learner outcomes in classrooms.

Future studies should involve a larger and more diverse group of pre-service and in-service teachers across multiple institutions to validate and expand upon these findings. Longitudinal research is also needed to examine how ESD competencies develop over time and how they influence actual classroom practices. Experimental or mixed-method studies could evaluate the effectiveness of specific ESD training interventions. In addition, collaboration with curriculum developers and education departments could support the co-creation of contextually relevant ESD materials for Life Sciences education. Ultimately, for South Africa to achieve its commitment to the Sustainable Development Goals (SDGs), teacher education must prioritize holistic, well-supported approaches that empower teachers as agents of change.

REFERENCES

Agbedahin, A. V. 2019. *Sustainable development, Education for Sustainable Development, and the 2030 Agenda for Sustainable Development: Emergence, eminence, and future*. Sustainable development, 1-10.

Bremner, N., Sakata, N., & Cameron, C. 2022. The outcomes of learner-centred pedagogy: A systemic review. International Journal of Educational Development. pp1-2.

Burgener, L., & Barth, M. 2018. *Sustainability competencies in teacher education: Making teacher education count in everyday school practice*. Journal of cleaner production, 174(10):821-826.

Chan, K.K.H. 2022. *A critical review of studies using the pedagogical content knowledge map approach*. International Journal of Science Education. 44(3), 487-513.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approach* (4th ed.). Sage Publications.

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2017). Implications for educational practice of the science of learning and development. Applied Developmental Science, 21(3), 167–177.

Dimenas, J., & M. Alexandersson. 2012. *Crossing Disciplinary Borders: Perspectives on Learning about Sustainable Development*. Journal of Teacher Education for Sustainability, 14 (1): 5–19.

Ferguson, T., Roofe, C., & Cook, L.D. 2021. *Teachers' perspectives on sustainable development: the implications for education for sustainable development*. Environmental Education Research. 27(9): 1343-1359.

Gresch, H., Hasselhorn, M., & Bögeholz, S. 2013. *Training in decision-making strategies: An approach to enhance students' competence to deal with socio-scientific issues*. Int. J. Sci. Educ. 35, 2587–2607.

Hogan, D., & O'Flaherty, J. 2021. *Addressing Education for Sustainable Development in the teaching of science: The case of biological sciences teacher education program*. Sustainability, 13(21): 1-22.

Howard, P. 2019. *Re-visioning teacher education for sustainability in Atlantic Canada. In Environmental and Sustainability Education in Teacher Education*. Springer: Cham.

Kandangama, K. G. C. (2018, November). Challenges and barriers for implementing education for sustainable development (Esd) in secondary schools in Sri Lanka. In *Proceedings of the international conference on future of education* (Vol. 1, No. 1, pp. 1-7).

Kandangama, K.G.C. 2018. *Challenges and barriers for implementing Education for Sustainable Development (ESD) in secondary schools in Sri Lanka.* International Conference on Future of Education, 1(1):1-7.

Khadim, M., Qureshi, N., & Khan, A.M. 2022. *Challenges of implementing Education for Sustainable Development: University Teachers' Perspectives*. PJE, 39(1):1-14

Kioupi, V., & Voulvoulis, N. 2019. *Education for Sustainable Development: A System Framework for Connecting the SDGs to Educational Outcomes*. Sustainability, Imperial Collage London: London.

Leicht, A., Heiss, J., & Byun, W. 2018. *Issues and Trends in Education for Sustainable Development, Education on the Move*. UNESCO Publishing: Paris, France.

Maidou, A., Plakisti, K., & Polatoglou, H. M. 2019. *Knowledge, Perceptions, and Attitudes on Education for Sustainable Development of Pre-service Early Childhood Teachers in Greece.* World Journal of Education, 9(5): 1-15.

Nousheen, A., Zai, S.A.Y., Waseem, M., & Khan, S.A. 2019. *Education for Sustainable Development (ESD): Effects of sustainability education on pre-service teachers' attitudes towards sustainable development (SD).* Journal of Cleaner Production. https://doi.org/10.1016/j.jclepro.2019.119537

Park, S., & Chen, Y.C. 2012. *Mapping out the integration of the components of pedagogicalcontent knowledge (PCK): examples from high school biology classrooms.* Journal ofResearch in Science Teaching, 49(7): 922–941

Park, S., & Oliver, J.S. 2008. *National Board Certification (NBC) as a catalyst for teachers' learning about teaching: The effects of the NBC process on candidate Teachers' PCK development*. Journal of Research in Science teaching, 45(7):812-834.

Qablan, A. 2018. *Building capacities of educators and trainers*. In Leicht, A., Heiss, J. and Byum, W.J. (Eds). Issues and Trends in Education for Sustainable Development Education on the Move: Paris.

Schleicher, A. (2018). World class: How to build a 21st-century school system. OECD Publishing.

Shulman, L.S. 1987. *Knowledge and teaching: Foundations of the new reform*. Harvard Educational Review, 57(1):1-22.

Sinakou, E., Donche, V., Boeve-de Pauw, J., & Van Petegem, P. 2019. *Designing Powerful Learning Environments in Education for Sustainable Development: A Conceptual Framewor*k. Sustainbaility, 11(29).

Somekh, B. 2011. Observation. In B. Somekh & C. Lewin (Eds.), Theory and methods in social research. (2nd ed.) 131-138. London: Sage Publications.

Ssosse, Q., Wagner, J., & Hopper,C. 2021. *Assessing the impact of ESD: Methods, Challenges, Results*. Sustainability, 13(5): 2854.

UNESCO. 2014. *Global Citizenship Education: Preparing Learners for the Challenges of the 21st Century*. UNESCO: Paris.

UNESCO. 2017. *Education for Sustainable Development Goals. Learning Objectives*. UNESCO, Paris: France.

UNESCO. 2018. *Education 2030: Incheon Declaration and Framework for Action Towards Inclusive and Equitable Quality Education and Lifelong Learning for All*. Paris: France.

United Nations Economic Commission for Europe (UNECE). (2013). Learning for the future: Competences in education for sustainable development.

United Nations. 2017. *Transforming Our World: The 2030 Agenda for Sustainable Development.* UNESCO: Paris.

Vukic, T. 2019. *Sustainable Development from High School Teacher's Perspective*. Philosophy, Sociology, Psychology and History, 18 (3): 131–148.