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STEM Education in Metaverse Environment: Challenges and Opportunities

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As the 21st century progresses, expectations and demands for STEM and STEAM education are increasing (Dönmez et al, 2022). Developed and developing countries are trying to increase the practice of students and teachers in STEM education by revising their education programs. STEM education, which emerged as a result of the increasing global economic and scientific competition, is seen as an educational approach that helps develop individual life skills and increase social welfare (Idin, 2018). One of the ultimate goals of the STEM education approach is to equip the individual with skills that enable the individual to solve real-life problems with a transdisciplinary education approach (Gülen, 2021). STEM education, it is aimed to implement multiple disciplines integrated with each other and within the framework of a common theme. It is known that these disciplines include sciences such as engineering, art, and technology along with many branches of science (Dönmez et al., 2021). It is important that updates and new studies in these sciences are integrated into STEM education and used in coordination. In particular, the rapid acceleration in technology should be reflected in educational environments and integrated with STEM education. As a matter of fact, the most popular of the innovative structures in the technological field is the metaverse.

In the Neal Stephenson 's 1992 “Snow Crash” book, there is the concept of metaverse, which is used as a beyond universe. Although this concept has a fictional meaning, it is considered as a dimension like "the future of the internet" or time. In fact, in theory, it can be called the precious state of real-world life in the virtual environment. It is estimated that the concept of metaverse will exist with its technological infrastructure and the universe it creates. The concepts of software, artificial intelligence, virtual reality, cloud storage, augmented reality, virtual reality and blockchain are related to the metaverse. There is no truly holistic metaverse, but fragmentary examples can be given. Education-based activations in the virtual world, cryptocurrencies and shopping with them, internet-integrated games and digital-based interactions such as virtual concerts, meetings, building a virtual city or buying land in this game, online shopping sites can be perceived as a metaverse. In other words, it is called the new concept formed as a result of the digital integration of these platforms in the virtual world. It is said that you can live in this world by making your own digital face, that is, your avatar, that you can join individually in the Metaverse. To give a few examples; For those who want to do sports at home, having avatars of the same or different sports coaches at the same time, increasing the number of referees in football matches with avatars, relieving the pain of virtual reality during childbirth, being exposed to global warming in the digital environment and being sensitive to the environment and atmosphere in the real environment are some examples (Birer, 2022; Özkahveci et al., 2022).

With metaverse components and the proliferation of metaverse candidate applications, the possibility of metaverse implementation in many areas is increasing. Recently, the Covid-19 pandemic has also severely disrupted the education system. Alternative education approaches have come to the fore and it is aimed to continue education by making many applications within the scope of digitalization in education. The training made with applications such as remote, (online) meet or zoom could not be productive due to many other factors such as internet infrastructure problems and technological inadequacies. A metaverse environment can provide an important environment for such virtual training. It can also be considered as the avatars of students and teachers, who could not be taken into the classroom environment during the Covid-19 pandemic, to come together in a virtual environment and provide education and this provides real learning. Although platforms are just beginning to be formed by adding the concept of a metaverse in many areas, a similar meta world can be created in the field of education. Concepts such as meta education or Meta education may be included in industry 5.0. Similarly, STEM education, which is the trend education approach of the age, can be an alternative environment as an application area (Tekin et al., 2022).

The problems experienced in the application areas for STEM education, such as time constraints, integration, and the high number of students, can be eliminated with the metaverse environment. The technology dimension of STEM education is integrated with the metaverse environment. STEM education can be applied in the metaverse environment by coordinating science, engineering, and mathematics with a transdisciplinary theme. Lesson topics integrated into the "universe" component of Metaverse can be realized with the participation of student and teacher avatars. The metaverse universe provides real-world conditions to be presented at a level close to reality. The transfer of disciplinary issues to the virtual world with real-world applications will enrich the universe. Examples such as learning systems over the human body in science, testing chemical reactions comfortably, mathematical calculations, testing various scenarios and possibilities, designing and making engineering products, enabling practical applications in the field of medicine, drawing and measuring digital or real objects, and creating creative ideas. Examples can be studies that can be done in the metaverse environment of STEM education. As with any approach, there will be challenges and opportunities in STEM education settings.

Challenges in STEM Education in the Metaverse environment;

- Finding the necessary equipment to enter the Metaverse environment,
- Production of software in a specific field,
- Inability to access a strong internet infrastructure,
- Legal loopholes,
- Problems of disconnection from the real world may arise.

Opportunities in STEM Education in the Metaverse environment.

- It will provide the development of cognitive, affective, and psychomotor skills for the learner.
- It will improve cooperation and teamwork.
- Virtual classrooms will facilitate access to hard-to-see experiments and applications.

- It will provide a modelling opportunity.
- It will provide equal opportunity for disadvantaged groups.

Especially the pandemic, war, economic and social problems make the transformation of school environments necessary. During the pandemic period, virtual classrooms came to our rescue. Now, with the digital revolution, we must take steps to move educational environments to virtual environments. However, there seems to be a need for more detailed research on the reflections of the metaverse on education and STEM applications, especially on education researchers. From this point of view, it seems that there is a need for multidimensional studies with researchers, students, teachers, and other stakeholders in the metaverse environment.

Conflict of Interest

The author declares no conflict of interest.

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Addressing Virtual Learning Challenges in Higher Institutions of Learning: A Systematic Review and Meta-analysis

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ABSTRACT

Many universities across the globe are set to keep lectures online, more especially in this era of COVID-19 and yet there is an increased spotlight on the challenges faced by learners. Some of these challenges include; issues related to communications, assessments and scheduling of lectures. Teaching and learning in an e-learning environment is said to happen differently as opposed to the traditional classroom and this can present new challenges to instructors and learners. The purpose of this study was to review the various ways of addressing virtual challenges in higher institutions of learning. Literature Search of databases of Google Scholar, PubMed, SCOPUS and ResearchGate using the keywords "Addressing virtual learning challenges" was done. Additional inputs were taken from blogs and relevant reports. The results varied; some learners reported that "It's difficult to share our points as online discussions can move swiftly from one topic to another. Engaging a big class in a live forum can be challenging too." Other learners asserted that by regulating who can speak up at one time, the moderator can ensure that no one is left behind. However, it is also reported that there is a growing concern of plagiarism surrounding online examination and thus stringent plagiarism checks must be enhanced to curtail such vice. Conclusively, a lot is still needed to address virtual learning challenges. No single measure is exhaustive enough and more vigilance is required to sustain the adopted measures and improve the quality of virtual learning.

Keywords: Virtual learning, Higher Institutions of Learning, Challenges, Lecturers, Learners, Instructors

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INTRODUCTION

Online learning, also called virtual learning, is defined as "learning that takes place partially or entirely over the Internet" (US Department of Education, 2010). Online or virtual learning is appealing to a number of learners and is becoming a more common form of teaching and learning for many universities across the globe.

In the wake of COVID-19 pandemic, changes in the process of teaching-learning in higher education institutions became inevitable and this greatly influenced the interaction between teachers and students. The end result of the pandemic constrained many universities to carry out their activity with students exclusively online (Claudiu et al., 2020). In Uganda, many universities had to shift to e-learning in order to ensure continuity of studies/learning following the indefinite closure of education institutions in the country. The National Council for Higher Education (NCHE) released immediate guidelines for e-learning in institutions of higher learning across the country. This was in order to commence remote teaching and learning activities during the ongoing Covid-19 lockdown (Anon., 2020).

Thus, now days, the higher education system is in a continuous process of change. This is because universities have to keep pace with the needs, desires and requirements of their students (Claudiu et al., 2020). Therefore, to carry out the university activities, information technologies and virtual learning systems are seen as very essential. As a consequence, many of these institutions have decided to invest more and more in online systems and devices (Popovici & Mironov, 2015). Meanwhile, in this technology era, integration of innovative virtual learning systems with intent to reinforce and support both teaching and learning processes has remained one of the main challenges of many universities (Fischer et al., 2014).

As shown in previous studies, virtual learning offers many benefits for students as it involves student-centeredness, more flexible (Dhawan, 2020). It can also improve interaction with students by providing asynchronous and synchronous tools, alongside other benefits (Marinoni et al., 2020). The said asynchronous and synchronous tools include e-mail, forums, chats, videoconferences, zoom and others (Adnan & Anwar, 2020). Again, internet technologies facilitate the distribution of content to a large number of users; E-learning platforms offer many advantages to learners such as control over the content and control over the time spent while learning. This is a huge advantage. In this way, learning process can be easily adapted according to the needs of the learner and objectives of learning (Claudiu et al., 2020). In another scholarly debate, it is argued that for centuries, education has relied on classroom methods and yet technology-enhanced learning can potentially bring about a revolution in learning, making high-quality, cost-effective education available to a greater number of people. The basic advantages of e-learning include anytime-anywhere access to learning, cost reductions, ability to reach larger markets, more effective learning with personalized instructions as well as flexibility (Yusuf & Al-Banawi, 2013).

However, when using virtual learning platforms there are also so many challenges that impede learning. These include; decreased motivation in students, delayed feedback from lecturers as they will not always be available online and due to lack of physical presence of classmates, there is feeling of isolation, which compromise learner for some learners. In another scholarly debate, it was argued that higher education institutions faced different challenges in their teaching-learning activities as a result of the unprecedented COVID-19 incident. Following lack of preparation superimposed with the inherent problems of remote assessment, conducting assessments remotely during virtual learning posed extraordinary challenges for higher education institutions (Fiseha et al., 2020; Claudiu et al., 2020).

Nonetheless, with the help of teachers who adapt their teaching strategies to the needs of students, these obstacles can be overcome with time, however slow it may be. For this to be more of a success, experience and knowledge about teaching in the online environment are highly necessary, without relaxation. Other scholars (Fiseha et al., 2020) asserted that in recent years, online learning was adopted in many higher institutions of learning and as a result remote assessment of students has become challenging. This is most especially when it comes to ensuring academic integrity. Lecturers are therefore, forced to devise strategies for appropriate remote assessment.

Objective

The objective of this study is to review the various ways of addressing virtual learning challenges in higher Institutions of Learning

MATERIALS & METHODS

The author followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and conducted a systematic review using PubMed, Google Scholar, Web of Science and other sources between 2011 and 2022.

Framing questions

The author identified the particular problem to be addressed by the review and specified it in the form of clear, unambiguous and structured question before beginning the review (Khan, et al., 2003).

Identifying relevant publications

The author made an extensive search for a number of studies. Multiple resources were searched without language restrictions both electronically and physically. Literature Search of databases of Google Scholar, PubMed, SCOPUS and ResearchGate using the keywords "How COVID-19 affected schools that opened or partially opened during the Pandemic in Africa" or "School closure in COVID-19 era in Africa" and "COVID-19" was made. Other additional inputs were taken from blogs and relevant reports (Linares-Espinós, et al., 2018; Khan, et al., 2003).

Furthermore, various internet engines were searched for web pages that might provide references. This effort resulted in 781 papers from which relevant studies were selected for the review. The potential relevance was examined and 763 papers were excluded as irrelevant. The full papers of the remaining 18 studies were assessed to select those primary studies of interest. These criteria excluded 763 studies and left 7 in the review. They came from different countries, published mainly in English language between 2011 and 2022. See **figure 1** for details of the selection process.

Assessment of the quality of studies

Assessment of study quality was done. Question formulation and study selection criteria above described the minimum acceptable level of design. Selected studies were subjected to a more refined quality assessment by the use of general critical appraisal (Linares-Espinós, et al., 2018). See figure 1.

Summarizing the evidence
Data synthesis consisted of appraisal of study characteristics, quality and effects as well as use of statistical methods for exploring differences between studies and combining their effects (meta-analysis). Exploration of heterogeneity and its sources was planned in advance. Where an overall meta-analysis could not be done, subgroup meta-analysis was considered (Linares-Espinós, et al., 2018).

Interpreting the findings
In order to interpret findings, the issues highlighted in each of the sub-sections above had to be met. The risk of publication bias and related biases was explored. Exploration for heterogeneity helped to determine whether the overall summary could be trusted, and, if not, the effects observed in high-quality studies was used for generating inferences. See **figure 1** for details of selection of paper with outcome of interest.

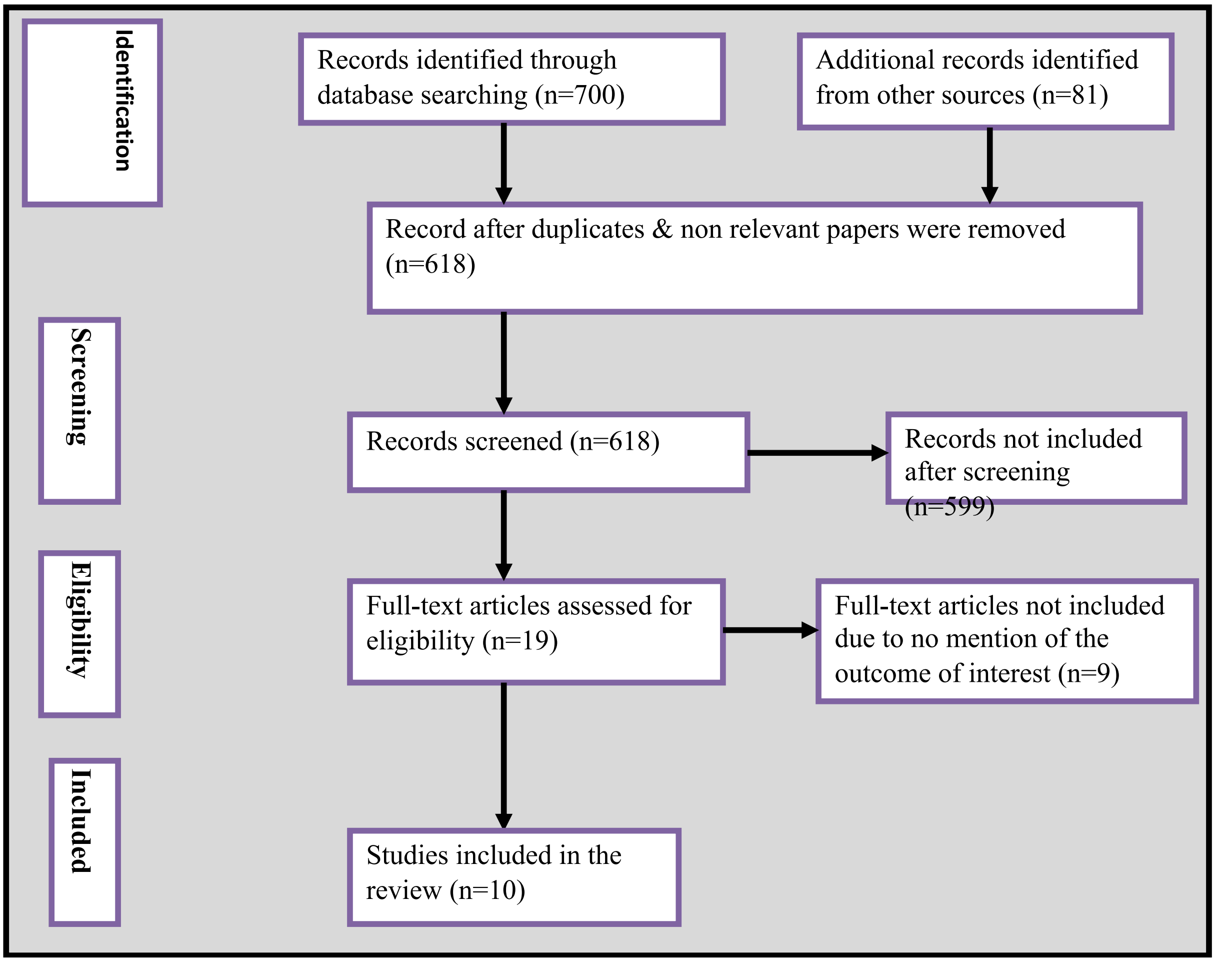

Figure 1: *Flowchart Showing the Selection of Studies for the Meta-Analysis of Ways of Addressing Virtual Learning Challenges in Higher Institutions of Learning*

Background Results

To answer the objective of the study, a thorough review of published materials was made to objectively analyze ways to address virtual learning challenges in higher institutions of learning (Figure 1). A total of ten (10) studies, most of which were retrospective and all of high quality, between 2011 and 2022 was used to examine virtual learning challenges in higher institutions of learning. See table 1 for summary of studies identified.

Table 1. Summary of Identified Factors for Addressing Learners' Engagement in Higher Education Learning

Identified Factors for Addressing Virtual Learning Challenges	Description	Research
Interpersonal interaction	**1)** Learner-to-instructor (such as sending announcements or e-mails, providing feedback, holding counseling hours and having instructors present in online learning) **2)**Learner-to-learner (such as, participation in online discussions, collaborative working & providing feedback)	Klawitter, 2022; Kearns, 2012; Suskie, 2009; Reddy & Andrade, 2010
Curriculum & learning design	**1)**Authentic learning activities **2)** Active learning **3)**Course resources (such as clear learning objectives and instruction, a wide variety of resource formats and difficulty levels, interactive digital content, multimedia)	Fiseha et al., 2020; Rutgers, n.d; University of Florida, 2020; Durfee, 2010; Baker, 2011; Reddy & Andrade, 2010
Achievement motivation	**1)**Learners' self-belief and inner desire to acquire knowledge **2)** Work autonomously **3)** Achieve self-learning goals	Fischer et al., 2014; Klawitter, 2022
High expectations	Set by learners and others such as high standards for acceptable academic work, high and clear academic expectations, and difficulty level of assessments	Durfee, 2010; Reddy & Andrade, 2010
Supportive environment	**1)** Instructor support such as, instructors' accessibility, presence and passion **2)**Infrastructure support (such as welcome and diverse learning environment, various support services, devices and internet accessibility)	Klawitter, 2022; Fiseha et al., 2020

Virtual Learning Challenges and their Solutions

There are a number of drawbacks and potential issues face by both students and educators while engaging each other in virtual learning (Brittany, 2015). In a recent study it was reported that recent polling from College Reaction showed that 77% of students surveyed said they felt distance learning was worse or much worse than in-person classes. This study was in more than 800 college students (Klawitter, 2022; Suskie, 2009). Thus, the list of challenges is endless. This review highlights only a few to mention;

Distractions everywhere

Distractions have become a reality of remote learning. Many distractions around the learner can be disruptive for everyone involved in the virtual learning platform, especially if you are in the middle of a virtual classroom session (Klawitter, 2022). As a result, these distractions have become more challenging to manage.

Solution: The solution to distraction is to aggressively look for better environment to learn. This lies in the hand of the learner

Time management

Poor time management on the part of learners or educators has always affected quality of virtual learning (Klawitter, 2022). Time management is one of the most difficult challenges for students to overcome. This is because time management depends entirely on self-motivation.

Solution: The solution is that students need to be serious with their education. As they get serious, they must learn how to manage time and set their daily schedules, and then learn to study amidst the constant distractions.

Staying motivated

Finding the motivation to get started on coursework can be extremely difficult, especially, given the fact that students may not be attending class at a set time on a physical campus environment.

Solution: Creating a daily schedule and finding a productive workspace is the best way to solve this. This can help to focus on the ultimate goal of studying. It helps to keep the learner's reason for pursuing his or her degree at the top of his or her mind. Similarly, students need to stay in touch with their classmates, in addition to reaching out to faculty or academic staff. This, also, is self-motivating (Fischer et al., 2014). The more involved one is with his or her distance education, the more it is on top of his or her mind. On daily basis, the students need to log in to see the course updates, class discussions and also to connect with other students and share questions or perspectives (Klawitter, 2022).

Technical issues

Unexpectedly, it is unfortunate that in online environment, technical issues are likely to occur. Even if this may appear too obvious, such technical issues grossly add to the frustrations of online environments, and hence, interrupt home learning. Computers may unexpectedly shut down couple with the fact that there are also moments when the internet or wifi becomes spotty and weak. This contributes to the difficulty in keeping up with one's virtual classmates (Klawitter, 2022).

The solution; again, **t**he most important step is for the learner to stay in touch with his or her lecturers and inform them about what is happening. They should understand and be flexible about the situation, perhaps even recording class sessions as a backup. Technical support services can be a valuable resource for virtual learning if the university has it for students.

Some Students being left behind

Normally, in the classroom, lecturer can monitor the students and adjust their pace to accommodate anyone who needs extra time. Meanwhile in a virtual environment, it's may be somewhat difficult. Virtually it is harder to read body language and thus learners may stay silent or put on a brave face and then leave the class feeling frustrated and having learned nothing at all without the lecturer noticing it (Klawitter, 2022).

Solution: Again, the solution here also lies with the learner; He or she needs to set up for success by asking for information on any relevant apps he or she may not understand or how to access the classes. The learners must be sure to know how to raise concerns to their lecturers, be it during the online classes, through e-mail or on a different form of communication.

Diminished social aspects

Of the many challenges of online learning system, another spot in the list of challenges goes to the loss of many social aspects with the online route. As requirement for completion of many degree programs in universities, there are certainly many aspect allotted to social interaction with peers online. Among these interactions are; classroom activities or even "social lounges" set outside of the digital classroom. Despite all the advantages of the online platform of learning, they are still not the same or a replacement of physical environment and or in-person relations. Interacting in person creates more considerable bonds and many other supportive attributes for the students. This indeed is a challenge harder to face for some learners than others. The adjustment can be particularly difficult for students taking classes that are better suited for the face-to-face format, such as those with science practical components, for example first aid course in health sciences (Klawitter, 2022).

Frustrations due to the lack of human contact, physical absence of lecturers, and an inability to discuss problems with classmates can easily creep in and disrupt learning process. Sometimes, the online world, no matter how enriching it may be, can become too small and the learner will need a physical space where he or she can resolve his or her queries and practice with real tools.

Solution; Should this is the case; one solution is to foster personal interaction within the online world as much as possible. The lecturers can organize and plan for webinars, group work or forums where students can discuss and resolve their queries.

Remote assessment

Many higher education institutions across the globe have faced different challenges in their virtual teaching-learning environment, which can be unique to individual institutions or cross-cutting among many institutions. In particular, remotely conducting assessments in the wake of COVID-19 posed extraordinary challenges for many higher education institutions. This was aggravated by lack of preparation superimposed with the inherently known problems of remote assessments. Thus, as online learning became adopted in many higher institutions, remote assessment of students became a very huge challenging, especially in ensuring academic integrity (Fischer et al., 2014). It is also reported that there is a growing concern of plagiarism surrounding online examination and thus stringent plagiarism checks must be enhanced to curtail such vice.

Solutions;

A number of remote assessments methods are available to evaluate the online learning of students (Kearns, 2012). Concerning plagiarism, stringent plagiarism checks must be enhanced before further assessments are made. The assessments are broadly classified into; (1) remotely proctored exams and (2) open-ended assessments.

1) Proctored exams

A Proctor is someone who watches candidates for examination to prevent cheating or someone who supervises an examination. This examination is time-bounded and proctored, as well. By using various learning management systems such as Canvas and Sakai, proctored exams can also be done remotely (Fiseha et al., 2020).

2) Quizzes

In order to demonstrate their understanding on the materials provided, series of quizzes provide low-stake opportunities for students. Quizzes also give ongoing information about the understanding of the students and can, thus, serve as means for feedback for improvement. Randomization of questions is easier for quizzes. Various applications software such as Canvas and Sakai to make cheating more difficult can be used, thus providing remedy for virtual assessment (Fiseha et al., 2020).

3) Open-book and take-home assessments

Open-book and take-home assessment provide, yet another alternatives, in remote assessment of students in higher institution of learning. These kinds of assessments are conventional and used under the traditional teaching-learning process. In the event that, there is no possibility of proctored exam, take-home exam can exclusively serve as the main method of assessment to cover the outcomes of learning by the learners (Fiseha et al., 2020).. The major challenge of using take-home-exam as assessment method lies in the preparation of more conceptual questions that cannot be found directly or easily in any type of sources, such as the internet and textbooks. The students will have to apply knowledge learned in order to complete the task; short of that, the students run the risks of failing the assessment (Fischer et al., 2014).

4) Professional presentations or demonstrations

Professional presentations and/or demonstrations can be done in audiovisual. These assessment methods are good in demonstration of the understanding of the learners, especially when presentation is conducted online. The presentation can be done using any web based online conferencing system, such as ZOOM, MS Team, and google meet, among others (Fiseha et al., 2020).

5) Annotated bibliography

An annotated bibliography is a summarization of essential ideas contained in a document, thesis, research article, and others and the learner discusses how they relate to his or her own ideas or thesis (Fiseha et al., 2020). An evaluative annotation adds to the judgments of the lecturer about the quality of ideas of the student. This method gives students a choice in selecting works while assessing their higher-order abilities to evaluate sources, compare multiple perspectives and provide rationales for their choices (Rutgers, n.d).

6) Fact sheet

By definition, a fact sheet provides information to the readers (lecturer) in a clear and concise format. The learner provides a fact sheet presented on a piece of paper or digitally. This informs readers (lecturer) about the business, organization, product, service, campaign or event on the topic under investigation, for which the lecturer intends to assess the learners' knowledge (Kearns, 2012). Fact sheets should centered around one issue or topic. It should not be more than one page with a clear, easy-to-read layout; otherwise, mix up of information will ensue, thus causing confusion to the reader, thus making assessment even more difficult. Sometimes, learners can also create fact sheets in a single page on various topics, works, or companies; subject to the requirement by the lecturer. In this case, students may select their own topic, or it can be assigned to them by the instructor (Fiseha et al., 2020).

7) E-portfolio

E-portfolio is considered a learning tool as well as tool for assessment. Learners are expected to compile their best or representative work from the semester. They write critical introduction to the portfolio and a brief introduction to each piece (Fiseha et al., 2020). Achievement of learners can then be evaluated collectively for a module improvement (Kearns, 2012). The lecturer can use this to organize, sample and assess how much a learner has what gained out of it. Therefore, E-portfolios enable lecturers not only to observe what learners know and can do, but also to indicate how much they learn through their personal reflections on the subject being assessed (Rutgers, n.d).

8) Use of Rubrics

Rubric is a scoring guide used to evaluate performance or product or a project. There are distinctively three parts: 1) performance criteria; 2) rating scale; and 3) indicators. Rubric defines what is expected and what will be assessed for both the lecturer and the learner (University of Texas, 2017; Reddy & Andrade, 2010). It is an invaluable addition to any assignment. This is because it promotes learner's success while also benefiting instructor at the same time. Therefore, a well-designed rubric sets a clear blueprint for an assignment by defining and clarifying expectations and demonstrating the importance of the individual components of the assignment at hand. It encourages authentic self-assessment of learners (University of Florida, 2020). Rubrics are important tools in teaching learners about their own learning. Because rubrics provide specific and consistent feedback on work submitted, the use of rubrics can be used as a tool for providing feedback during self-assessment and peer review of submitted assignment. Faster grading of assignments and providing greater consistency over time and amongst graders is enhanced because rubrics give room for predetermining expectations. Rubrics also allow instructors to easily identify weak points and re-teaching opportunities, while offering powerful feedback (University of Florida, 2020; Durfee, 2010).
A sample assessment rubric (University of Texas, 2017) is shown in table 1 below;

Table 2. A modified Student assessment rubric

		Grades & Scores			
		4	3	2	1
		5points	**3points**	**1point**	**0point**
Assessment areas	1)Task required	All	Most	Some	Very few or none
	2)Frequency of attendance	Always	Usually	Some of the time	Rare or not at all
	3) Accuracy	No errors	Few errors	Some errors	Frequent errors
	4)Content covered	Full	Adequate	Partial	Minimal

Many times rubrics were mentioned more than once as being an effective way to highlight the important features of a large assignment, communicate target performance to students and also simplify grading for the lecturer (Kearns, 2012). Another scholar asserted that a rubric is a scoring guide that lists criteria against which assignment submissions will be evaluated (Suskie, 2009). Several instructors used rubrics to guide online discussion to specify how long discussion posts should be, how often students should post, and the level of critique and analysis they were looking for in each post (Kearns, 2012). Many other examples exist in the literature describing effective use of rubrics for assessing online discussion (Baker, 2011).

DISCUSSION

Way back in 2010, nearly 30% of U.S college and university students were already engaged in at least one online course, thus, online learning enrollments continued to grow at a much faster rate than overall enrollments in higher education (Allen & Seaman, 2010).

It is very clear that online learning faces many challenges which range from learners' issues, educators' issues and content issues. It is a huge challenge for many institutions of higher learning to engage students and make them participate in the teaching–learning process. Likewise, it is a challenge for teachers to move from Physical offline mode of teaching to online mode of teaching. This may bring about changing their teaching philosophies and managing their time (Dhawan, 2020). It is also very challenging to develop learning contents which do not only cover the curriculum but also engage the students during learning process. This is a skill which can be gained individually over time (Kebritchi et al., 2017).

LIMITATION OF THE STUDY

The results of this meta-analysis should be interpreted with caution. This is based on the observational and retrospective nature of the selected studies which limited my ability to draw causal inferences. Therefore, the results may be affected by reverse causality bias or other unknown confounders that were not adjusted for in these studies. Despite this limitation, the study has important strengths. An extensive database searches was performed to ensure that all relevant and published studies were identified.

CONCLUSION

Whereas virtual learning has numerous advantages, the quality of e-learning programs is a real challenge. There is no clear stipulation by the many governments in their educational policies about e-learning programs. There is a lack of standards for quality, quality control, development of e-resources and e-content delivery. Thus, these problems need to be tackled immediately so that everyone can enjoy the benefits of quality education via e-learning mode.

RECOMMENDATIONS

Based on the findings from the reviewed literature, the author proposes the following recommendations for instructors;

1) In the case of complex written assignments that require synthesis of material from the entire semester, divide the assignment into phases and have students submit interim deliverables for feedback.
2) Use of rubrics to guide student activity on the discussion as well as in written assignments may be of great benefit to learners. A rubric may be as simple as a checklist that specifies target performance criteria for an assignment. This rubric must be developed ahead of time to help you clarify your own thinking about the objectives of the assignment.
3) In case of courses that require dense, technical material, self-check quizzes are encouraged as this can be very effective for students to complete the required reading and help the instructors to gauge their understanding of the material.
4) Instructors must make use of synchronous technologies, where appropriate and as much as possible. Asynchronous nature of most online learning is only to complement the synchronous learning. Zoom meeting, google meet and other are very vital synchronous tools.
5) Instructors should explore the use of peer-assessment strategies to foster community development and give students chances to learn through analyzing and critiquing the work of others.
6) Instructors need to look for appropriate opportunities to address the entire class so as to reduce the time spent giving the same feedback to multiple students.

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The authors do consent for publication of this work.

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Atmosphere-Related Environmental Problems Diagnostic Test: A Validation Study in Bosnia and Herzegovina University Student

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ABSTRACT

This study was conducted with three aims. The first aim of our study was to examine both construct-related validity and content validity of the Atmosphere-related environmental problems diagnostic test in Bosnia and Herzegovina university student sample. The Atmosphere-related environmental problems diagnostic test is a three-tier multiple-choice diagnostic test consisting of 13 questions on global warming, greenhouse effect, ozone layer depletion and acid rain. The second aim of this study was to examine scientific understanding as well as misunderstanding of atmosphere-related environmental problems among B&H university student sample. Finally, the third aim of our study was to compare scientific understanding and misconceptions of the atmosphere-related environmental problems with respect to educational background. A total of 445 students of three faculty participated in the research. Results indicate that Atmosphere-related environmental problems diagnostic test measures a single construct of general scientific knowledge about atmosphere-related environmental problems. In addition, the content validity and reliability were satisfactory. Results obtained in our study show that students' overall understanding of each content area was low but comparable to knowledge of pre-service teachers in the USA. Similar to earlier research, most incorrect answers resulted from lack of knowledge rather than from misconceptions. Students who attended ecology classes scored higher than students who had not attended these classes. However, although having higher scores on Atmosphere-related environmental problems diagnostic test, students who attended ecology classes also exhibited more misconceptions related to atmosphere-related environmental problems compare to who had not attended ecology classes. This finding indicates that in the context of university education in Bosnia and Herzegovina, one has to also check for possible sources of didaktikogenic misconceptions related to environmental education. Identifying and understanding their possible origins is critical for designing better educational materials and programs.

Keywords: Three-Tier Diagnostic Test**,** Misconception, Environmental Education, University Students

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INTRODUCTION

Over the past decades, various studies were conducted that show us the effect of human activities on climate changes on Earth. Although there are certain regional differences in intensity and volume of climate changes, it is evident that the global sea level rise and rise in surface temperature lead to an increased precipitation and the more extreme tropical storms (Salinger, 2005; United Nation's Intergovernmental Panel on Climate Change (IPCC), 2007). Climate changes are globally one of the most serious problems that threaten our environment with severe social, environmental and economic consequences. Climate changes may disrupt food and water availability, energy production and consumption, plant and animal survival, human health and social and political stability (Paterson, 1996). Climate change is the defining issue that require serious attention of scientists, politicians and the public in general. Climate change prevention requires an urgent international cooperation and consensus, as well as serious changes in the modern lifestyle.

Education is crucial in understanding processes that cause climate change. It also contributes to the scientific understanding of effects and causes of climate change. Compulsory education in Bosnia and Herzegovina, elementary and secondary, offers classes on environmental issues from 5^{th} grade (11-year-old pupils) through the Nature and Society course while these issues are taught in Chemistry, Biology and Geography in the secondary schools. Teaching in the lower grades of elementary schools focuses on acid rain (AR) and ozone layer depletion (OLD). Higher grades offer teaching on global warming causes and effects (GW), greenhouse effect (GE), ozone layer depletion (OLD) and acid rain (AR). High schools continue education on environmental issues and climate change in biology, chemistry and geography. Schools for higher education offer relevant education on climate change in the biology, chemistry and geography departments. Students therefore acquire practical and theoretical knowledge that contribute to the scientific understanding of causes, processes and effects of climate change.

Relatively strong focus on climate change issues in the courses offered throughout the compulsory education suggest that the high school graduates obtain solid knowledge on climate change issues. Studies on the other hand show that many students and teachers have misconceptions on these issues.

Misconceptions on environmental issues had been analyzed through various diagnostic processes. Closed-form Likert type questionnaires (e.g. Boys et al., 1993,1995; Groves & Pugh, 1999, 2002; Michail, Stamou & Stamou, 2007; Pekel & Ozay, 2005), interviews (e.g. Pruneau et al., 2001; Rye et al., 1997; Summers et al., 2000), and open-ended questionnaires (e.g. Anderson & Wallin, 2000; Gowda et al., 1997, Papadimitriou, 2004), are the most common methods in identifying environmental misconceptions.

Multiple choice tests are frequently used in the misconception studies. Although the conventional multiple-choice tests are practical in evaluating content knowledge, test answers do not provide profound understanding of misconceptions. Treagust (1988) developed the two-tier test that requires an explanation for the answer given by the student. The two-tier test cannot differentiate mistakes caused by the lack of knowledge from mistakes caused by the existence of alternative conceptions. Thus, researchers introduced the level of certainty of the respondents for their answers to the first two tiers (Hasan et al., 1999) as a third tier. A right answer with a high degree of confidence indicates a thorough understanding of the related concept. However, answers with low confidence are considered as a lack of knowledge irrespective of if the answer is correct or wrong. A wrong answer accompanied by a strong confidence level indicates the existence of a misconception (Peşman & Eryılmaz, 2010). An enhanced version of the two tiers tests are four tier tests, in which one tier measure the level of participants' confidence in the content and the addition tier measure confidence in the reason tiers.

In a lot of research, two/three/four-tier tests aiming to determine conceptual understanding in science were used. This type of test were used to determine conceptual understanding in physics (Peşman & Eryılmaz, 2010; Caleon & Subramaniam, 2010a; Kutluay, 2005; Chu et al., 2009), chemistry (Costu et al., 2007; Tan et al., 2002; Cetin-Dindar & Geban 2011; Chandrasegaran et al., 2007; Tan et al., 2002; Sreenivasulu & Subramaniam, 2013), biology (Sesli & Kara, 2012; Kılıç & Sağlam, 2009; Yen et al., 2007; Mann & Treagust, 1998; Lin, 2004) and environment (Griffard & Wandersee, 2001; Arslan et al., 2012; Cheong et al., 2015). A detailed list of studies using tier tests can be obtained in the supplementary material of Cheong et al. (2015).

With the aim to reveal common misconception of global warming (GW), greenhouse effect (GE), ozone layer depletion (OLD), and acid rain (AR) Arslan et al. (2012) develops and validate a three-tier multiple-choice diagnostic test, the atmosphere-related environmental problems diagnostic test (AREPDiT). The instrument comprised of 13 questions, each one having a standard format of three tiers: the content tier, the reasoning tier and the confidence tier. To differentiate a lack of knowledge from a misconception, a certainty response index is added as a third tier to each item. As Arslan et al. (2012) stated, the overall response possibilities to the instrument bring out five categories: Scientific knowledge, Misconception, False positives/negatives, Lucky guess, and Lack of knowledge. Results obtained in Arslan et al. (2012) study indicate that the AREPDiT is a reliable and valid instrument not only to identify pre-service teachers' misconceptions about GW, GE, OLD, and AR but also to differentiate these misconceptions from lack of knowledge. The results also indicate that a majority of the respondents demonstrated limited understandings about atmosphere related environmental problems.

Our study was conducted with three aims. The first aim of our study was to examine both construct-related validity and content validity of the AREPDiT in Bosnia and Herzegovina university student sample. The second aim of this study was to examine scientific understanding as well as misunderstanding of atmosphere-related environmental problems among B&H university student sample. Finally, the third aim of our study was to compare scientific understanding and misconceptions of the atmosphere-related environmental problems with respect to educational background.

In the line with aims, the following research questions of our study were stated: 1. What is the constructive and content validity of AREPDiT in the sample of students from the university in Bosnia and Herzegovina? 2. How do students at universities in Bosnia and Herzegovina understand environmental problems related to the atmosphere? 3. What is the understanding of these problems among students with different educational backgrounds.

METHODOLOGY

Sample

Study was conducted on 445 under-graduate students in departments of biology, geography, chemistry, mathematics, mathematics-physics and physics at the Faculty of Natural Science, Mathematics and Education in Mostar, Teachers Faculty "Džemal Bijedić" in Mostar and the Faculty of Natural Science and Mathematics in Sarajevo. In our research, 22,7% of the total examinees were male. The average age of examinees was M=20,1 (SD=0,78). Our research includes the first-year students (33,9%), the second-year students (3%), the third year students (22,7%) and the fourth year students (40,4%).

Instruments

Diagnostic test on atmospheric environmental problems (AREPDiT) Arslan et al. (2012) includes 13 tier questions on global warming, greenhouse effect, ozone layer depletion and acid rain. The first tier contains conventional multiple-choice questions that offer two to five options. The second tier offers an explanation of the answer given in the first tier. Students are given 4 to 6 possible options (one correct answer and alternative answers). The third tier determines the level of certainty in the answers given in the first two tiers. Our research determines the certainty degree via Likert 5 points scale (1 - not at all certain to 5 – absolutely certain). Topics comprised in AREPDiT are being taught to students in layered structure.

The first author of our research and an expert in climate change had analyzed contents of questions in AREPDiT from a perspective of educators that are involved in determining teaching programs that cover atmospheric environmental problems. They confirmed that topics comprised in AREPDiT are being taught to students in Bosnia and Herzegovina.

Data collection and analysis

The AREPDiT was administered to the students during the regular classes. Students completed the test in a group. The survey administration lasted approximately 25–35 min. All the statistical calculations were performed by Microsoft Office Excel and IBM SPSS Statistics v. 20.

In line with standard procedure (Pesman & Eryilmaz, 2010), based on the obtained data the following eight scores were calculated: 1) The first tiers. Only the first-tier scores are considered. The correct answer in the first tier is scored 1, incorrect 0. 2) Both tiers. The first- and second-tier scores are considered. Correct combinations are scored 1; other combinations are scored 0. 3) Total. All three tiers' scores are considered. Correct combinations of the first and second tiers with a circled “certain” and “absolutely certain” in the third tier are scored 1 point; all other combinations are scored 0 points. Total score is indicator of scientific knowledge. 4) Certainty. Only the third-tier score is considered. 5) Lack of knowledge. Combinations of responses from all three tiers are used as indicator of lack of knowledge (correct/incorrect/uncertain, incorrect/correct/uncertain, and incorrect/incorrect/uncertain). 6) Misconception first tiers (M-first tiers). 7) Misconception both tiers (M-both tiers), and 8) Misconception all tiers (M-all tiers).

RESULTS AND DISCUSSION

Validity evidence with regard to the AREPDiT

The first aim of this study was to examine both construct-related validity and content validity of the AREPDiT in Bosnia and Herzegovina university student sample. Firstly, exploratory factor analysis was conducted to identify the factor structure of the test. In addition, the correlation between score 2 and confidence levels as well as correlation between misconception score 2 and confidence levels were examined. Finally, the percentage of false positives and false negatives were calculated for content validity.

To examine construct validity of AREPDiT the exploratory factor analysis (EFA) was employed for both correct scores depending on the answers given to the three-tier questions. When factor analysis is used to test the construct validity of an instrument, it is important to take into account the measurement scale that is being used (Maydeu & D'Zurilla, 1995; Flora et al., 2003). With respect that scores are binary (correct vs. incorrect) and that distributions of items are asymmetric or with excess of kurtosis polychoric correlations, rather than the Pearson correlations is advised when carrying out this kind of analysis (Muthén & Kaplan, 1985, 1992).

The EFA was computed using FACTOR (Ferrando & Lorenzo-Seva, 2017; Lorenzo-Seva & Ferrando, 2006), a comprehensive and user-friendly program for fitting exploratory and semi-confirmatory factor analytic models (see Ferrando & Lorenzo-Seva, 2017 for conceptual view of the origins and development of FACTOR). The polychoric matrix of correlations was analyzed and principal component analysis was specified as method for components extraction. As measures of sampling adequacy of the data for conducting factor analysis, the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's sphericity test were applied. The obtained results of Kaiser-Meyer-Olkin (KMO) test (0.75978) indicate fair sampling adequacy whereas value of Bartlett's statistic (χ^2=641,6, p=0,00001) indicate suitability of data for structure detection. The analysis was conducted with specifying four components due to four groups of items (GW, GE, OLD and AR). Parallel Analysis (PA) was used as a technique for determining the number of retained components. A total of 500 random polychoric correlation matrices were created using method of permutation of the raw data (Buja & Eyuboglu, 1992). Only one eigenvalue derived from the actual data (λ=5.28306) was greater compare to eigenvalues derived from the random data (λ=2.05729) indicating one significant component. This component explains 40,64% of total variance. In conclusion, the results of EFA indicate that all correct scores of three-tier questions were loaded under one component, which could be named as general scientific knowledge about atmosphere-related environmental problems.

According to Cataloglu (2002) and Pesman and Eryilmaz (2010), higher correlation between two-tier composite score and confidence tier composite score indicate construct validity of the three-tier test. If test items work properly, it could be expected that students with higher score are more confident in their answers than students with low scores (Cataloglu, 2002). Therefore, Pearson-product moment correlation coefficient between two-tier composite scores and confidence tier composite scores of the AREPDiT was calculated. Moderate positive correlation was obtained ($r= .29$, $p< .01$). It can be concluded that items of the AREPDiT work properly.

As Hestenes and Halloun (1995) claimed, the advantage of the three-tier test is the opportunity to calculate percentage of false positive and false negative to establish evidence of content validity of the test. Namely, minimization of the probability of false positive and false negative provides greater validity in multiple-choice test. Percentages of false positive and false negative were calculated by the combinations of 'correct and incorrect and certain' and 'incorrect and correct and certain' respectively. Table 1 shows the percentages of false negatives and false positives item by item.

Table 1. Percentages of false negatives and false positives

	Item													M	SD
	1	2	3	4	5	6	7	8	9	10	11	12	13		
False negative	2,7	0,7	1,1	3,4	0,7	0,2	3,2	0,2	5,6	1,1	4,8	1,4	2,5	2,1	1,7
False positive	5,0	1,4	7,0	7,2	1,4	0,5	3,4	0,2	0,7	0,2	4,8	1,1	1,4	2,6	2,5

Mean percentage of false positive (M=2,6; SD=2,5) is higher compare to mean percentage of false negative (M=2,1; SD=1,7), what is in line with Hestenes and Halloun (1995) explanation that the percentages of false positives are higher than the percentages of false negatives because reducing the probability of false positives is more difficult. The highest percentage of false negative were obtained for Item 9 (5,6%) and Item 11 (4,8%) what could be attributed to failure of some student to give sufficient attention to avoiding errors as Hestenes and Halloun (1995) suggested. When the percentages of false positives were checked, the highest percentages were obtained for greenhouse effect Item 3 (7%) and Item 4 (7,2%). Even having some misconceptions regarding greenhouse effect, students might select the correct choice in the first tier (see table 4). Taken together, it could be concluded that percentages of false negatives and false positive for all the items were smaller than 10 percentages, indicating satisfaction validity of the test.

Descriptive statistics of the AREPDiT total score

Since thorough understanding of the concepts include correct answer on content and reason tier accompanied by high confidence (Hasan, Bagayoko, & Kelley, 1999; Caleon & Subramaniam, 2010) descriptive statistics are conducted over the sum of correct responses to both first and second tiers along with being certain (correct and correct and certain). The overall descriptive statistics and the item analyses have been summarized in Table 2.

The highest score obtained in our study is 11 and the lowest is 0. The mean was M=1,77 (*SD* = 2.07) out of 13 and was very small, what indicate difficulty of the AREPDiT. The difficulty indices of the AREPDiT items indicated that the test was very difficult for students. Difficulty levels of all items except for Item 7 were below .40, with a mean of M=0.14. Skewness of the results also support this claim (Skewness=1,581, p<0,01).

Table 2. Descriptive statistics of the AREPDiT total score

Statistics	Value
Number of items	13
Number of participants	445
Mean	1,77
Median	1
Standard deviation (SD)	2,07
Minimun	0
Maximun	11
Skewness	1.581**
Kurtosis	2.805**
Cronbach alpha	0,706
Difficulty indices	
Mean	0,14
n of items < 0.10	3
n of items (0.10-0.19)	8
n of items (0.20-0.29)	1
n of items (0.30-0.39)	-
n of items (0.40-0.49)	1
Point biserial correlation	
Mean	0,480
n of items (0.30-0.39)	2
n of items (0.40-0.49)	5
n of items (0.50-0.59)	6

** p<0,01

However, item discrimination indexes indicate that items are able to distinguish between students who are knowledgeable and those who are not. As seen from Table 2, most of the point-biserial correlation coefficients are equal or above 0.30 indicating good to excellent items regarding discrimination (according to Crocker & Algina, 2008). In addition, the mean point-biserial correlation coefficient of the AREPDiT is good (r_{pb}=0.55). Item discrimination analysis indicates that the items and a test as a whole can effectively discriminate between students having high and low levels of conceptual understanding of atmosphere-related environmental problems. Finally, Croanbach's alpha reliability coefficient was found to be α= .706 which can be considered acceptable internal consistency according to criterion-referenced tests (Crocker & Algina, 2008; Kane, 1986)

Students' understanding of the atmosphere-related environmental problems

The percentages of student's correct responses according to only the content tiers, both content and reason tiers, and all three tiers as well as percentages of student's lack of knowledge and mean of confidence level are given in Table 3. The first tier shows the percentages of the

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student's correct responses based on the first (content) tier. Both the first and the second tiers shows the percentages of the student's correct responses to both the first (content) and the second (reason) tiers. All three tiers shows the percentages of student's correct responses to both the content and reason tiers and also were certain about their answers. Lack of knowledge is the percentages of students who were uncertain regardless of their responses. Confidence level shows the mean value of the student's certainty regardless of their response to the content and reason tier.

Table 3. Percentages of students' correct responses, lack of knowledge and mean values of confidence level

		% Correct responses			% Lack of knowledge	Confidence level
	Item	**First tiers**	**Both the first and the second tiers**	**All three tiers**		
GW	1	30,2	15,8	6,8	54,4	3,31
	2	36,0	32,5	11,1	42,0	3,31
	5	18,7	11,0	2,7	62,8	3,02
	6	24,2	23,3	14,0	45,0	3,43
	M	27,3	20,7	8,7	51,1	3,27
	SD	7,5	9,4	4,9	9,4	0,17
GE	3	77,3	50,9	20,0	35,4	3,17
	4	55,0	29,3	11,0	49,0	3,18
	M	66,2	40,1	15,5	42,2	3,18
	SD	15,8	15,3	6,4	9,6	0,01
OLD	7	68,1	61,9	40,2	22,1	3,67
	8	24,5	23,9	10,1	53,5	3,16
	9	31,8	27,9	15,7	42,5	3,42
	10	30,3	27,2	13,3	40,9	3,42
	M	38,7	35,2	19,8	39,7	3,42
	SD	19,9	17,9	13,8	13,0	0,21
AR	11	46,3	30,6	12,8	52,1	3,09
	12	13,9	9,9	6,1	64,9	3,11
	13	42,2	33,6	13,5	48,1	3,08
	M	34,1	24,7	10,8	55,1	3,09
	SD	17,6	12,9	4,1	8,8	0,02
TOTAL	M	38,4	29,1	13,6	47,1	3,26
	SD	19,0	14,5	9,1	11,3	0,19

As Table 3. illustrates, the total percentage of correct answers decreases as the number of tiers that are taken into account increases. More specifically, the mean percentage of total correct responses in content tiers was M=38,4% (SD = 19,0%), both content and reasoning tiers was M= 29,1% (SD = 14,5%,) while in all three tiers was M=13,6% (SD = 9,1%). The mean difference between the content tiers and all three tiers (M=24,7%) is noticeable. Almost quarter of students who correct answer on the content tier was unable to choose correct reason and showed confidence. The mean difference between the correct responses with regard to both and all three tiers (M=15,4) is also meaningful and correspond to students who demonstrate lack of confidence. In general, differences can be explained by lack of knowledge, lack of confidence, or misconceptions. The same pattern of decrease of percentage of correct answers as the number of tiers increase is obtain for each content area (GW, GE, OLD, and AR). As can be seen from Table 4, the students' overall understandings of each content area are low (M_{GW}=8,7%, M_{GE}=15,5, M_{OLD}=19,8, and M_{AR}=10,8). This low rate could be explained by the complex and abstract nature of the concepts of atmosphere-related environmental problems (Boyes & Stanisstreet, 1992; Cordero, 2001) as well as their educational background.

Although students' overall understandings of atmosphere-related environmental problems were very low, their confidence level were above moderate (M=3,26; SD=0,19). Overconfidence obtain in this study is in line with findings in other study in domain of psychology (Pallier et al., 2002; Renner & Renner, 2001) and educational study (Arslan et al., 2012; Caleon & Subramaniam, 2010; Taslidere, 2016).

The overall lack of knowledge mean percentage was M=47,1% (SD=11,3) indicated that almost half of the students had no understanding or were confused about their understanding of atmosphere-related environmental issues. The highest mean percentage of lack of knowledge were obtained for AR (M=55,1%; SD=8,8%) and for GW content area (M=51,1%; SD=9,4%). Somewhat lower mean percentage of lack of knowledge were obtained for GE (M=42,2%; SD=9,6%) and for OLD content area (M=39,7%; SD=13,0%).

With regard to percentages of the all three tiers score of each item, students demonstrated the higher percentage of scientific knowledge for Q7 (M=40,7%), which is about the nature of the ozone layer, and they were very certain of their answers (M=3,67). What follow is Q3 (M=20%), the question about greenhouse effect. The lowest percentages of scientific knowledge were obtained for Q5 (M=2,7%), which is about the changes in the composition of the atmosphere, and for Q12 (M=6,1%), the question about acid rain. For these two items the highest percentage of lack of knowledge were obtained (M=62,8% and M=64,9%, respectively).

In general, students' understanding of the atmosphere-related environmental problems is low. Results obtain in our study show low rate of correct responses with high certainty, what Hasan, Bagayoko, and Kelley (1999) interpreted as the indicator of misconception, an aspect which will be discussed in the next section.

Student's prevalent misconceptions

The percentages of the students holding misconceptions considering only the content tiers (M-first tiers), both content and reason tiers (M-both tiers), and all three tiers (M-all tiers) are summarized in Table 4.

Table 4. Percentage of one-tiered, two-tiered and three-tiered misconception

Misconceptions	M-first tiers	M-both tiers	M-all tiers
1. GW is caused by OLD	57,5	21,2	7,9
2. GW will cause skin cancer	23,0	22,7	8,1
3. AR is a result of GW	41,0	38,0	13,8
4. Recycling more paper is not an effective cure for GW	37,7	31,8	10,2
5. Generating electricity from renewable sources does not help to reduce GW	15,8	12,6	4,5
6. Stopping the usage of CFCs is not a cure for GW	27,5	21,6	10,9
7. GW can be reduced by setting limitations on chemical waste released into rivers	45,4	34,6	12,9
8. GW can be reduced without building nuclear power plants	21,0	19,0	9,7
9. Set a limit on pesticide usage on farmland	9,5	9,0	2,7
10. GE is not a natural phenomenon	8,3	4,5	1,1
11. Carbon dioxide (CO2) is the only gas that increases	14,2	6,3	2,2
12. GE is a totally harmful phenomenon for mankind	41,4	26,3	9,5
13. GE is a totally helpful phenomenon for mankind	1,8	0,9	0,2
14. GE has no effect on mankind	1,6	0,9	0,2
15. The ozone layer protects the Earth from AR	6,3	4,0	0,9
16. The ozone layer helps to keep the Earth's temperature stable to make it livable	25,6	16,7	6,3
17. CO2 depletes the ozone layer in the stratosphere	28,4	26,6	8,6
18. GE leads to OLD	20,7	18,3	6,1
19. Nuclear power plants affect the depletion of the ozone layer	11,5	8,3	1,1
20. Carbon monoxide (CO) causes OLD	14,9	12,0	2,9
21. OLD causes an increase in the number of floods	3,6	2,3	0,9
22. Too much sun rays enter the atmosphere by OLD	16,9	0,0	0,0
23. OLD lets the air escape from the atmosphere	2,5	0,0	0,0
24. Using public transportation reduces OLD	5,2	3,6	2,3
25. Using filters for smoke from factories and cars reduces OLD	64,5	29,7	12,8
26. OLD leads to AR	13,5	1,1	0,0
27. Methane (CH4) from landfills leads to AR	40,2	10,1	1,6
28. OLD becomes worse by AR	19,8	11,3	2,5
29. AR leads to an increase in GW	13,0	7,4	0,7
30. AR helps some plants and animals to survive	24,7	5,2	0,5
31. AR can burn everything that it comes in contact with	28,5	25,2	11,3
32. Avoiding activities that damage the ozone layer is a precaution for AR	28,2	19,4	6,5
33. CO is the main culprit of AR	29,3	25,1	7,2
M	22,5	14,4	5,0
SD	15,8	11,2	4,5

Table 4. shows that, as the number of tiers increased, the percentage of students holding misconceptions decreased. For example, 64,5% of the students hold misconception M25 (*Using filters for smoke from factories and cars reduces OLD*) according to the first tiers of the related item (item 10). However, the value decrease to 29,7% after both content and reason tiers were taken into account, indicated that 34,8% of students selected misconception alternatives in the content tiers, but not related alternatives of M25 at the reason tiers. Furthermore, when all three tiers are taken into account, 12,8% of the students select both the content and the reason tiers, and denoted confidence in terms of the confidence tiers.

The differences between mean percentage of both tiers and all three tiers indicated that16,9% of students selected the misconception alternatives in previous tiers but showed uncertainty at the confidence tiers. In line with explanation given by other authors (Arslan, Cigdemoglu, & Moseley, 2012; Hasan, Bagayoko, & Kelley, 1999; Kanli, 2014; Korur, 2015; Peşman & Eryılmaz, 2010) it seems that this 16,9% of the students had lack of knowledge rather than having corresponding misconception. Similar decreases are also noticeable with regard to all other misconception, what is expected because, as Peşman and Eryılmaz (2010) explained, student can wrongly select any specific misconception alternative at the content tier, but it is hard to find an explanation supporting that misconception at the reason tier, and to indicate confidence at the confidence tier.

Prevalent misconceptions were associated with all three tiers misconception alternatives that were selected by at least 10% of the sample, criteria proposed by Arslan, Cigdemoglu, and Moseley (2012), Caleone and Subramaniam (2010), Tan et al. (2002) and Taslidere (2016). As seen from the M-all tiers percentages in Table 4, the students hold the six prevalent misconceptions with percentages equal to or greater than 10. The prevalent misconceptions identified in this study are:

- *AR is a result of GW* (M3),
- *Recycling more paper is not an effective cure for GW* (M4),
- *Stopping the usage of CFCs is not a cure for GW* (M6),
- *GW can be reduced by setting limitations on chemical waste released into rivers* (M7),
- *Using filters for smoke from factories and cars reduces OLD* (M25),
- *AR can burn everything that it comes in contact with* (M31).

Scientific understanding and misconceptions of the atmosphere-related environmental problems with respect to educational background

The final aim of the study was to compare scientific understanding and misconceptions of the atmosphere-related environmental problems with respect to educational background. Figure 1 summarizes the mean scores for students who attend ecology classes and students who did not attend ecology classes on scientific understanding and misconception of the atmosphere-related environmental problems. The scientific understanding was calculated as a mean number of all-three tiers correct response, whereas misconception of the atmosphere-related environmental problems as mean number of M-all tiers.

Consistent with expectation, the group of students who attend ecology classes obtain higher average results of scientific understanding (M=2,16; SD=2,15) than did group of students who did not attend ecology classes (M=1,32 SD=1,86), t(443)=4,353, p<0,001. Furthermore, the group of students who attend ecology classes obtain higher average misconceptions (M=1,82; SD=1,66) than did group of students who did not attend ecology classes (M=1,46 SD=1,80), t(443)=2,188, p<0,05.

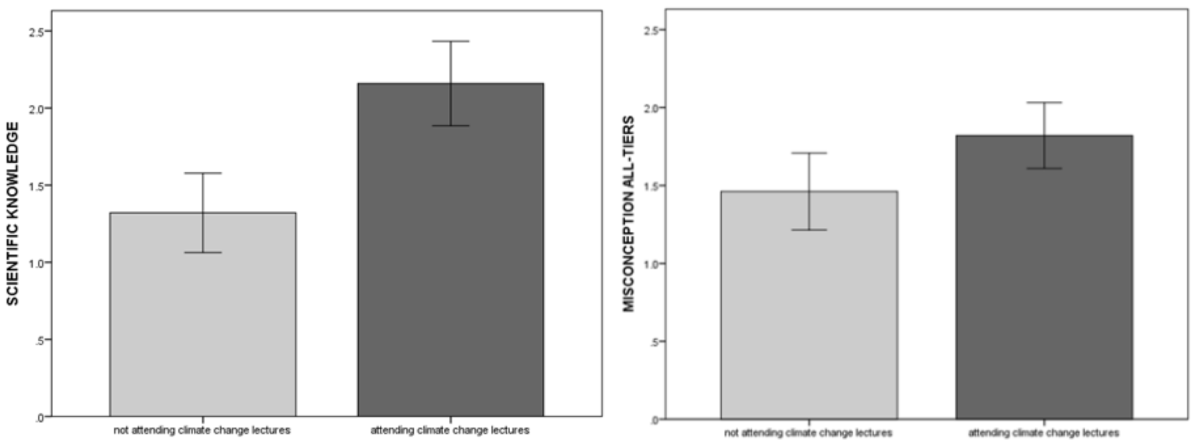

Figure 1. Means and corresponding 95% confidence intervals of the mean on the scientific understanding and misconceptions of the atmosphere-related environmental problems

CONCLUSION AND IMPLICATION

The aim of this study was threefold. Firstly, we examined both construct validity and content validity of the AREPDiT in Bosnia and Herzegovina university student sample. Further, we examined scientific understanding as well as misunderstanding of atmosphere-related environmental problem among B&H university student sample. Finally, the third aim of our study was to compare scientific understanding and misconceptions of the atmosphere-related environmental problems with respect to educational background.

For purposes of gathering evidence for construct validity, the principal component analysis was conducted on all three tiers of response. One component has been extracted which suggested that, implemented with university students in Bosnia and Herzegovina, AREPDiT measures a single construct which is general scientific knowledge about atmosphere-related environmental problems. On the other hand, in the study by Arslan, Cigdemoglu, and Moseley (2012) no reasonable factors could be obtained which was explained by loose relationship between the individual items. This once more speaks for the fact that validity is a situation-specific concept (McMilan & Schumacher, 2006) and shows that in the context of university students from Bosnia and Herzegovina it is reasonable to calculate and interpret composite scores for the whole AREPDiT scale. Further, a moderate and statistically significant correlation between correct scores and confidence scores has been found, which additionally speaks for construct validity (Cataloglu, 2002).

Content validity of AREPDiT has been checked through the analysis of false positives and false negatives. For none of the items the percentage of false positives and false negatives was above 10% which is an evidence for good content validity. Similar results were obtained by Arslan, Cigdemoglu, and Moseley (2012). However, in the study by Kahraman (2019) for two items the percentage of false positives was above 10%. We can conclude that compared to similar research, the level of content validity for our study was satisfactory.

Besides allowing us valid conclusions about students' knowledge on atmosphere-related environmental problems, it has been also found that AREPDiT scores for the Bosnia and Herzegovina university students sample may be considered as reliable.

Generally, the results of our study show that Bosnia and Herzegovina university students' knowledge about atmosphere-related problems are low but comparable to knowledge of pre-service teachers in the USA (Arslan et al., 2012; Kahraman, 2019). Similar to earlier research, most incorrect student answers resulted from lack of knowledge rather than from misconceptions. Students who attended ecology classes scored higher than their peers who had not attended these classes. However, it is even more important to note that although having higher scores on AREPDiT these same students also exhibited more misconceptions related to atmosphere-related environmental problems. This finding indicates that in the context of university education in Bosnia and Herzegovina one has to also check for possible sources of didaktikogenic misconceptions (Zajkov, Gegovska-Zajkova, & Mitrevski, 2017) related to environmental education.

As in the study conducted by Arslan et al. (2012) six misconceptions held by more than 10% of students could be identified. It is interesting to note that two of the misconceptions detected in the study by Arslan et al. (2012) were also detected in our study. One is related to the erroneous belief that acid rains are a result of global warming and the other is that chemical waste released into rivers is one of the reasons for global warming. Relating river pollution with global warming was also very common in the study by Kahraman (2019).

It is important to consider why some of the prevalent misconceptions identified in our study arise. Identifying and understanding their possible origins is critical for designing better educational materials and programs. The occurrence of these misconceptions could be related to different factors.

Students in higher education institutions rarely have the opportunity to obtain quality information related to climate change. It is often the case that curricula rely on outdated knowledge, and there is no interconnectedness between different subjects in order to address topics related to environmental issues in a clear way (Rajeev, 1997).

One of the reasons for the misconceptions related to climate change among students is the information that students receive from the media (Michail et al., 2007; Kahraman, 2020). The media most often transmit incomplete and distorted information related to environmental problems, which is justified by the task of the media to inform the public rather than educate (Dunwoody, 1992). There is also a difference in the knowledge of climate change among people who are more informed from the print media compared to those who receive news through television (Morgan & Moran, 1995). Also, most contributions related to scientific research contain a large number of factual errors leading to a misunderstanding of scientific studies (Singer & Endreny, 1993).

Fischhoff and Furby (1983) developed a research program that addresses the psychological dimensions of climate change to better understand the heuristics or mental shortcuts that people use to understand complex and uncertain threats such as climate change. This heuristic, used by both experts and lay people, often leads individuals to misjudge complex phenomena (Rajeev, 1997). Slovic et al. (1993) showed that humans are particularly vulnerable to the use of heuristics in the context of environmental risks. One example is the availability heuristic, according to which people estimate the frequency of problems according to how easily they remember certain evidence, while the other example is the representativeness heuristic, where people generalize based on limited evidence, ignoring basic statistical principles.

Although students have expressed pro-environmental views in most studies, this can lead to a combination of all adverse environmental impacts resulting in unclear knowledge related to climate change. Based on this, students can "assume" that any damage to the environment could lead to global climate change. For many students, these concepts are not yet clear enough to allow for a sophisticated consideration of cause and effect, resulting in confusion around critical issues related to climate change (Rajeev, 1997).

The effectiveness of educational messages often depends on trust in the source of the information. Rajeev (1997) states that students trust scientists the most, followed by teachers, and environmental groups and newspaper media. Government officials, family and friends had poor results on the scale with low confidence. The enormous level of trust in scientists gives both the opportunity and responsibility to the scientific community to play an active role in strengthening students' knowledge of climate change and of the actions that students can take to prevent it (Wachholz, Artz, & Chene, 2014). Together with educators, who are also trusted, scientists can help students increase understanding and especially help them avoid the significant misconceptions found in this and other studies.

The AREPDiT can be administered to university students before and after the instruction on atmosphere-related environmental problems to gain a deeper understanding of the different views that students have on the particular topic. The results obtained by this instrument could help educators to develop the appropriate teaching-learning sequences to better address their ideas. As it is proposed by Arslan et al. (2012), the instrument could be used by educators as a tool for evaluating the effectiveness of their instruction.

This study has certain limitation. The AREPDiT is a three-tier instrument, means that it includes only one level of confidence for the answers at first and second tiers (content and reason). Therefore, it is unclear whether the confidence level is different for each tier. In the future studies a four-tier test should be applied.

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What Teachers Notice: The Impact of an Online Graduate Program on Middle School Science Teachers' Noticing

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ABSTRACT

What teachers notice is important because it can impact their curricular decisions. As teachers acquire experience over time, they are more able to notice and interpret critical facets of effective science instruction. This qualitative study shares how a two-year online master's degree program impacted what middle school science teachers noticed during observations of a video of instruction. Constant comparative method was used to generate categories of what teachers noticed at the start of the two-year program, after the first year, and at the end of the two-year program. The results were categorized as; (1) context, (2) classroom management, (3) students, and (4) teacher. Data analysis found that, in general, what teachers noticed did not change over the two-year period. For teachers with six or more years of experience, they noticed more regarding student-centered instruction and lesson format (inquiry) over time.

Keywords: Notice, Science teachers, Middle school

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INTRODUCTION

To implement reform-based science education (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996), teachers must be adequately prepared and supported to develop relevant competencies for effective instruction. One of these competencies is to be able to notice certain aspects of classroom interactions, such as listening and interpreting students' ideas to help students investigate authentic questions (van Es & Sherin, 2002; 2008). What teachers notice leads to what teachers recognize and attend to in the classroom (Haverly et al., 2020; Luna 2018; Sherin, Jacobs, & Phillip, 2011).

What teachers notice is important because it can impact their curricular decisions. Previous research shows that experienced teachers are better able to interpret classroom situations and propose practices that integrate developed levels of pedagogical knowledge (Kersting, 2008; Koenig, et al., 2014), while novice teachers notice important situations but are less able to offer input on effective practices in response (Kersting, 2008; Koenig, et al., 2014). Novice teachers, especially, need support to understand the sense-making opportunities during classroom instruction and student talk (Haverly, 2020).

One way to capture what teachers notice is the use of videos of practices. Videos provide a good medium to assess what pre and in-service teachers notice (Kaiser, Busse, Hoth, Koenig, & Bloemeke, 2015; Wiens, Hessberg, LoCasale-Crouch, & DeCoster, 2013). Sherin (2004) identifies affordances that videos provide for teacher education, including the ability for a video to be played repeatedly without losing any of the complexity of the lesson, the evolution in noticing using the same video of practice over time, and the emergence of an "analytic mind-set" (Sherin, 2004, p. 13) in teachers when observing a video as opposed to in-the-moment teaching.

Perspective

This study was framed with a constructionist perspective, which presumes that individuals and groups interact within their environment and that these interactive experiences generate meaning. Constructionism is, "the view that all knowledge, and therefore all meaningful reality, is contingent upon human practices, being constructed in and of interaction between human beings and their world and developed and transmitted within an essentially social context" (Crotty, 1998, p. 42). Therefore, in this study, we viewed participants as interacting to find meaning and relevance and designed the research methods and classroom activities to maximize the interaction between individuals, groups, and resources. This, in turn, elucidated participants' notice over time.

Literature Review

Importance of Teacher Noticing

Noticing, or what teachers' pay attention to, is an emerging yet critical area of work in science education although it has been present in mathematics education for years (i.e., Kaiser et al., 2015; Kersting, 2008; Sherin, 2004; van Es & Sherin, 2002, 2021). Noticing is an important skill that allows teachers to interpret classroom situations and interactions that mediate the processes of learning (Haverly et al., 2020; Koening et al., 2014; Luna, 2018; van Es & Sherin, 2021). For example, teachers need to notice and interpret students’ ideas and feedback to make sense of those ideas, and in turn, respond so that content and learning objectives are identified, made explicit, then addressed (Luna, 2018).

Noticing can play a role from planning lessons to assessment of subject matter knowledge. For example, teachers need to notice students ‘preconceptions so that adaptation of instruction is made to respond appropriately to students’ learning needs (Schwichow, 2022). Haverly et al., (2020) found that teachers must have the specialized knowledge and skill to notice the spaces during instruction for class discussions that can lead to sense-making, such as implementing various responses to clarify student ideas, wait time, and determination of next steps to scaffold science learning. To understand student learning, teachers need to pay attention to what students are doing and resulting student artifacts to notice students’ science thinking and understanding of content (Luna et al., 2018). It is important that teachers notice students’ preconceived ideas, developing knowledge, and what is learned to continue providing meaningful opportunities that lead to science learning.

Characteristics of Noticing

Van Es and Sherin (2002) defined notice by three key aspects. First, noticing is identifying what is critical and important in a classroom situation or interaction. Teachers need to be able to prioritize what is important in complex situations (van Es & Sherin, 2002; 2008) and decide what needs more attention when compared to other facets (Goodwin, 1994, as cited by Sherin & van Es, 2005). This also includes a teachers’ ability to disregard classroom interactions that are unimportant (van Es & Sherin, 2021). Teacher noticing also leads to ideas about what and how a teacher assesses to gauge learning, which results in subsequent decisions made during lesson instruction (Leinhardt et al., 1991; van Es & Sherin, 2008; 2021). It is vital that teachers know what to pay attention to, and what to concentrate on, to remain focused on prioritized objectives, such as student learning over minor classroom management issues. Research finds that as teachers gain experience in the classroom, they are better able to identify what to use for assessment that will impact classroom instruction (Leinhardt et al., 1991).

Second, noticing is a teachers’s ability to use their knowledge about the subject matter, how students learn the subject matter, as well as their knowledge about the contexts in which they teach and analyze classroom events (van Es & Sherin, 2008; 2021). This is especially important since knowledge, beliefs, prior experiences, and education can influence what one notices (Pajares, 1992). These knowledge and beliefs act as a filter in which a teacher decides what to prioritize in certain contexts (Pajares, 1992; Richardson, 1996). To adapt an example from van Es & Sherin (2008), science teachers will make sense of a classroom interaction more accurately in a science classroom than a language arts classroom, or a biology teacher will better reason in a biology classroom than a chemistry one. Again, experience plays a vital role in a teachers’ ability to use their knowledge to reason about what they notice. As teachers gain experience, they are more able to assess classroom interactions and their significance towards teaching objectives (Brown et al., 1989).

The third aspect of the learning to notice framework is teachers' abilities to make connections between certain interactions and the general pedagogical and learning ideas the event relates to (van Es & Sherin, 2002; 2008; 2021). This is important because connecting events to pedagogical ideas and principles offers teachers the opportunity to understand how situations relate to teaching principles that may be abstract. Instead of focusing on interactions in isolation, teachers need to be able to notice how these interactions connect to pedagogical principles and refer to these connections during future situations. This helps teachers to develop knowledge and skills to better respond to students in ways that foster teaching objectives, like student learning. Furthermore, as teachers build these connections between events and principles, they develop an ability to see a larger picture of the educational landscape. This fosters teachers' reform pedagogy by seeing students as a community of learners and emphasizing equity in their instruction (Collins, 1999). Since this skill is developed over time, experienced teachers are more apt to think of classroom concerns as concepts and principles that the specific interaction symbolizes when compared to more novice teachers (Glaser & Chi, 1988).

Using Videos to Assess Teacher Noticing

Video analysis provides a more holistic way of assessing teacher skills and capacity when compared to more traditional approaches like pencil-and-paper examinations (Kaiser et al., 2015). It presents the complexity and context of a lesson and instruction (Kersting, 2008), and allows the same actions and interactions to be viewed multiple times from various perspectives. Using videos also provides teachers the opportunity to view instruction that is separate, but related to their own teaching experiences. Watching videos of other teachers' instruction also offers examples of teaching that allow for reflection on what happens in their own classrooms (Sherin & van Es, 2005). For example, Haverly et al., (2020) suggests that novice teachers observe videos of classroom talk that shows teachers noticing sense-making moments. The talk in the classroom may seem disorganized or confusing, but it is actually an authentic representation of how teachers notice the happenings in the classroom to make critical decisions that foster meaningful talk and sense-making. Viewing videos of how teachers notice and, in turn, make curricular decisions may pivot novice teachers' notice to focus on the essence of students' thinking in instances of sense-making.

Another benefit of using videos of instruction to study what teacher notice is that it provides researchers the opportunities to better understand the intricacies of teacher professional development, especially as teachers acquire experience over time. According to Kaiser et al., (2015), using video analysis to understand noticing allows researchers the opportunity to, "evaluate how differently balanced cognitive effects and situated competence facets are shaped comparing different groups of teachers and which facets and levels of professional competence are characteristic for expert teachers in contrast to novice teachers" (p. 384). Kersting (2008) noted that experimental studies in cognitive psychology indicated that more experienced teachers were, "found to systematically perceive and interpret classroom events differently from novices" (p. 847). Specifically, more experienced teachers were able to better rationalize what they noticed in videos of instruction, as well as offer more detailed and meaningful interpretations of what they observed. More experienced teachers were also able to pinpoint crucial instructional facets and interactions, and suggest alternatives to instruction (Kersting, 2008).

There are limitations to using video-based methods to understand teacher knowledge and competencies. One limitation is that teachers need support to develop their ability to notice and interpret actions and interactions (Sherin & van Es, 2005). Another limitation is the video is used to represent a real-life situation, but there are embedded biases in recording instruction versus watching it in real-time. For example, the perspective of the camera can limit what a teacher sees and focus on specific happenings that the teacher may not have noticed if they were to have witnessed the lesson in-person. This may influence what the teachers notice during the lesson (Kaiser et al., 2015). Another

METHOD

This study used quantitative measures to explore what middle school science teachers notice from a video of instruction at the start of the program, after the first year, and the end of the program.

Description of iSMART

Integrated Science Mathematics and Reflective Teaching (iSMART) was a two-year cohort-based online graduate program that focused on the pedagogy of effective and reform-based science and mathematics instruction, and the integration of both content areas. The program began with enrollment in an in-person one-week summer workshop before the first semester of the graduate program. During this workshop, the teachers participated in activities that helped them build community as a group. We discussed program expectations and spent significant time exploring aspects of effective science and mathematics education, including underlying principles of reform-based instruction. The teachers also learned how to use the technological tools required to participate in the courses of the program which took place synchronously online. Teachers also began work on projects that were tied to the courses in their first semester of the program.

All of the courses during the academic year were held online. All iSMART courses occurred via Blackboard Collaborate, which was the university-supported online platform. The classes occurred synchronously in order for all teachers to interact in real time. This provided the opportunity for the teachers and the instructor to engage in discussion, collaborate during group work, partake in activities, and complete presentations to a live audience. Blackboard was the platform used to house course materials, such as readings, assignments, and discussion boards which the teachers accessed asynchronously.

Over the two-year period, the teachers participated in various courses that emphasized methods for science teaching and mathematics teaching. During this time, teachers also engaged in classes that discussed and modeled ways to integrate science and mathematics so that both content areas worked synergistically together for instruction. Courses also focused on emphasizing student learning and inquiry-based instruction in science and mathematics over more general issues, such as classroom management. Since the teachers were all full-time instructors, classes occurred once a week but toggled between the two. In other words, students would take science methods during week one, then mathematics methods during week two, science methods again during week three, and so forth. Again, even though the class titles indicated a science focused, or math focused course, the content was integrated to foster the integration of the two subjects.

In between the two academic years, teachers attended a second in-person one-week summer workshop. The teachers built on previous knowledge and experiences from the program to develop additional capacities to create and engage in inquiry-based lessons, explore technological tools for teaching and learning, and begin work on the culminating project for the program which was a capstone paper on a relevant topic of their choosing as it related to science and mathematics education. For a more detailed description of iSMART, see Lee et al. (2013).

Participants

The participants (N=12) in this study consisted of 12 Texas-based middle school science teachers. 10 of the teachers were female, and two were male. Of the participants, 10 were white, one one was Hispanic, and one was African American. The teachers ranged from two to 26 years of classroom experience at the start of the study. Of the participants, 10 worked in public schools, and two worked in private schools. All participants in this study gave consent for their relevant data to be included in research and publications purposes.

Data Collection

Data was collected in this study via open-ended prompts which were generated by an author of this paper. During the initial meeting of the first summer workshop, or T0, the teachers watched a 45-minute video of a middle school science lesson. Each teacher was provided a flash drive that contained a word document. The first page of the document asked for the participants' coded identifier, date, and included the prompt, "Notes on what you notice during the video". The only directions provided to the participants were to write what they notice while watching the video, and to not view the second page of the document until asked to do so. At the conclusion of the video, participants were instructed to save and answer open-ended prompts on the second page that asked for what they noticed regarding the teacher, students, instruction, content, lesson purpose, communication, and lesson strengths and weaknesses. This same process was followed during the second summer workshop, or between the first academic year and the second academic year. This data collection point is labeled as T1. Lastly, participants were asked to view the video after the completion of their degree at the end of year two and repeat the same procedure. Since we did not hold a third in-person workshop, the teachers did this remotely. Again, the teachers were asked to watch the video and complete the "Notes" document which provided the opportunity to take notes on what they noticed while watching the video. Afterward, they responded to the same prompts as before. In all three cases, the same video was used for data collection.

Data Sources

We constructed our rubric following Glaser and Strauss' (1967) constant comparative method to generate a theory that explains a phenomenon that is founded in reality. Constant comparative method is the analysis of data to develop a grounded theory in which concepts that provide explanation of social phenomena are revealed through the analysis of data. In order to capture the conditions and responses over time, constant comparative method was used to code responses to the prompt "What do you notice in the video." Each response to the first document that only had the prompt "Notes on what you notice during the video" was given an alpha and a numerical code that were randomly assigned to keep the identities of the respondents and dates of the responses anonymous. Three researchers then used open coding for "breaking down, examining, comparing, conceptualizing, and categorizing data" (Strauss & Corbin, 1990, p. 61). Then, all three coders met to collaborate and generate categories in which the codes could be placed. After axial coding (Strauss & Corbin, 1990), the researchers used selective coding (Straus & Corbin, 1990) to generate core categories. We placed these five categories into a rubric which were (1) context, (2) classroom management, (3) students, and (4) teacher, and (5) lesson. The researcher again coded the responses and revealed sub-categories for the rubric. (Please see Appendix A.)

The "Context" category included notes regarding student demographics, student context, student placement in the classroom, classroom materials and environment, technology resources, and science resources. The "Classroom Management" category involved classroom norms, cooperative learning strategies, teacher proximity, how students were selected to share ideas, and whether students remained in their seats during the lesson. The "Students" category included notes on student behavior, whether students were on or off task, engagement, and interaction. The "Teacher" category revealed notes on teacher practices, teacher questions, time management, wait time, teacher-student relationship, affect, and encouragement. The "Lesson" category was generated from notes on descriptions of the lesson, cognitive level of the lesson, content, whether the lesson was teacher or student-centered, presence of a laboratory activity, the relevance of the lesson to students' lives, and whether there was the incorporation of class discussions.

After the generation of these codes, the researchers re-coded all responses according to the categories. If a response regarding the sub-category was present, and it involved interpreting and/or analyzing with evidence or rationale, it was given 2 points. If a response regarding a sub-category was present, but there was low or no evidence or rationale, it was given 1 point. If the notes did not address the sub-category, it was given 0 points. The means from the rubric categories were calculated to understand general trends of responses overall and within the four sub-categories. The following is an example of Participant E3's responses and coding:

- 2 points: "I felt the kids were too busy with playing with stuff and he lost their attn. – but they were engaged in the activity" (Participant E3, T0).
- 1 point: "The teacher had a class that was actively engaged" (Participant E3, T1)
- 0 points: (no response for T2)

RESULTS

Overall, the scores for the rubric resulted in a decrease in means across all categories T0 (16.6), T1 (13.4) and T2 (13.1). The means for context were T0 (2.8), T1 (1.5) and T2 (2.8). The means for classroom management were T0 (2.8), T1 (1.6), and T2 (1.6). The means for the student category for all participants was T0 (3.7), T1 (2.7), and T2 (2.6). For the teacher category, the means were T0 (3.7), T1 (3.5), and T2 (3.1). For the lesson category, the means were T0 (3.5), T1 (3.9), and T2 (2.9). Please see Table 1.

Table 1. Average Level of Noticing of Student Engagement

Participant	T0	T1	T2
All Teachers	16.6	13.4	13.1
Context	2.8	1.5	2.8
Classroom management	2.8	1.6	1.6
Student	3.7	2.7	2.6
Teacher	3.7	3.5	3.1
Lesson	3.5	3.9	2.9

To understand whether teachers noticed items that were iSMART objectives, means for three sub-categories were calculated. The sub-categories were student engagement, teacher / student-centeredness, and lesson format (inquiry). For each sub-category, we also disaggregated by years of experience (1-5 vs. 6 or more years) considering literature that states more experienced teachers were able to notice and offer more insight. For student engagement, the means were 1.18 (T0), .91 (T1), .73 (T2). When disaggregated by years in practice, teachers with less than six years of experience had 0.8 (T0), 0.8 (T1), and 0.6 (T2). For teachers with six or more years in practice, the means were 1.5 (T0), 1 (T1), and 0.83 (T2).

Table 2. Average Level of Noticing of Student Engagement

Participant	T0	T1	T2
All Teachers	1.18	0.91	0.73
Teachers less than 6 years in practice	0.8	0.8	0.6
Teachers with 6 or more years in practice	1.5	1	0.83

For student-centered instruction, overall, it was 0.55 (T0), 0.64 (T1), and 0.73 (T2). Teachers with less than six years of experience resulted in 0.8 (T0), 0.6 (T1), 0.4 (T2). Teachers with six or more years of experience had 0.33 (T0), 0.61 (T1), and 1.0 (T2).

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Table 3. Average Level of Noticing of Student-Centered Instruction

Participant	T0	T1	T2
All Teachers	0.55	0.64	0.73
Teachers less than 6 years in practice	0.8	0.6	0.4
Teachers with 6 or more years in practice	0.33	0.67	1

(Table 3.) For lesson format (inquiry), overall teachers' means were 0.0 (T0), .018 (T1), and 0.18 (T2). Teachers with less than six years of experience were 0 (T0), 0.2 (T1), and 0 (T2). For teachers with six or more years of experience, the findings were 0 (T0), 0.17 (T1), and 0.33 (T2). (Table 4.)

Table 4. Average Level of Noticing of Lesson Format (Inquiry)

Participant	T0	T1	T2
All Teachers	0	0.18	0.18
Teachers less than 6 years in practice	0	0.2	0
Teachers with 6 or more years in practice	0	0.17	0.33

CONCLUSIONS

The findings of this study were surprising because it was hypothesized that teachers would make note of more items that focused on highly effective science and mathematics instruction over time or shift their focus from classroom management-type actions to more about student learning and the lesson. This was not the case for the overall scores. This could have been due to the notion that teachers noted more items in general during the first viewing of the video (T0) and the start of the iSMART program, but during the second (T1) and third (T2) data collection periods, the teachers noted items that were more important for science learning. Since the rubric only assessed the frequency of noticing, it could mean that participants started to notice what they viewed as important over time, whereas they noted more general items at T0.

The findings from the subcategories were also of interest. Overall, for student engagement, the scores decreased over time. This was also the case for those with six or more years of classroom experience, and novice teachers. In other words, participants noticed less about student engagement over time. This was surprising because one objective of iSMART was to increase student engagement in the classroom. Teachers need to be able to gauge and influence student engagement to foster students' science learning. The decrease in noticing in this sub-category indicates that participants either did not notice this, or they did not find the level of student engagement to be particularly noteworthy.

For the last two sub-categories that we investigated, there was a difference found. Student-centeredness and lesson format (inquiry) slightly increased overall. When examined by years of experience, the results show that noticing scores for novice teachers decreased for teacher/student-centeredness and remained the same for lesson format (inquiry). This was not the case for the scores of these two sub-categories when we examined teachers with six or more years of experience. For student-centeredness, the more experienced teacher's scores increased from 0.33 to 1.0 over the two-year period. For lesson format (inquiry), their scores increased from 0.0 to 0.33 over the two-year period. These differences between the novice and more experienced teachers may be explained by Kersting (2008) and Koenig et al. (2014), who noted the different abilities of novice and expert teachers to notice and interpret classroom situations. This result may have also been impacted by the fact that the other two of iSMART's main objectives were to emphasize student-centered instruction, as well as the theories behind, and teaching of, inquiry-based lessons. Due to these emphases of the program, the teachers may have paid more attention to these aspects of science teaching (NGSS Lead States, 2013; NRC, 1996), and were able to interpret and rationalize (Kersting, 2008; Koenig et al., 2014) their responses when making notes of what they noticed during the video.

Significance

The implications of this study support long established research that teachers' practices are imperative to student learning (Crawford, 2007). Teachers must be able to notice the critical interactions within their classrooms in order to implement effective strategies to support students' learning (Luna, 2018, Luna et al., 2018; van Es & Sherin 2008, 2021). In science, this is especially important as teachers negotiate ways to interpret and respond to the development of authentic student (van Es & Sherin, 2002; 2008). Our results reveal that teachers notice, in general, less over time. Both experienced and novice teachers notice similarly overall (Kersting, 2008; Koenig, et al., 2014). The two exceptions were when we disaggregated the data for the sub-categories of teacher/student-centeredness and lesson format (inquiry).

Fundamentally, science teachers need to be able to notice critical moments in the classroom and enact appropriate pedagogies that encourage student engagement with the content and promote participation in discourse that maximizes student learning within inquiry-based settings. If teachers do not hold sophisticated skills in noticing what is occurring in their classrooms, the practices implemented in those classrooms will be impacted. Teachers are the negotiators of content and curriculum (Ramsey & Howe, 1969). Therefore, teacher noticing is a much-needed area of further research. To build on this study, those that teach science, integrate science in their teaching, develop science curriculum, educate preservice and in-service teachers, and education administrators should consider how to foster teachers' ability to notice key facets of effective science instruction in the classroom.

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Improving Access to STEM for Girls of Color through Community Programs

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ABSTRACT

Our study examines community youth workers' perceptions, attitudes, and aspirations regarding the development of STEM programming for American girls of color gathered through a focus-group discussion embedded in a professional development workshop. *Results:* Although many of the community youth workers commented about being unprepared to plan or offer STEM programming, they suggested that a collective community effort could be a worthwhile approach for increasing STEM programming for girls of color. The middle school girls of color being served by the community agencies represented in the sample corroborated these results as they too perceived themselves as not belonging in STEM. However, when probed about how they wanted to spend their out-of-school time, many of the girls who asserted lack of interest or belonging in STEM suggested everyday activities that were, indeed, STEM-based. *Conclusions:* This pattern of results suggests that persuading girls of color to pursue STEM-related activities in outside-of-school contexts requires a cultural reframing and the use of empowering language that considers their existing interests.

Keywords: STEM, gender-specific STEM programming; science education; girls of color; community youth workers

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INTRODUCTION

Strong preparation in science, technology, engineering, and math (STEM) is associated with the development of technical skills, high-level critical thinking skills, and the ability to perform inquiry-based scientific analyses (Seymour et al., 2004; Thiry et al., 2011), all of which are necessary for a scientifically and technologically advanced global society (English & King, 2015; Kelley & Knowles, 2016). However, the benefits of STEM education and training are not equally available to all students and workers (National Science Board, 2016). Although individuals from all cultural groups display high levels of STEM talent and comprise 38% of the US population, they make up only 13% of the STEM workforce (Jackson et al., 2021). As students, they also are underrepresented in both STEM courses and out-of-school time STEM programs (Amerasinghe, 2016; Stromquist & Monkman, 2000). Increasing participation in out-of-school programs is important because schools do not provide the totality of the experiences required to motivate children from diverse groups to participate in STEM (Ihrig et al., 2018). These programs also are an essential context for STEM learning as they offer more flexible learning opportunities than school courses, especially for students from racially and ethnically minority groups (Moran et al., 2021). Furthermore, culture, family, and the outside community can provide unique opportunities to motivate STEM learning (Young et al., 2019).

Well-developed community-based programs can compensate for the lack of STEM courses in underfunded schools, which are disproportionately attended by students of color (Perry et al., 2012). Although school-based teaching staff plays a critical role in encouraging students' interest in and understanding of STEM educational pathways and careers (Brophy et al., 2008; Campbell, 1995), out-of-school learning programs are frequently operated by community youth workers (Christensen & Rubin, 2020; Colvin et al., 2020). STEM programs staffed by social workers and community youth workers have had success working with students to integrate STEM concepts (Mosatche et al. 2013). Staff competency is critical to community programming (Astroth et al., 2004; Cross et al., 2010; Lardier et al., 2018). However, efforts to regulate the training of community youth workers have been underwhelming (Starr & Gannett, 2016), which could adversely impact the quality of community-based programs (Donaldson & Franck, 2020). The current paper describes a qualitative research effort concerned with whether and how programming developed or supported by community youth workers may increase access to STEM for girls of color. We gathered original data through a focus group discussion with community youth workers aimed at increasing community support for STEM education for girls of color. We were careful to suspend all stereotypical ideas about girls from racially and ethnically minoritized backgrounds and their participation or lack thereof in STEM programming as we engaged with and listened to participants' narratives (LeVasseur, 2003).

American Girls of Color and STEM

Cultural and structural manifestations in STEM may privilege indicators of success that are associated with accomplishments of White male scientists (Miller et al., 2005). Compared to Latin American males as well as White males and females (Simpkins et al., 2015), Latina girls report having the lowest motivation for STEM subjects. Blacks and other students of color are less likely to enroll in and perform less well and have lower interest in some STEM subjects than their White and Asian American counterparts, perhaps because of cultural norms and stereotypes, such as low teacher expectations (Moron & Smith-Mutegi, 2022), that may interfere with their enrollment and participation in STEM courses (Curran & Kellogg, 2016; Kerr & Robinson-Kurpius, 2004; National Science Foundation, 2015; Zilanawala et al., 2018). Still, students of color who persist in STEM courses are equally as likely as their non-minority peers to complete STEM degrees (Tyson et al., 2007). At the same time, girls and women perform less well in STEM-related courses at all levels, have lower interest in STEM (Dasgupta, 2011; Else-Quest et al., 2010), and are less likely to work in STEM-related careers (Ceci & Williams, 2007).

The exclusivity of the STEM industry is echoed in K-12 classrooms where women and girls of color experience dual marginalization and power inequities (Iruka et al., 2020; Moss-Racusin, et al., 2015). However, focusing exclusively on equity concerns discounts the fact that girls of color can provide a unique perspective that encourages innovations in STEM and advance STEM knowledge in ways that benefit individuals from all sociodemographic groups (Sinnes & Løken, 2014). Attention to equity concerns in the absence of a consideration of the structural intersection of gender and STEM also ignores feminist policies and practices that could address systematic social inequality (Allegrini, 2015). Exposure to sexism irrespective of racial and ethnic backgrounds also appears to negatively influence girls' interest and involvement in STEM (Brown, & Leaper, 2010). Still, gender socialization among some racially minoritized groups may provide girls with experiences and opportunities that discourage interest in STEM (Hanson, 2007). That is, some girls of color do persist in the STEM education pipeline (Joseph, 2017) in spite of being positioned outside of science and mathematics courses as early as the elementary school years, although these numbers remain small (Gholson, 2016). As compared to their White counterparts, some girls of color express positive dispositions toward STEM (Perna, Lundy-Wagner et al., 2009; Riegle-Crumb & King, 2010). However, many studies fail to consider the associations among the multiple identities of race, ethnicity, socioeconomic status, and gender and whether and how they converge to explain variance in student outcomes (O'Brien et al., 2015; Shields, 2008).

The Current Study

Importantly, girls of color are frequently engaged with community organizations that promote culturally relevant values, attitudes, and behaviors (Adams, 2010; Baldridge, 2018). In line with recent research, we reasoned that community youth programs can be influential spaces for teaching and learning about STEM (Lane & Id-Deen, 2020). These programs provide opportunities to explore STEM concepts beyond the classrooms in ways that may be more meaningful and empowering for some learners (King & Pringle, 2019) because they encourage communal responsibility for learning (Young et al., 2019). Below, we describe a program focused on helping community youth workers expand their work to contribute to the development of gender-specific STEM programming aimed at motivating the development of a positive STEM identity among middle-school girls of color. The underlying premise of this work is that access to high-quality programming affirms students' identities and belongingness in STEM (Jackson et al., 2021). We address two research questions:

Research Question 1: What are the perceptions, attitudes, and aspirations of community youth workers regarding the development of gender-specific STEM programming for girls of color?

Research Question 2: What data-driven strategies can community youth workers use to successfully recruit and engage girls of color in community-based STEM programs?

METHODOLOGY AND MATERIALS

To analyze participants' responses, we applied a grounded theory approach, the purpose of which is to generate theory that is steeped in the data, such that the results are driven by the phenomenon that emerges through the process and not from a priori hypotheses advanced by the researchers. Similarly, grounded theory is inductive in that it allows theory construction based upon the data. Specifically, researcher simultaneously code and analyze the data by developing concepts, searching for themes, and integrating them into a coherent theory. This approach also allows for a combination of data sources and methodologies (Glaser & Strauss, 1967), which we present here.

Participants

After first obtaining University Institutional Review Board approval (#1411884-1), we used a purposive sample to recruit community youth workers from a county-collaborative located in mid-Atlantic region of the United States that encouraged staff to learn together, share knowledge, perform needs assessments, develop community-wide solutions, and consider the collective community impact of services and supports. Their perceptions, attitudes, and aspirations regarding the development of STEM programming targeted girls of color were gathered through a focus-group discussion embedded in a professional development workshop. Participants were 17 female community youth workers, 14 of which were Black, one was White, one was Latina, and one identified as bi-racial. Nine of the workers were between 26 and 40 years of age, five were between 44 and 60 years of age, and three were between 21 and 25 years of age. Ten were employed in community afterschool programs; four were employed in schools, and three worked in faith-based programs. Seven had a bachelor's degree, five had a master's degree, four had completed some college, and one had a high school diploma. Fifteen workers had between one and five years of experience and two others had between six and 10 years of experience. We used a focus group methodology because it facilitates interactions that are not possible in one-on-one interviews and produces rich and detailed information from all participants, lending to credibility of the data (Levitt et al., 2018). Sensitive and personal disclosures are especially likely in a focus group setting and some themes only emerge in this context (Guest et al., 2017). All participants gave consent for their comments to be used in program evaluation research.

The Workshop. The six-hour professional development workshop was predicated on research demonstrating that integrating arts and humanities content into STEM education (STEAM) can increase interest in and acceptance of STEM for all students and reduce gender differences (Conradty & Bogner, 2018). STEAM encourages children to illustrate STEM concepts in imaginative ways, such as expressing knowledge through music and dance, communicating with descriptive language, communicating ideas with crafts, graphs, and model-building (Sharapan, 2012). Likewise, social-emotional learning is also important to STEAM learning (Garner et al., 2018; Levykh, 2008) and, therefore, was incorporated into the workshop.

Facilitators discussed the disproportionality of girls and women of color in STEM, beginning in elementary school and into the college years and possible reasons for these patterns. The developers were committed to helping participants understand that working with girls who have experienced exclusion in educational settings requires sensitivity, compassion, competence, and the use of pedagogical practices that encourage confidence in their STEM talents (Stapleton, 2015). Another objective was to work with community youth workers to develop strategies that they could use to successfully recruit and retain girls of color into community-based STEM programs. Distinct practices and experiences that result in successful outcomes for girls of color, such as storytelling, (see Nelson et al., 2008) also were included as elements. Given that safe spaces and the building of community through relationships are important in efforts to bring girls of color to STEM (Brinkman et al. 2018), training in relationship-building also was included.

To establish methodological integrity, we provide information about our positionalities as researchers. The first author who was involved identifies as a Black female from a working-class background with over 20 years of expertise in child development research with children and families from racially and ethnically minoritized groups. The second author is a White female of immigrant origins who developed and conducted the workshop in conjunction with the third author who both have extensive training in STEM and program development for young girls of color. All three authors were involved in the conceptualization of the study, initial code development, and manuscript preparation. The research team operated consensually and met regularly to talk through the questions, coding, and issues related to patterns that were emerging in participants' responses. Discrepancies were resolved through consensus.

The workshop combined instructor-led discussions, and sharing and teaching that included practical hands-on activities, discussions, and reflections. Afterwards, participants were invited to respond to a set of focus group questions and their verbatim quotes were interpreted through a qualitative analysis, which were audio-recorded and supplemented by researchers' pencil and paper notations. Responses were kept confidential and viewed only by the researchers.

FINDINGS

Data Sources and Analyses

The first data source was the community youth workers' responses to three questions: "Is your organization adequately preparing girls of color for futures in STEM?", "What are some of the challenges your organization faces in this endeavor?", and "What are some possible solutions to these challenges?" The focus group discussion was conducted after the formal workshop began and was monitored by two female researchers, both with minoritized backgrounds. We first familiarized ourselves with the data. Next, initial codes for organizing the data were generated, and the data were organized in relation to the themes, which were reviewed for accuracy, and defined and labeled to assign meaning to response patterns (Braun & Clarke, 2006). A theme captures important information about the data in relation to the research questions and represents patterned and meaningful responses within the data. Researchers studied the comments to identify emerging categories using unrestricted coding until theoretical saturation was reached, such that no "new" categories or themes emerged from the data (Guest et al., 2006). After coding the data individually, two researchers met and came to final consensus about the themes yielded from individual analyses.

To establish trust and confidence in the data, we demonstrated rigor by noting that all the available community youth workers in the collaborative from which we recruited were included, which means that responses provide an accurate representation of participant perspectives (Thomas & Magilvy, 2011). We also considered how well the themes represented the data and determined similarities within and differences across themes by presenting representative quotations from the transcribed responses. Lastly, we sought agreement among the coders and the participants themselves (Campbel et al., 2013). Two researchers independently coded the responses into categories. We provide labels for the categories below. A comparison of the responses resulted in a kappa of .82.

Analysis of the responses yielded three themes regarding community youth workers' conceptions about why so little out-of-school and community-based STEM programs target girls of color: Lack of Belonging in STEM, Focus on Mental Health Services, and Community Cohesion. Lack of Belonging in STEM reflected the community youth workers' perceptions of themselves as lacking in knowledge about the definition and applications of STEM to real-world concerns. For example, although the community youth workers indicated awareness of the importance of STEM for girls of color, their statements also demonstrated ambivalence about what offering that type of training meant for their work lives and whether there was support from their supervisors for this type of programming. Participants also discussed feeling undervalued and underperforming in STEM when they were students themselves and commented that girls of color would benefit from learning about STEM from appropriately trained community youth workers with whom they share a common history and cultural experience (see Nolas, 2014). The Focus on Mental Health Services theme centered on the community youth workers' perceptions of and prioritization of their agencies' roles in the provision of community mental health services and support for students and their families. The final theme of Community Cohesion reflected community youth workers' perceptions that, although they felt unprepared as individuals to plan for or offer STEM programming, they believed that a collective effort among the organizations would be helpful in this regard. Some of the community youth workers acknowledged that their individual agencies could offer STEM-related programming with the help of outside STEM experts and that they could work together to develop a model that could be implemented in one of the programs to work out kinks and develop a model for others to follow.

Table 1.
Quotes Illustrative of Each Theme.

Theme	Quotes
Lack of Belonging in STEM	"I need to know more about all of the careers girls of color can pursue STEM careers so that I can help provide the right kind of training. If the girls see me as interested in STEM, maybe they will be too." (Participant 7) "I stayed away from STEM classes when I was in school. I know it is important, but I am not sure I can make a real contribution to this effort" (Participant 3) "I don't think my supervisor is confident in my ability to plan or organize STEM training" (Participant 5) "I am trying. I know jobs in STEM are going to outnumber other jobs, but teaching STEM is not my interest." (Participant 12) "I did not have an interest in STEM as a young person. I do not have an interest in it, cannot teach it. Looking online to find activities is also a big challenge. (Participant 10)
Focus on Mental Health Services	"We are a mental health organization and we are barely able to address the broader issues that girls of color experience, such as anxiety and depression" (Participant 3) "The girls we serve have so many unmet social needs that we have difficulty addressing as it is. Adding STEM would be an uphill climb." (Participant 5) "The main thrust of my program is to provide afterschool care for children whose parents work late. The programs we offer are focused on the social emotional needs of at-risk youth. We are behind the eight ball and are working with students to enhance their social-emotional skills and help them with homework they already have" (Participant 1) "Working on STEM is very time consuming and I have too many other things to do because of the community's large need for mental health services." (Participant 17) "Sometimes, I am forced to be a mother to the girls in my program because they have so many needs that are not being met within their families, which can prevent me from engaging in creative programming like STEM education. We are a family" (Participant 17)
Community Cohesion	"I have colleagues who work on these kinds of programs and I could connect to some of them for help with this kind of programming." (Participant 11) "I could start small and get other people to help me." (Participant 11) "One solution may be to figure out what my program needs and to consider what new staff I can bring in who can teach and lead in this area when there is a chance to hire." (Participant 15) "Better communication between agencies could improve planning for STEM" (Participant 1) "Maybe we could work together to identify the agency with the most resources and best opportunity to develop a STEM program and use it as a model for the rest of us" (Participant 6)

Table 1 displays an illustrative quote for each theme.

These data were triangulated and verified with the community youth workers' quantitative workshop ratings and through quantitative data collected from girls served by the represented community agencies. After the focus group discussion, community youth workers completed a 10-item survey, which examined their overall satisfaction with the workshop. Questions were concerned with the extent to which they believed that STEM programs should be staffed by individuals who reflect the demographics of program participants, their conceptions of the potential of the workshop to inspire confidence about STEM program development, and beliefs about the extent to which the workshop impacted their own STEM learning and plans for future STEM work with girls of color. Participants responded to each question using a 5-point Likert-type scale (1 = *completely disagree* to 5 = *completely agree*). Internal consistency for this measure was .88. Mean ratings ranged from 4.23-4.71 (out of 5), indicating that, overall, they perceived participation in the workshop as adding value to their thinking about STEM in relation to improving access for girls of color.

As multiple data sources strengthen qualitative data analysis, we also used insights from the girls being served by the community youth organizations represented by participants to triangulate the data. One semester later, one of the authors visited two middle schools located in the same catchment area as the community collaborative that sponsored the workshop. Her objective was to recruit girls into a community-based STEM enrichment program. School personnel and parents had earlier given permission for students to receive information through strategically-placed flyers in classrooms, lunchrooms, and other high-traffic areas in the school. School staff worked with the authors to brainstorm about how to best to reach interested girls. During lunchtime and between classes, interested girls in grades 6-8 were directed to a table staffed by community youth workers who spoke directly to the girls about the program using a brief PowerPoint presentation and STEM-related game. In all, 70 girls engaged with the researchers. Thirty-two girls identified as Black, 18 as Asian, 11 as Latina, and nine identified as White. Girls who approached the table were asked two questions: "Are you interested in STEM?" If girls responded "yes", there were probed with an additional prompt of "What do you like about it?" If girls answered no, they were asked: "What *are* you interested in and what would you like to do in an out-of-school program?" Girls' responses to question were coded as "0" for *no* and "1" for *yes*. Sixty girls responded "*no*" and 10 responded "*yes*". This finding bolstered the lack of belonging that the female and racially minoritized community youth workers commented about during focus group discussions. Results also demonstrated a significant difference in STEM interest across race/ethnicity, $\chi 2(1, N = 70) = 9.32, p < .03$. A post-hoc subgroup analysis revealed that Asian American girls were particularly interested in STEM, $p = .01$. No other significant differences emerged.

When asked what they *were* interested in and what they *would like* to do afterschool, the 60 girls who perceived themselves as uninterested in STEM, 24 reported that they wanted to spend their out-of-school time doing art, seven were interested in social media, six were interested in language, five were interested in music, five others were interested in fashion, three were interested in cooking, and three girls were interested in robotics. Girls most often suggested art, $\chi 2(1, N = 53) = 76.17, p =.0001$. As discussed below, these activities require STEM knowledge and suggest that many girls of color who perceive themselves as not belonging are indeed interested in STEM when they can see real-world applications and how arts and humanities content is integrated into the learning. Qualitative and quantitative data are integrated and included as part of the interpretation and discussion of the study results.

DISCUSSION

We examined the perceptions, attitudes, and aspirations of community youth workers regarding the development of STEM programming for girls of color. We also evaluated whether proposed strategies operated to interest and engage girls of color into out-of-school time STEM programs. We focused on community youth workers because they work in organizations that are designed to be a safe space where the self can be developed and supported. As well, these programs offer a counterspace to the ones that marginalized and racially and ethnically minority students often encounter in schools (McLaughlin et al., 1994). Moreover, community youth workers typically work and live in the same communities as the children they are serving, and, therefore, they are especially likely to understand the cultural nuances that these students experience at home and school (Baldridge, 2018; Hirsch et al., 2000). These workers also have a major decision-making role regarding the types of programs that are available to students. Equity concerns regarding STEM have typically focused on increasing the representation of White females and males of color (Campbell, 1995), despite the fact that males and females of color have unique experiences with regard to STEM. For example, girls and women of color experience both racism and sexism in the pursuit of STEM (Ireland et al., 2018; Joseph, 2017; Wright et al., 2016). In fact, many girls of color lose interest in and confidence about STEM during the late elementary and middle school years (Hughes et al., 2013). Although some girls of color derive their self-concept of smartness from "doing" of science or math (Gholson & Martin, 2014), data compiled by the NSF (2011) suggests that Black, Latina, and Native American women comprise only about 3% of the STEM workforce, with the exclusion of the biological sciences. This trajectory for this lack of participation may begin much earlier, as many elementary school teachers do not have the background knowledge, interest, confidence, and efficacy for teaching STEM (Joseph et al., 2017).

Consistent with possible selves' theory, which is focused on describing how one's current and future self-representations motivate behavior and factor into career choices and goals (Lips, 2007; Markus & Nurius, 1986), many teachers also disregard the potential of girls of color for STEM learning and training because they endorse stereotypical beliefs about who 'should' be interested in STEM (e.g., Pringle et al., 2012). Our results suggest that these conceptions and beliefs also are endorsed by community youth workers for both themselves and the girls they serve. Thus, many girls of color are deprived of STEM opportunities both within and beyond the classroom. Although the vast majority of the participating girls perceived themselves as not being interested in STEM, all who responded indicated interest in activities based in or inspired by STEM, even when they did not use STEM-related language. Integrating the arts and humanities into STEM activities and vice versa can help children develop critical thinking skills and may make STEM learning science more relevant and encourage enthusiasm and support individual self-efficacy (Garner et al., 2018). This may be particularly true for girls, who tend to be insecure about their skills in this area (Henriksen, 2014). Film, music, and design, when integrated into STEM education, can propel girls' interest and engagement in science. That is, research has revealed robust correlations between artistic, musical, literary and crafts activities and measures of later success in STEM subjects, including Nobel Prizes and numbers of patents or companies founded (Root-Bernstein, 2015). Many of the girls also indicated an interest in social media, which represents a variety of technology and communication-based activities and provide a means for scientists to boost their professional profiles. Similarly, cooking, which some of the girls listed as an out-of-school interest, requires rudimentary understanding of chemistry as well as mathematical measurement concepts, and a basic understanding of agriculture and conservation science (Aguilera, 2018). Fashion, a choice of several of the girls, also intersects with STEM in that it involves design thinking, an understanding of shapes and patterns, geometry and math, and embraces elements of engineering, 3D thinking, and material design (Braddock Clarke, 2018; Deaton et al., 2018; Shirley & Kohler, 2012). Thus, out-of-school programs that offer STEM content for girls of color through a culturally-relevant lens and embrace their interests and innovations within the context of scientific inquiry may be especially effective (Morton et al., 2022).

In relation to our goal of advancing a discourse that disrupts stereotypical beliefs about who belongs in STEM, our results suggest that professional development opportunities and the collective skills, talents, and resources of colleagues working in other community organizations may encourage community youth workers to support STEM programming that specifically targets girls of color. Findings also suggests that there is much work to do at the administrative levels of community organizations. Structural disruptions, community influences, and resilience strategies play a significant role in whether girls of color persist in STEM subjects (Joseph, Hailu, & Boston, 2017). It is important that females of color to participate in counter spaces that protects them from isolation and microaggressions related to their participation in STEM. These spaces should operate in ways that are conceptually and ideologically congruent with how girls of color learn (Ong et al., 2018). Culturally-relevant STEM programs can serve as a counterspace that encourages racial/ethnic and gender equity (Borum & Walker, 2011). The workshop we presented integrated program elements and pedagogical strategies that encourages individual agency and the inclusion of STEM-related content that closely aligns with students' prior experiences and ways of knowing (Aronson & Laughter, 2018; Kayumova et al., 2015).

Focus group responses and surveys indicated that community youth workers perceived themselves as benefitting from participation in the workshop. Benefits of one-shot interventions for improving individuals' perceptions of their attitudes and skills have been demonstrated in another research (e.g., DeBacker et al., 2018). Regarding the focus groups, the community youth workers reported being cognizant of the fact that girls of color can benefit from exposure to STEM enrichment activities that occur outside of school because these non-school activities allow for more "doing" and emphasize creativity and real-world applications in a grade-free environment (Dasgupta & Stout, 2014). Although we found that Asian American girls were especially likely to report being interested in STEM, there is evidence that they too often question their own STEM competence (Cooc & Kim, 2021) and are subject to stereotypical views and attitudes that limit their STEM opportunities (Paik et al., 2018). Thus, these girls should be included in any effort to promote interest and engagement in STEM for girls of color.

CONCLUSIONS

Our findings suggest creative and design activities that are not accessible during the school day may attract girls to STEM (Cooper & Heaverlo, 2013). Non-traditional approaches to STEM education also may serve as an engaging introduction to its real-world applications, which may be particularly important for girls of color. We also found that empowerment language worked best for recruiting the girls into the STEM classes. Interest in and engagement with STEM for girls of color also can be improved through the adoption of culturally-respectful and compassionate approaches that validate and utilize their own cultural resources (e.g., Tan & Calabrese Barton, 2012). More also needs to be done to introduce teachers and program developers to well-known scientists, inventors, and female STEM professionals of color, as the community youth workers could only point to two women who fit these criteria. Media images of STEM professionals influence public perceptions of the participation, status, role, and contributions of women in STEM. These images are primarily of males. Even when females are presented, they often are projected in secondary roles and females of color are typically non-existent (Steinke & Tavarez, 2018). Programs absent of the culture and context of girls of color may send a message to them that they do not belong to STEM. Whether and the extent to which this workshop worked to motivate community youth workers to increase their efforts to develop, design, and/or facilitate culturally responsive STEM programming for girls of color is a highly relevant question for future research.

Declarations

Authors 'contributions
All authors were involved in all elements of the research and approved the final manuscript.

Availability of data and materials
All data generated or analyzed during this study are included in this published article. The data generated during and/or analyzed during the current study are not publicly available for reasons of confidentiality.

Conflicts of interest/Competing interests
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Transformative STEAM Education as a Praxis-Driven Orientation

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ABSTRACT

This paper reflects my orientation on transformative STEAM educational theory and praxis in my doctoral research journey. It attempts to address the need for innovative approaches to transformative learning in response to the question—how are the agendas of the transformative praxis aligned with transformative STEAM education? Likewise, this paper brings the discourse of new approaches to transformative STEAM education by bridging the gap between philosophy, theory, and practice. Again, positing myself within critical social theories, transformative STEAM education is a host of the pedagogical engagements with theoretical roots in critical pedagogies and/or paradigms. The paper further highlights some of the ranges of theoretical perspectives, which are aligned with Habermas (1972), Freire (1996), Kincheloe et al. (2011), and Mezirow (1981, 1991, 2000, 2003) by challenging the standard normative ideological frameworks such as efficiency, effectiveness, and improvements. In this line, my notion of the transformative praxis covers the dimensions of the theory (e.g., explore), values (e.g., community values), and practices (e.g., capabilities and services). These dimensions representations pursue change while implementing culturally responsive pedagogies and addressing humanitarian crises. In this way, I tried to explain that, in the context of praxis-driven transformative STEAM education, praxis is the ego turning into itself, and practice is the ego turning to others. The paper landed by arguing the agendas of equity, empowerment, social justice, authentic learning, meaningful learning, meaning center learning, and humanizing education based on theoretical perspectives and critical pedagogies, considering the discourse of STEM metaphorically as "Avidya" and STEM with Kala as "Vidhya".

Keywords: Orientation, STEAM, ego, Avidya, Kala, Vidhya, praxis, practices.

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INTRODUCTION

This paper reflects my orientation towards transformative STEAM education and how these orientations contributed to my doctoral journey of being and becoming an informed, transformative educator with transformative sensibilities. In doing so, I reflected on how critical theory, values, and practices are linked to transformative STEAM education. This paper, in particular, focuses on how critical theories, values, and practices that are aligned to informing, reforming and transforming educational practices (e.g., equity, empowerment, social justice, authentic learning, meaningful learning, meaning center learning, and humanizing education) by incorporating the 3Hs—hands-on, heads-on, and hearts-on learning (Inan & Inan, 2015). The practical application of these ideas is the need for 21st-century education at the school level in general and the university level in particular.

This paper further examines my transformative STEAM educational journey's dissemination, perspectives, and impact, focusing on active engagement in teaching and learning STEAM disciplines—curriculum and standards. It also provides an opportunity to reflect on STEM and STEAM education by highlighting the need for praxis-driven orientations. Reflecting on the research process, on the other hand, allowed me to distinguish between STEM and STEM with *Kala* (i.e., the Arts) within transformative STEAM education. I have used the metaphors of STEM as "*Avidya*" and STEM with *Kala* (i.e., the arts) as "*Vidhya*", both of which have transformative intents. This intent offers the *Kala* do have the power of world-saving abilities (Ebrahimzada, 2019).

Avidya and *Vidhya* discourses also assisted me in clearly reflecting the "what, who, and how" notion of transformative STEAM education. For instance, I consider my understanding of *Apara Vidya* and *Para Vidya*, as found in the Upanishads, to be the only worthwhile knowledge that allows me to reflect on the dialectical relationship between praxis and practice. Wherein *Apara Vidya* is a lower level of knowledge that encompasses all empirical and objective information. It is based on the intellect and senses, which confine it to a finite world. The higher knowledge of the *Atma* or *Brahman* is known as *Para Vidya*. It is not the subjective perception of ideas and feelings that frees us from ignorance and leads us to God-realization. With the above, i argued in the final section of this paper that praxis is the ego turning in on itself, while practice is the ego turning out on others. These egos, practices, experience, discourse, and metaphorical considerations of STEM as "*Avidya*" and STEM with *Kala* as a "*Vidhya*" have helped me better understand transformative STEAM education.

Transformative Education and Research: Some Considerations

In this section, I have attempted to reflect on my understating of transformative education and research. Broadly transformative education is aligned with Freire's (1972) critical pedagogy and Mezirow's (1996) concept of transformative education. In recent times, various strands have taken transformative education as theoretical referents. These strands are generally aligned with the critical pedagogy and transformative education itself. Some strands are emancipatory, critical reflexive, developmental, and extra-relational (Drikx, 1998).

The emancipatory strand of transformative education is rooted in Freire (1972) and/or Habermas (1972), wherein consciousness-raising via critical reflection. Critical reflection attempts to shift thoughts, feelings, actions, and consciousness. These processes alter our ways of seeing and being in the world. The critical-reflexive strand of transformative education aligns with Mezirow's (1996) concepts of meaning schemes, meaning perspective, and transformations. The developmental and extra-relational strand of transformative education is associated with holism and intuition, considering less reflectivity and rationality.

More so, based on Freire's (1972) critical pedagogy, transformative education is viewed as a process of developing students' critical awareness of themselves and their environments. My experiences showcase that the critical pedagogy of Freire (1989) offered me to exercise the power of learning. These learnings are shifted from teacher to student center learning by offering opportunities for empowerment via their self-learning.

Likewise, Mezirow's (1996) definitional concept of transformative education is based on living and possible ways to improve human existence and life. Simply said, a shift in our consciousness will alter our ways of being and experiencing the world pertaining to the intent of transformative education. Undoubtedly, Mezirow's (1996) transformative learning is considered as a learning process to construct a new or revised meaning of the phenomenon to act in the future.

Different Nepali researchers have offered various approaches aligned with transformative educational research. Some of them in our context are Luitel (2009), Dahal (2013), Pant (2016), Shrestha (2018), Manandhar (2021), and Aryal (2021), to name a few. These approaches do have a significant association with transformative intents. Likewise, their research projects suggest that critical and creative research will lead to flourishing human actions and critical consciousness. In this line, Titchen and McCormack (2010, p. 5) suggested that critical social science involves "deconstructing a political, social, historical, and cultural environment, situation, crisis, conflict, or challenge, then reconstructing it to produce a new understanding for the goals of practicing transformation and the development of ever-evolving knowledge." In this line, transformative educational research challenges individual change by creating the spaces of the created knowledge about the change. Consequently, the quest for transformation engages the researchers to shift consciousness and/or profound learning experiences (Sterling, 2003). Hence, transformative STEAM education is an educational approach that focuses on an action-oriented process of learning that gives rise to consciousness. This consciousness covers the notion of emancipatory, critical reflexive, developmental, and extra-relational.

Entry with STEAM Education

It could be any day in October 2020. I got the opportunity to share my initial ideas on STEAM education at The Ninth Appalachian Ohio Mathematics & Science Teaching Research Symposium organized by Ohio University, USA. I shared my praxis and practice aligned with STEAM education that might provide the platform to help 21st-century learners explore the various dynamics of STEAM education. Likewise, my orientation promotes learning to be aware of continuous personal and professional development rather than a culture of competition. My normative definitional sharing at the symposium was that the purpose of teaching STEAM education is not merely to produce new teachers but also to produce highly skilled professionals who can do something miraculous for this world via research and innovation. Next, STEAM education is a new interdisciplinary curricular approach that aims to create unique and powerful synergies between the arts and STEM fields in order to educate the whole person (Taylor, 2015). Further, STEAM education is an interdisciplinary approach to learning that encourages learners to incorporate creativity into their technical knowledge for solving curriculum issues in general and global crises in particular. I reflected that the symposium enabled me to identify the purpose of teaching and learning in STEAM disciplines, thereby providing critical awareness of current educational practices.

Similarly, in the middle of June 2019, I presented the paper that brings the discourse of STEAM education into the mainstream of the Nepali existing education system. The presentation was guided by the questions such as what the transformative STEAM education shall be? What are the roles of the educational institutions and other stakeholders? as initiation as a STEAM Education scholar at the Second International Conference on Applications of Mathematics to Nonlinear Sciences (AMNS-2019). Some of the reasonable criticisms that got the room for discussion in the presentation were mainly one-size-fits-all approaches to educational practices. It occurred to me as I looked at my work as a researcher that I had produced a number of STEAM projects that accurately and meaningfully integrated topic areas in order to address real-world problems in mathematics. I shared my views, perspectives, ideas, thoughts, and research, and these are some platforms that give rise to conceptualized transformative STEAM education. The sharing has allowed me to conceptualize and present concrete examples of innovative models and curricula that have been conceptualized and integrated in a meaningful way. These processes have created a need for transformative STEAM education to a certain degree. This opportunity allowed me to investigate some STEAM-related tips and resources.

During the study, as learning is a continuous lifelong process, I got the opportunity to study relevant literature regarding STEM and STEAM educational trends in my doctoral engagement in the coursework. These engagements, which have theoretical roots in critical social theories and a focus on integrating hands-on, heads-on, and hearts-on learning, have enabled me to gain a more in-depth, intrinsically motivated understanding of STEAM education by guiding learners' knowledge, skills, inquiry, and appreciation as lifelong learning processes. As a result, the MPhil and Ph.D. courses like Lenses of STEAM Education, Teaching and Learning in STEAM education, Curricula in STEAM education (to name but a few), and various online/offline teacher training, workshops, and seminars are milestones for me to conceptualize transformative STEAM education further.

Re-Entry with STEAM Education

As I re-enter the ethos of STEAM education, I attempt to review some of the literature associated with my orientation toward transformative STEAM education. The review aims to help me understand the goals of STEAM education in general and transformative STEAM education in particular. Some of the definitional frameworks or approaches of STEAM education include, "STEAM education is ways of learning as access points for guiding student inquiry, dialogue, and critical thinking" (Guyotte, 2020, as cited in Institute for Arts Integration and STEAM, 2020, para. 1). This definitional framework is an access point for guiding learners' dialogue, inquiry, and creative and critical thinking. But how to drive the learners to excel in those skills is the central concern of transformative STEAM education.

Likewise, "STEAM is a method of teaching that encourages students to become lifelong learners who are always on the lookout for new and innovative ways to solve challenges they encounter in the real world" (Bauld, 2022, p. 1). The above view aligns with empowering the students to seek the unique and creative solutions that will be useful for developing hard and soft skills to succeed in their careers, but the central question arises: how to empower students with such skills? What sort of frameworks or approaches are required for the students? These pertaining questions offer and seek the need for practice-driven orientations in STEAM education. While with the help of the arts in STEM model, Wigmore (2020) stated that:

By combining art and design with traditional STEM subjects like science, technology, engineering, and mathematics (STEM), we call this method "STEAM." Any of the visual or performing arts can be incorporated into STEAM programs, such as dancing, design, painting, photography, and writing. (p. 1)

The above is some of the definitions of STEAM education and still seem incomplete in orienting towards a broad spectrum of transformative STEAM education. These definitional frameworks of STEAM education are insufficient unless it covers the broad area of transformative praxis-driven action and reflection aligned with the practices. The wide areas of STEAM education offer transformative intents—these transformative intents, including arts, that shall lead to continued innovative approaches for understanding STEM concepts. All of the above, Taylor (2016) considers five interconnected ways of knowing, in general, are "cultural self-knowing, relational knowing, critical knowing, visionary and ethical knowing, knowing in action" (p. 92) as the basis of transformative learning. Arriving at this stage, I reflected on the interconnected ways of knowing in my transformative journey to demystify the need for a soulful inquiry and praxis-driven action and reflection.

In addition, the existing educational practices seek competency-based orientation, approach, and discourse in 21st-century skills for teachers and students (Smyth, 2017). These approaches offer the shift to a multidisciplinary, interdisciplinary, and transdisciplinary approach. Among the approaches, the transdisciplinary approach is vital in designing curriculum and implementing transdisciplinary-learning approaches in praxis-driven orientation. This process shall promote 21st-century skills in both teaching and learning. For this, teachers must possess some of the competencies such as "model social and/or critical learning theories through the curriculum development of real-world problem identification, classification, definition, and ultimately the solution" (Smyth, 2017, p. 65) by promoting trans-disciplinarity approaches. The host of transformative STEAM education is seeking beyond the boundaries from the disciplinary-specific subject-driven activity to the highly interactive processes of learning where the learners are the producers of new knowledge, and the facilitators are the interactive learning designers by nurturing the learners with 21st-century skills (Park & Son, 2010). Hence, this paper reflects the orientation of praxis and practices aligned with transformative STEAM education.

Transformative STEAM Education

In retrospect, transformation is all about the transformation processes. The transformation of these change processes into 21st-century educational leaders with a critical awareness is required. The transformation processes include transformation on one size fits all educational practices approaches and saving the existing global issues. Next, transformative teaching and learning are the main wheels of transformative education. Transformative education helps learners perceive the world through a unique and ethical perspective, challenging and changing the status quo as a change agent. These processes uphold the current power relations, in repose to the question, whose interests are being served? It promotes creativity and critical thinking skills that will allow learners to relate new knowledge to their own experiences when it comes to transformative STEAM education. It is toward the transformative philosophy of learning. The integration of arts into STEM disciplines is in the process of being developed to create powerful and inspiring interdisciplinary curriculum development spaces to design transformative learning experiences for all students. Through these activities, learners will be able to gain STEM disciplinary knowledge and skills and transdisciplinary abilities, ensuring that they take an active role in the learning process. More so, Taylor and Taylor (2019) offered views on education for sustainable development as:

Transformative approach to curriculum development that results in socially responsible STEM education. By integrating STEM and the arts, we can create interdisciplinary STEAM curriculum spaces for developing transformative pedagogies that help students develop their disciplinary knowledge/skills, awaken their creative self-awareness, enhance their moral/ethical and spiritual awareness, and empower them to practice environmentally responsible behavior. (p. 1)

Social responsibilities for globally sustainable STEAM education are another discourse of transformative STEAM education that might enable us to envision future perspectives on preparing young people's knowledge and skills. In the next section, I tried to clarify transformative learning further based on some social and critical theories.

Reflection on Theoretical Orientations

While reflecting the theoretical orientation primarily for myself as a researcher in various forms of the roles and responsibilities--change agent, researcher, advocate of transformative STEAM education, and open-minded person adopting a critical way of thinking. This section attempts to explain the need for being theoretically informed about the conditions and ongoing events in the educational setting, especially in transformative STEAM education. This can also be interpreted as a form of association between mutually agreeable ideas that have evolved. Following that, the theoretical foundations and underlying understandings differ between methodologies, methods, and practices. These distinctions highlight the importance of theories in improving current practices. Transformational learning theory is one of the concepts that has emerged as an educational technique for comprehending and cultivating transformative orientation on both an individual and social level. Thus, transformation is about the "reflections and action upon the world in order to transform it" (Freire, 1996, p. 36). The theoretical perspectives of transformative learning theory highlight some of the ranges of the theoretical orientation of Mezirow (1981, 1991, 2000, 2003), Habermas (1972), Freire (1996), and Kincheloe et al. (2011). More so, Mezirow (2003, pp. 58-59) describes transformative learning as "learning that transforms problematic frames of reference—sets of fixed assumptions and expectations (meaning perspectives and mindsets)— to make individuals more inclusive, discriminating, open, reflective, and emotionally adaptable". It is said that the central concept of transformative learning theory is to engage and be aware of the practitioners in critical reflection against their ongoing practices by challenging the ideas of structures of the meaning-making process. The concept of the structures of the meaning limits the practitioners in the frame of the reference. Thus, critical reflection in transformational STEAM education is the process of awareness of various ways of thinking and testing some of them via discourse and action. Critical dialectical discourses (Mezirow, 2003) also provide a transformative learning process related to the role and relevance of rational discourse.

Similarly, transformative learning theory is crucial for the transformative STEAM educator's continuing growth through critical reflection and professional development (Cranton et al., 2003), wherein transformative pedagogy combines educational philosophy, social constructivism, and critical pedagogy (to name). STEAM educators shall nurture the learners about the sociocultural issues to raise awareness of social ills. In doing so, STEAM educators showcase the high levels of reflections that focus on equity and diversity. Transformative professional development, in general, emphasizes a mindset shift toward inclusiveness and empowerment. Action plans, introspective exercises, and critical dialogues are some of the techniques for transformative professional growth in this area. The professional development process is undoubtedly unique and constantly changing (Mezirow, 1991). Creating and appropriating new, altered, and reflective interpretations of current meaning and behavior as part of the learning process in transformative STEAM education with transformative action and reflection is the process of developing and adopting new, altered, and reflective interpretations of previously established meaning and activity.

In the end, I believe that transformative STEAM education with a praxis orientation is based on a sociocultural approach and critical pedagogy that emphasizes personal empowerment and social transformation in developing researchers' and participants' identities (Freire, 1996). The STEAM educators are viewed as agents of social change by being aware of practices, social and political dimensions. Eventually, this process allows professionals, such as researchers, to awaken and interact in meaningful ways, progressing toward the non-contradictory meaning space known as conscientization (Freire, 1972). In my view, the above dimensions representations of transformative learning pursue change while implementing culturally responsible pedagogies and addressing humanitarian crises and issues of global sustainability.

Transformative Praxis: Theory, Values, and Practices

My understanding of transformative praxis is all about the change process of the practitioners. These change processes shall create nexus to the reflexive research and practices to raise the consciousness of the researchers and practitioners by embracing the critical stance of their ongoing research and practices. Luitel and Dahal (2020, p. 1) describe "transformative praxis as epistemology, theory, methodology, professional development, genres and logics, and empowerment." Different interpretations of transformational praxis refer to diverse ways of knowing, critical scholarship as a change agent, holistic meaning-making engagement, reflective engagement, autonomy, and accountability. These sensibilities offer multiple ways of doing, being, and valuing the notion of transformative STEAM education. Following a series of acts and critical reflections, the sensibilities process of praxis is used to enhance the awareness of researchers, participants, and performers (Maseko, 2018). This awareness could be helpful for understanding the processes and outcomes of practices and research. Ultimately, these opportunities offer the researchers and partitioners knowledge production through critical and reflective research and practices. The ethical and participatory engagements of the researchers and practitioners have multiple ways of meaning-making. However, my goal here is to cultivate critical consciousness. It necessitates a continuous commitment to a critical approach to study and practice in the interests of fairness, social justice, and inclusiveness. As a result, my perspective on transformational sensitivities is critical for questioning and scrutinizing my beliefs, assumptions, and behaviors. The activities might help improve the actions. These actions shall create unique systems and practices. More so, quality engagement with dialogue with the community of the STEAM group shall be the first step of the engagement for transformative praxis. In the next section, I tried to clarify praxis and practices further within the notion of transformative STEAM education.

Praxis: A Debate from within Transformative STEAM Education

Considering that learning is a continuous process from childhood to the end of life, I have been involved in various forms of learning in my learning and teaching journey. Those learnings sometimes require some form of the practical application of the learning process, whereas others require repetition (Arnold & Mundy, 2020). Both approaches have significance in improving my knowledge, skills, and competencies. Likewise, philosophically praxis is considered a synthesis of theory and practice. I conceptualized transformative STEAM education as critical, reflective, investigative praxis. Praxis "involves the critical and inseparable meld of theory and practice" (Stewart, 2003, p. 4). On the contrary, practice is the repetition of activity with the vested interest to improve the skill.

While I viewed the notion of transformative STEAM education, the terms 'praxis' and 'practice' do have some forms of the ego to self and others. These egos have been in practice for informing, reforming, and transforming the research and practices of self and others. The ego is conscious thinking against the ongoing praxis/practice associated with theory and practice. In the discourse, Freire's central concept of praxis (Glass, 2001) adopts the dialectical association between consciousness and the world, which shall reflect the pedagogical approach (Mayo, 2020) of transformative STEAM education. However, critical pedagogy offers multiple forms of teaching philosophy of the egos by inviting transformative STEAM educators to critique the structure of existing research and practices (Chalaune, 2021).

The rising debate of the transformative STEAM educator on the ego do have multiple forms, such as the ego turns to self and others. Ego, to some extent, mediates part of the mental process among the conscious and the unconscious constructs. The constructs shall describe the mental process of activities and interactions. This process is also responsible for testing the reality by sensing the person's identity in general in transformative STEAM education and vice versa. Within the ego, praxis is oriented to the Habermasian (1972) notion of critical pedagogy that creates nexus between the researchers' and practitioners' transformative sensibilities via critical self-reflection, reflective practices, and investigative nature of the inquiry. Critical self-reflection is "the process of questioning one's assumption, presuppositions and meaning perspectives" (Dirkx et al., 2006, p. 2). This process critically reflects one's positioning, feelings, assumptions, and behaviors. Critical self-reflection oriented the transformative STEAM educators or the practitioners towards being conscious by analyzing and articulating their ongoing practices. This consciousness offers the transformative STEAM educators their sensations, existence, surroundings, and thoughts. This process alters the practitioners' continuous practices and makes them aware of their practices, feelings, thoughts, and emotions. In a nutshell, this process of praxis is likely to be the ego that turns to itself (Habermas, 1972) as a researcher and transformative STEAM educator.

On the contrary, practices are the unaware repetitions of the ego that shall transform to achieve some skills. Ultimately, praxis is the ego that turns into itself and practices as the ego that turns to others within the context of praxis-driven transformative STEAM education. Furthermore, in the next section, metaphorically, I attempt to explain the broad terms STEM and STEM with "*Kala*" that are associated with "*Avidyā*" and *Vidhyā* with the notion of transformative STEAM education.

STEM as "*Avidyā*" and STEM with the *Kala* as "*Vidhyā*"

In the previous sections, I reflected on how I entered the field of STEAM education and how I have conceptualized STEAM education by re-entering the discourse. Likewise, I have reflected on transformative STEAM education with the theoretical roots of critical social theories and critical pedagogy. In doing so, I attempt to blend transformative praxis as theory, values, and practices. While blending praxis and/or practices within transformative STEAM education, I offer the debate of praxis and practices. With the above discourse and debate, this section attempts to bring "*Kala*" in the form of arts while re-conceptualizing further STEM education. More so, the word *Kala* connotes magical and miraculous power, deception, and enticement.

The two broad concepts, *Avidyā* and *Vidhyā* do have significant associations while conceptualizing STEAM education. Both the words—*Avidyā* and *Vidhyā* are derived from the Sanskrit word. Among the various meanings of *Avidyā*, largely in the yogic sense, the literal meaning of Avidyā is all about "something that goes far beyond the ordinary ignorance" (Wirtz, 2021, p. 1). This ignorance leads to the *Avidyā* as fundamental blindness to the ongoing realities (Bhattacharyya, 1989). So, it is the form of an incorrect understanding of the subject. In this line, I consider *Avidya* as something that does not have *Kala*. Moreover, as illustrated in *Vedic* epistemologies, *Kala* is essential for exploring possibilities. Thus, STEM can be compared with *Avidya* as it is limited and lacks *Kala*, which is a basis for expansion and fullness in Vedic traditions. With *Kala* embedded in STEAM, it could be compared with *Vidhyā*. Here I am not using *Avidyā* and *Vidhyā* in a literal sense, as they could be used slightly differently in the religious domain.

All of the above, here, I have attempted to connect the terms 'STEM broadly' and 'STEM with *Kala* as STEAM' in the discourse of *Avidyā* and *Vidhyā*. The embodied epistemological meaning of *Avidyā* is all about beyond the ordinary ignorance as to the form of fundamental blindness of the ongoing realities and incorrect understandings of the subjects. This understanding is limited to finding the meaning of the subject and/or life. On the contrary, *Vidhyā* is some form of "knowledge", "clarity", or "higher learning" among the meanings that shall describe the knowledge. Knowledge in *Vidhyā* is the form of intellectual and spiritual or higher knowledge. This knowledge shall be obtained through intellectual and spiritual knowledge that might lead to enlightenment or wisdom. Opposite of the *Vidyā* is *Avidyā*, as *Avidyā* is the form of "misunderstanding" or "ignorance". In the following section, I attempt to connect the discourse of *Vidyā* and *Avidyā* in the mainstream of transformative STEAM education. Lower *Apara Vidya* is the knowledge recognized by the Upanishads, while higher *Para Vidya* is considered the only worthwhile knowledge. Lower knowledge includes all empirical and objective knowledge and is based on the intellect and senses. However, the higher knowledge is that of the *Atma* or *Brahman*, known as *Para Vidya*. It is not familiar with the outside world. It is also not the subjective perception of ideas and feelings that leads to the transformative STEAM educators conceptualizing STEAM education.

With the above consideration of forms of *Vidyā* (i.e., *Apara Vidya* and *Para Vidya*) and *Avidyā* within the various forms of epistemological meaning and understanding, among the meaning and interpretation of STEM education, Tsupros et al. (2009) defined STEM education as:

an interdisciplinary approach to education in which rigorous academic concepts are combined with real-world lessons in which students apply science, technology, engineering, and mathematics in contexts that connect school, community, work, and global enterprise, thereby enabling the development of STEM literacy and the ability to compete in the new economy. (p. 1)

Using an interdisciplinary perspective, STEM education helps researchers and practitioners see the world as a whole rather than as a collection of individual pieces. Morrison (2006, p. 1) describes this process as the "creation of a discipline based on integrating other disciplinary knowledge into a new 'whole'. This interdisciplinary bridging among discrete disciplines is now treated as an entity, known as STEM". Likewise, STEM education creates a multi-faceted whole with more complexity and new realms of understanding, allowing for multidisciplinary and/or trans-disciplinary academic integration. The plethora of STEM educators believes that the learners shall be problem-solvers, inventors, self-reliant, critical and logical thinkers, and technologically literate. However, various forms of incorrect understandings and/or misunderstandings about the STEM education, such as STEM education is considered as the integration of math and science, technology education regarded as basic computer skills, inquiry, and hands-on activities are considered the same. Engineers cannot teach math and science, and STEM education focuses more on workforce issues (to mention). These incorrect understandings and/or misunderstandings of the terms as *Avidyā* ignore the humanitarian aspect and may not address problems globally via education. This aspect might embrace the learners' feelings, emotions, beliefs, and thoughts against the subject and/or issue(s).

On the contrary to STEM education, STEM with *Kala* as STEAM education and/or transformative STEAM education shall be bound by the dimensions of the theory, values, and practices. In general, I could write from my reflective practices that STEM dimensions with *Kala* as STEAM education and/or transformative STEAM education are associated with preparing future generations to use STEAM wisely. More so, " STEAM (Science, Technology, Engineering, Arts, and Mathematics) is an emerging inter-disciplinary educational approach that seeks new and powerful synergies between the Arts (i.e., *Kala*) and STEM, intending to educate the whole person " (Taylor, 2015, p. 1). These processes consider the knowledge as *Vidhyā*, where *Vidhyā* is in the form of intellectual and spiritual or higher learning. By obtaining this knowledge—intellectual and spiritual knowledge that might lead to enlightenment or wisdom. These dimensions pursue change while implementing culturally responsible pedagogies and addressing humanitarian crises through the host of STEM with *Kala* as STEAM education and/or transformative STEAM education. Transformative STEAM education encourages researchers and practitioners to engage in experiential teaching and learning, take thoughtful risks, embrace collaboration and problem-solving skills, and work creatively toward praxis-driven orientation. The agendas of equity, empowerment, social justice, authentic learning, meaningful learning, meaning center learning, and humanizing education are discussed in this section, considering the discourse of STEM as "*Avidya*" and STEAM with *Kala* as "*Vidhya*".

Concluding Remarks

The reflection is, to some extent, the process of thoughts or consciousness. This consciousness shall offer various perspectives. In this alignment, Kopnina (2020, p. 5) suggested that "we have moved from wisdom to knowledge, and now we're moving from knowledge to information, and that information is so partial – that we're creating incomplete human beings". Opposingly, the reflection is significantly associated with the theory and our practices. Next, this reflective paper reflects my experiences, praxis, and practices that orient me to the transformative STEAM education with sensibilities of transformation. The processes of the reflective paper further raise new perspectives, questions, and opportunities for the future development of STEAM education. Likewise, these reflections shall be relevant to the personal and professional transformation of 21st-century educators, especially while teaching and learning in school to university level today with transformative intents. I also metaphorically offer the space for conceptualizing STEM as "*Avidya*" and STEM with *Kala* as a "*Vidya*" while reflecting on my research journey. I have exemplified some critical social theories with some forms of consciousness of transformative teaching and learning. The discourse of praxis has also got room for discussion as the ego that turns into itself and practices as the ego that turns to others have enabled me to view the orientation of transformative STEAM education broadly on the lower form of knowledge as *Apara Vidya* and higher form of knowledge as *Para Vidya*. To this end, my writing reflects how my doctoral research journey is a part of the transformative educational journey.

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Environmental Knowledge, Attitudes, And Practices for Behavior Change of University Students: The Case of Indonesia

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ABSTRACT

Environmental knowledge has been learned formally in schools including universities and informally through lineage, the community, and the media. Knowledge, attitudes, and practices is a survey technique used to measure the phenomenon of human life as well as its impact on behavior and how it contributes to environmental management. The objective of this research is to examine the relationship between university students' environmental knowledge and attitudes, practices, and their contribution to behavior change. It was conducted at Indraprasta University PGRI-Jakarta, Indonesia, with a sample size of 137 students, 49 undergraduates of biology education, and 88 postgraduates of mathematics and natural science. In addition, the data analysis method used is a Statistical Non-parametric Bivariate Pearson Correlation. The research concluded that 63 percent of students learned environmental knowledge formally from schools, 15 percent from non-formal education, and 22 percent by both formal and non-formal means. Moreover, the students' understanding did not contribute to their attitude but encouraged their practices significantly. Furthermore, their attitude did not influence the implementation within their real life, but those who practice the information can promote environmentally friendly behaviors.

Keywords: Environmental; Knowledge; Attitude; Practice; Behavior Change

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INTRODUCTION

The environment is critical for both biotic and abiotic survival, but it is plagued by numerous crises. Population growth causes poverty and environmental damages (Tariq & Aziz, 2015), including water, air, and soil pollution, where marginalized people often receive more impact. Moreover, natural resource extraction increases energy consumption which also harms the environment (Hussain, Haseeb, Tvaronaviciene, Mihardjo & Jermsittiparsert, 2020), impacting human life. Likewise, the conversion of natural forests to agricultural lands contributes to plantation loss, and many anthropogenic activities in tropical forested countries give rise to fragmented landscapes (Meyer, Struebig & Willig, 2016). The international community has been fully aware of the importance of this environmental knowledge for sustainable development as mandated by the World Conference on the Environment in Rio de Janeiro, in 1972.

Unfortunately, the demand for natural resources and the use of products continues to increase. Therefore, the environmental impacts are becoming more complex and substandard. Having information about the environment can assist in managing human behavior to become more eco-friendly (Wu, Cheng & Zhang, 2020). Environmental knowledge can help comprehensively in understanding the relationship between human activities and ecological problems (Shimaoka, Kuba, Nakayama, Fujita & Horii, 2016). However, due to different experiences and educational backgrounds, people have varying levels of proficiency regarding these issues. Students can gain this knowledge formally at school, meaning it can be incorporated into subjects to make the information relevant and easier to understand in daily practices. Additionally, it can be learned informally from the interactions within the family and society. They can absorb it from television, magazines, newspapers, and current digital information sources. Otherwise, some countries have a range of programs and curricula on ecological education, which are compulsory for undergraduate students of biology, arts, science, and commerce, including integrating textbooks with environmental concepts (Verma & Dhull, 2017). It is also mandatory for postgraduate students to do environmental education in Indonesia.

The knowledge, attitudes, and practices implemented continuously will reflect good behavior in reducing environmental problems. An increase in environmental knowledge has a significant effect on one's attitude (Fabrigar, Petty & Smith, 2006). Besides, an attitude is a tendency to think, have feelings or preferences about an object based on their beliefs, which can be positive or negative (Kususanto, Fui & Lan, 2012). Also, this education will provide people with skills, good attitudes, and practices to create appropriate solutions to solve environmental issues (Sadik & Sadik, 2014). Moreover, behavior change encourages people to protect the environment, create awareness of their daily habits and establish practices of environmentally sound activities.

Problem of research

Knowledge about the environment in Indonesia is quite good (Nastuti & Lelfita, 2020), even though the understanding related to waste and marine debris is still inadequate. There are many issues regarding climate change and political debates internationally but still a lack of effort to reduce emissions at the field level. According to Boca & Saraçlı (2019), there was no difference in attitude between students who studied environmental education in protecting the environment and those who did not. Many people want to save the earth, but they ignore preserving the environment. At the beginning of 2020, floods shocked Indonesia and there were haze plus forest fires in both Indonesia and neighboring countries. People failed to prepare for these disasters because of their ignorance of the environment's safety (Firdaus, 2020). According to Djuwita & Benyamin (2019), environmental education is critical to developing pro-environmental behavior, but it is still uncertain if the knowledge contributes to positive outcomes, especially in Indonesian schools.

Research focus

The focus of this research was on the environmental issues of waste found around the student living areas, greenhouse gases that significantly contributed to climate change and ocean debris which is already an ecological problem in Indonesia.

METHOD

General background

The objective of this research was to examine the relationship between students' environmental knowledge and attitudes, practices, and how they may contribute to behavior change. It investigated the relationship between students' knowledge and attitude, knowledge and practice, attitude and practice, as well as practice and behavior change. The research questions were (1) How is the university students' environmental knowledge? (2) How is the university students' environmental-based attitude? (3) How is the university students' environmental-based practice? and (4) What is the relationship between environmental knowledge, attitudes, practices, and behavior change?

Sample of research

The research took place in the Indraprasta University Jakarta with a sample size of 137 students, stratified by two levels of education. The population comprised 49 4th semester undergraduate students in biology education and 88 2nd semester postgraduate students in mathematics and natural science.

Instrument and Procedures

The research instruments used for environmental knowledge were waste, greenhouse gases, and ocean debris, measured with the Likert Scale. There are two Likert Scale options: 1 for not agree/do not know, and 2 for agree/very agree/know. These implements were organized into questionnaires and sent to the students in a Google form. Table 1 shows the research questionnaires developed based on a study by Ahmad et al. (2015).

Table 1. The questionnaire used in KAP survey.

Number	Question
Q1	I learned environmental knowledge from (a) formal education in school/university, (b) non-formal education (training, course, discussion), (c) both
Q2	Waste resulted from human activities is unavoidable. (a) not agree, (b) do not know, (c) agree and very agree
Q3	Ocean debris is a hazardous waste to the ocean biotic life. (a) not agree, (b) do not know, (c) agree and very agree.
Q4	Green House Gases emission is harmful to human life. (a) not agree, (b) do not know, (c) agree and very agree.
Q5	What do you know about ocean debris?
Q6	What do you know about a waste bank?
Q7	A waste bank is an important source to support the family economy. (a) not agree, (b) do not know, (c) agree and very agree.
Q8	A community can learn environmental waste management from field school. (a) not agree, (b) do not know, (c) agree and very agree.
Q9	Neighborhood institution (RT) takes responsibility for managing waste around my house. (a) not agree, (b) do not know, (c) agree and very agree.
Q10	I give my full attention to the cleanliness of my residential areas (a) inattention, (b) very considerate.
Q11	Waste collected from my residential area will be burnt, thrown away, or treated. (a) do not know, (b) I know
Q12	I do waste processing conversions into fertilizers or/and other recycled products. (a) never done, (b) have done.
Q13	I have the confidence to solve the waste problems in my house and its surrounding areas. (a) not confident, (b) very confident.

Data Analysis

Data from the questionnaires were presented in tables along with graphs and tested using a Non-parametric Bivariate Pearson Correlation Test with SPSS Statistical Software Version 23.

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RESULTS AND DISCUSSION

Results

The total number of respondents used for this research was 137, with 68.6 percent females and 31.4 percent males. Ranging from the ages 17-25 years were 47.5 percent, the remaining were 26-35 years of 29.9 percent and more than 35 years being 22.6 percent. Most of the participants (64.5 percent) were postgraduate students, and the remaining 35.5 percent were undergraduate students.

Sixty-three percent of students learned environmental knowledge from a formal study in school, 15 percent from non-formal, and the remaining 22 percent from both formal and non-formal. Magister students gained the understanding formally (65 percent) more than undergraduates (61 percent). However, 27 percent of those students learned both formally and informally more than postgraduates of 19 percent (Figure 1).

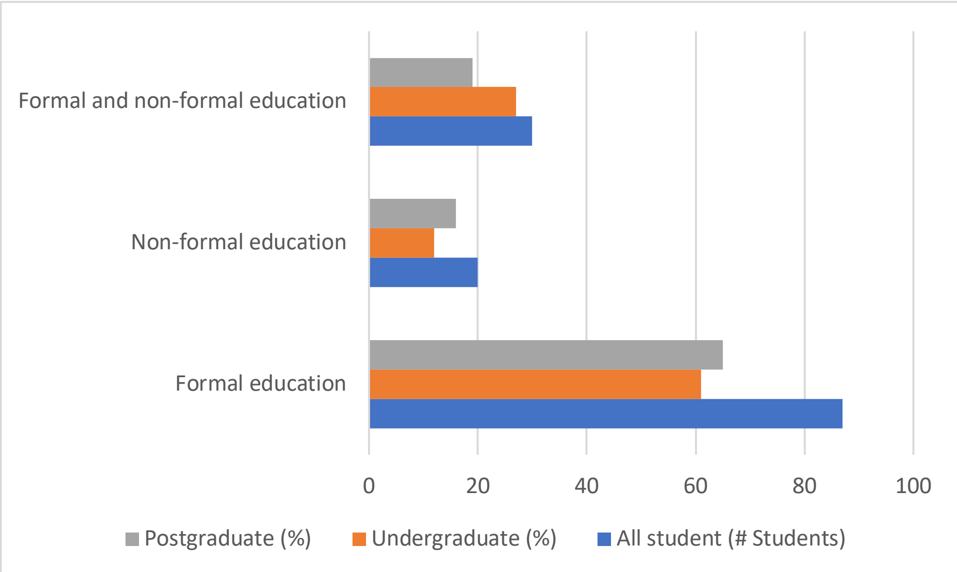

Figure 1. How students learned the environmental knowledge

Students' environmental knowledge varied according to their prior study backgrounds and experiences. Eighty percent of students thought that waste is unavoidable (Q2). Then, sixty-six percent believed ocean debris was dangerous for biotic organisms living in the sea (Q3). Also, they felt that greenhouse gases contributed to harmful effects on human life of 89 percent (Q4), and 91 percent understood that the waste bank creates the family income (Q7). Likewise, ninety-one percent assumed field schools could teach students waste management (Q8), and 75 percent of students stated that the neighborhood institution (RT) is not only responsible for waste management (Q9). Figure 2 shows the students' environmental knowledge.

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Additionally, undergraduate students believed that the waste bank helps the family economically more than postgraduates (Q7). They agreed more than undergraduates that waste is unavoidable (Q2), ocean debris is harmful to the life of biotic organisms in the sea (Q3), the emission of greenhouse gases damage human life (Q4), field schools can teach students about waste management (Q8), and RT is not the only responsible institution for waste management (Q9). Figure 2 conveys the environmental knowledge of undergraduate and magister students.

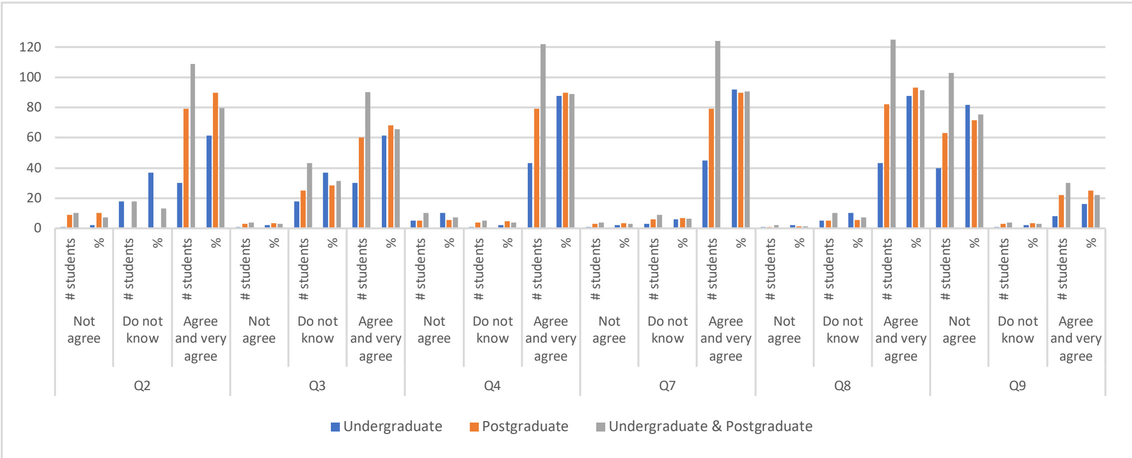

Figure 2. Environmental knowledge of students

In response to the in-depth questions, 69 percent of students had difficulties in elaborating their knowledge on ocean debris (Q5), and 91 percent on the waste bank (Q6), shown in Figure 3. According to figure 3, 67 percent of undergraduates and 70 percent of postgraduates also had challenges elaborating their knowledge on ocean debris (Q5). Meanwhile, 88 percent of undergraduate students and 92 percent of postgraduate students had an issue elaborating the waste bank (Q6).

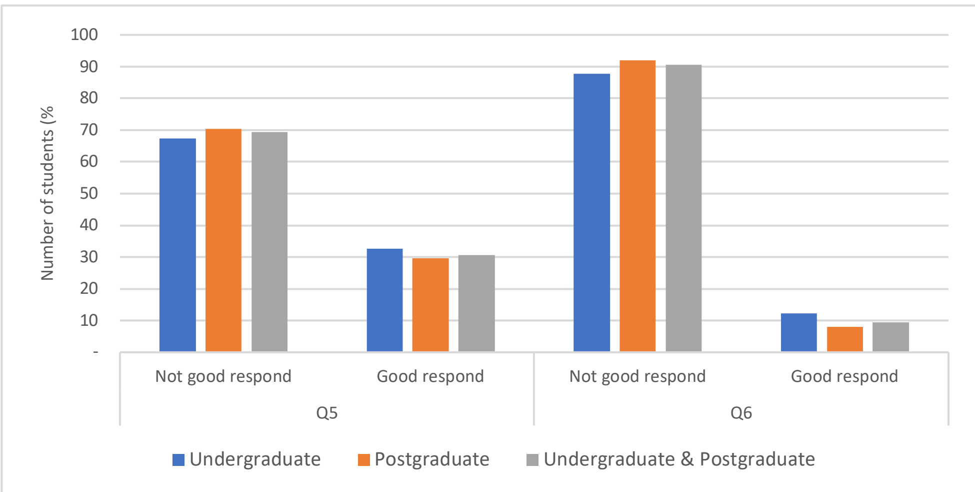

Figure 3. Environmental knowledge of the student in responding to the open questions

Figure 4 shows that 82 percent of students gave serious attention and confidence to maintain the cleanliness of the household and its surrounding area (Q10), and 62 percent of students know how waste is handled in their environment (Q11). Figure 4 also conveys that 86 percent of undergraduate students and 81 percent of postgraduate students were concerned about the cleanliness of their housing area (Q10). Furthermore, 61 percent of undergraduates and 63 percent of postgraduates know how to handle waste in living areas (Q11).

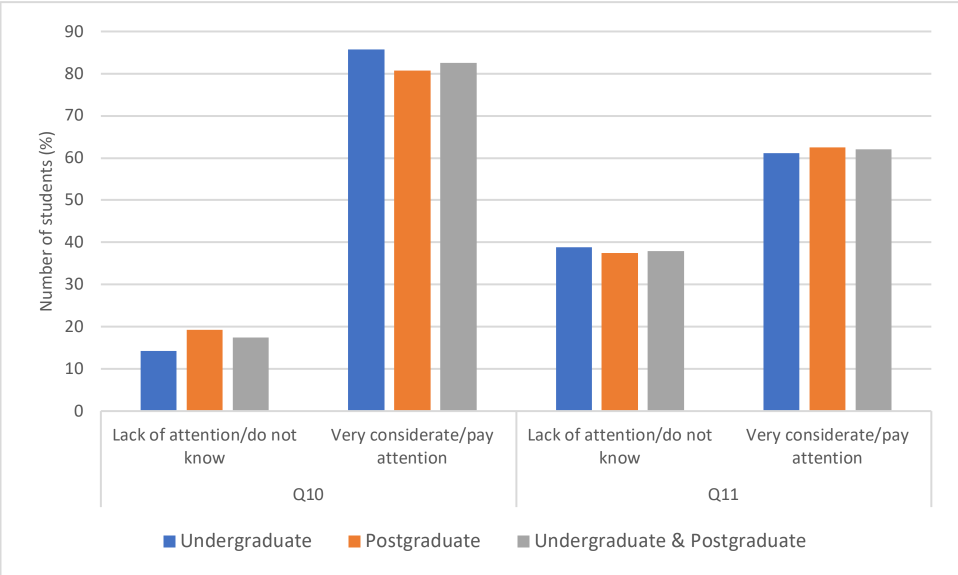

Figure 4. The attitude of the students on environmental care

People can turn waste generated as a by-product of human activities into valuable products by recycling it. As shown in Figure 5, 62 percent of students had prior experience processing waste into beneficial goods, such as fertilizer (Q12). Figure 5 reveals that 66 percent of postgraduate students had more experience recycling waste into more useful materials than undergraduate students of 55 percent.

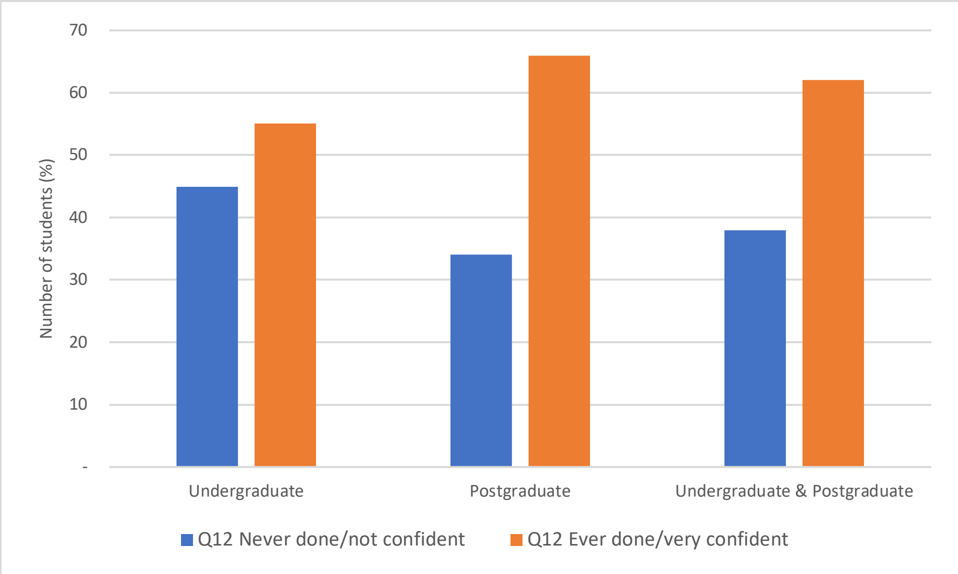

Figure 5. Students' environmental practice in daily life

Figure 6 expresses that only 42 percent of students had the self-confidence to manage waste problems surrounding their household (Q13). Meanwhile, the remaining 58 percent did not have confidence and never undertook any activities to reduce the waste (Q13). Moreover, figure 6 shows 60 percent of postgraduate students had self-confidence, higher than 40 percent of undergraduate students.

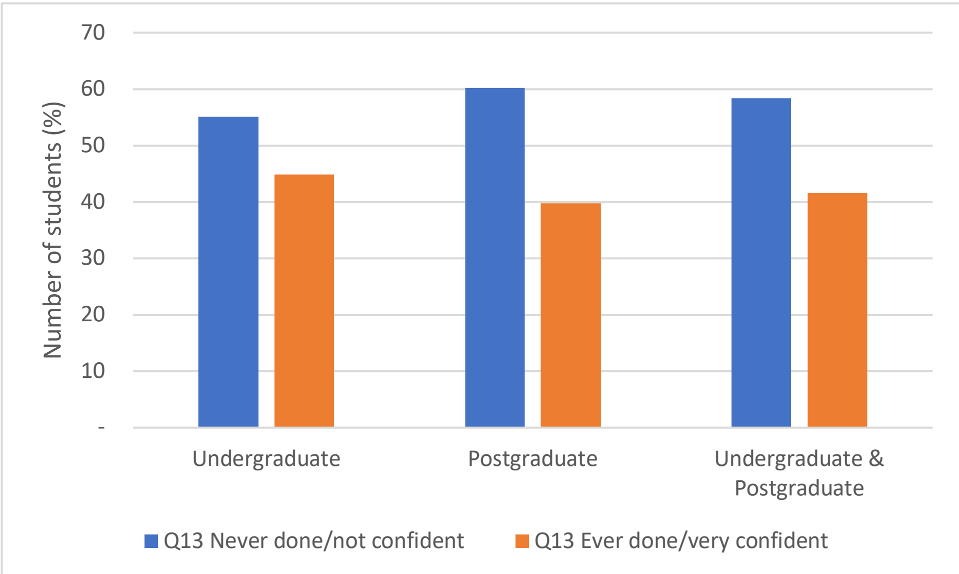

Figure 6. Students' behavior changes to protect the environment

DISCUSSION

This research underlined that most students learned environmental knowledge formally from school, and postgraduate students learned formally more than undergraduates. Incorporating environmental education into the school curriculum enhances awareness (Erhabor & Don, 2016), and this creates a more comprehensive treatment of ecological problems (Jekayinfa & Yusuf, 2008).

Many students knew that waste is produced continuously and can be reduced as well as processed into valuable materials, and some more than others understood that ocean debris and greenhouse gas emissions are ecological problems. Also, they learned about field schools, waste banks and agreed not to rely on RT to manage waste. Additionally, the postgraduates knew better than the undergraduates about waste, ocean debris, greenhouse gas emissions, field schools, and the role of RT. Undergraduate students had better knowledge than magister students on a waste bank. Unfortunately, most had difficulties elaborating their knowledge in response to the open question.

Theoretically, a higher education level would have a greater grasp and experience in the field. This, however, is not always the case. Around 80 percent of students paid close attention and had confidence in maintaining the cleanliness of the household and its surroundings, with undergraduate students giving more attention than postgraduate students. However, only 62 percent gave awareness to waste handling (postgraduates more than undergraduates). Furthermore, just 62 percent of students had prior waste processing experience (postgraduate students with more confidence and knowledge). Indeed, students' self-confidence aids their understanding of the problem, but the level of education did not guarantee assertiveness. Individuals with higher self-confidence are more motivated to engage in ways in which they are confident (Greenacre, Tung & Chapman, 2014), and confidence create supportive conditions for behavior change (Young, Davis, McNeill, Malhotra, Russell, Unsworth & Clegg, 2013).

The Non-parametric Bivariate Pearson Statistical Test examined the relationships within parameters (environmental knowledge, attitudes, practices, and behavior change). Pearson and Spearman correlation coefficients range between -1 to 1, with a 0.0 indicating no correlation; the effect is low if the correlation is around 0.1, medium if 0.3, and large if more than 0.5 (Cohen, 1988). The relationship between environmental knowledge and attitudes was not significantly linear, with a weak correlation of $r = 0.110$, $n=137$, $p = 0.202$. Moreover, the same result occurred at the University of Benin in Nigeria (Erhabor & Don, 2016) and in a secondary school at Kajangtown, Selangor, Malaysia (Aminrad, Zarina, Hadi, & Sakari, 2013). Further, students with good environmental knowledge gave strong positive ecological attitudes and good environmental behavior in Oman (Al-Rabaani & Al-Shuili, 2020). Likewise, an outdoor learning process could develop students' awareness and contribute to their thinking (Bogner, & Wiseman, 2004). Formal education does not always influence attitudes, therefore, it is recommended to combine such with outdoor classes.

Environmental knowledge teaches students new skills, assists in problem-solving, supports their day-to-day lives, and aids in dealing with ecological issues in their surroundings. The understanding may come from the media, educational institutions, and families to encourage environmental-sound practices (Ahmad, Shuhaida, & Ismail, 2015). This research found a significant linear relationship between environmental knowledge and practices, with a weak correlation of r = 0.225**, n = 137, and p = 0.008. It means that students' knowledge helped in field implementation.

Meanwhile, no correlation was found between attitudes and field practices. The relationship between students' attitudes and practices was insignificant, with r = 0.026, n = 137, and p = 0.761 indicating a weak correlation. That is, students may engage in environmentally friendly activities without being aware of them. Due to one's attitude being one of the most important success factors in providing environmental solutions (Esteban, Ferrer, Vicente, Muñoz, Claros, Javier, & Ruiz, 2020), it is suggested that students' attitudes be improved.

The association between students' practices and behavior change was a highly significant linear with a medium correlation of r = 0.325**, n = 137, p = 0.000. The more students who implement good practices in the field, the better their behaviour to practice activities consistently. Personal beliefs, which influence pro-environmental actions, also affect individual intentions to practice environmentally responsible behaviours (Wu, Cheng & Zhang, 2020).

CONCLUSION

Protecting the environment is critical for saving living organisms and human existence, as well as ensuring a higher quality of life for future generations. University students have a challenging responsibility to protect the environment by developing good environmental knowledge, attitudes, and practices to change their behaviors to become more environmentally friendly.

Accordingly, the findings of the study showed that 63 percent of students received formal environmental knowledge from schools, 15 percent from non-formal education, and 22 percent from both formal and non-formal teaching. Students' knowledge did not influence their attitudes, but it did significantly encourage their practices. Furthermore, their attitudes did not affect their actual application in real life, but those who put their environmental knowledge into practice can contribute to environmentally friendly behaviors.

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Views of Gifted Secondary School Students on the "Matter and its Nature" Courses Taught through the EPTS (Education Program for Talented Students) Curriculum Model*

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ABSTRACT

The study aimed to determine the views of gifted students on "Matter and Its Nature" using the Education Program for Talented Students (EPTS) Curriculum Model. The data was collected from four gifted 6th graders. Semi-structured interviews and diaries were analyzed thematically. They stated that the lessons were taught with modeling, experimentation, and computer-assisted simulation. They enjoyed learning these lessons. The students stated that they did not like the traditional education system in formal education, but they found the lessons taught in this context interesting. The fact that the students found the science courses created using this model effective and enjoyable. It shows that the stakeholders can teach science concepts more effectively and permanently by using this model. teachers should use this model in their lessons, and researchers should also carry out studies where they can adapt the curriculum model to other units.

Keywords: Differentiated instruction, giftedness, science education, the education programs for talented students (EPTS) curriculum model.

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INTRODUCTION

In our country, the education of gifted individuals has become crucial in recent years. Considering both the increase in academic studies on this subject in recent years and the publications of the Ministry of National Education (MEB, 2006, 2013), it is clear that this subject is becoming more prevalent day after day. A child who is diagnosed as gifted must receive special education in order to realize his / her potential (Ataman, 2012). Thus, he/ she can be useful to the society and one of the prominent people of the future (Andersen & Ward, 2014). In addition, one of the reasons for the change in education policies for gifted students who have better mental skills compared to their peers and the increasing importance given to gifted students, is the emergence of a field where different disciplines such as STEAM (science, technology, engineering, art, math) that requires the use of thinking skills are combined (Çepni, 2018). For gifted students, who are expected to receive a different education from their peers, more substantial and more efficient programs aiming to fulfil their potential are developed by using educational strategies and curriculum (education programs) models.

The use of various educational strategies during the schooling years, individuals develop their thinking skills and make learning more meaningful (Schunk & Zimmerman, 2003). In the education of gifted students, on the other hand, some teaching strategies have been developed considering their learning capacities, learning profiles, learning needs and the methods in which they can express themselves unreservedly. The teaching strategies that will be focused on in this study are acceleration and enrichment.

The acceleration has emerged since the gifted students have faster learning characteristics compared to their peers. Due to these special characteristics of gifted students, more advanced, complex and in-depth teaching is offered than the subject/outcomes of their currently existing grade level (Kanlı, 2011). The acceleration teaching strategy, which allows the gifted students, who are likely to know the subjects taught at their existing grade level, not to become bored and spend their time with relatively new (unfamiliar) subjects, is included in many framework curriculum (education programs) models. Integrated Curriculum Model (VanTassel-Baska, 1986), Grid Model (Kaplan, 2009) and EPTS Curriculum Model (Sak, 2011) include the acceleration teaching strategy.

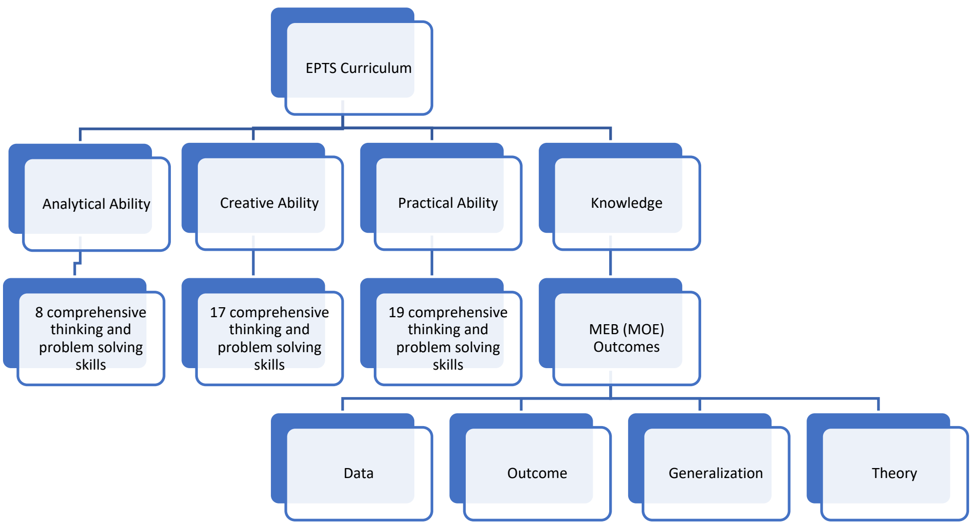
Another educational strategy for gifted students is enrichment. In this strategy, depending on the needs and characteristics of the students, there are differences such as deepening/expanding the course topics, changing the teaching methods and/or learning environment, (Schiever & Maker, 2003; Sak, 2017). The Maker Model (Maker, 1982), Curriculum Narrowing Model (Reis & Renzulli, 1978), Integrated Curriculum Model (Van Tassel-Baska 1986), Grid Model (Kaplan, 2009) and EPTS Curriculum Model (Sak, 2011) utilize the enrichment strategy.

The curriculum models enable the planning and development of lessons by offering a theoretical framework for the teaching practices of the target audience in dimensions such as content, process, product and learning environment (Sak, 2017). The teacher prepares lesson plans by adopting the theoretical framework presented by the curriculum model s/he uses. By this means, students are supported and enabled to reveal their potential. Maker Model (Maker, 1982) Parallel Curriculum Model (Tomlinson, Kaplan, Renzulli, Leppien, Burns & Purcell 2002), Curriculum Narrowing Model (Reis & Renzulli, 1978), Integrated Curriculum Model (Van Tassel-Baska 1986), Grid Model (Kaplan, 2009) and EPTS Curriculum Model (Sak, 2017) are among the curriculum models created for gifted students.

Among these curriculum models, the Gifted Education Programs (ÜYEP/EPTS) Curriculum Model, which includes both enrichment and acceleration strategies, draws attention. This curriculum model was created as a program at Anadolu University and entered into service in 2014 as an application and research center (Sak, 2017). The objective of the institution is to identify the gifted students, to teach and evaluate them with the program they have created. EPTS, in addition to providing after-school education to gifted students, aims to accelerate and enrich the teaching of curricula. The Gifted Education Program consists of components including diagnosis, curriculum, program format, teaching, assessment and teacher training; the EPTS Curriculum Model, on the other hand, proposes a mix of acceleration and enrichment.

There are various components in the curriculum dimension of this model. These components are illustrated in Figure 1. While preparing the EPTS Units, the national outcomes from the target group's own grade level and the following grade levels are integrated with the skills under the headings of analytical ability, practical ability, and creative ability. The outcomes of the following level's outcomes in the unit provide the acceleration, and the inclusion of EPTS skills provides enrichment (Sak, 2017). The EPTS unit is finally completed when the teaching method techniques are identified in accordance with the learning outcomes and the teaching materials are prepared.

Figure 1. EPTS Curriculum Model Components (Sak, 2017, p.192)



EPTS has adopted a university-based education and implements its education activities in the campus of Eskişehir Anadolu University. Before, during and after these education activities, diagnosis, curriculum, program format, teaching, teacher training dimensions and evaluation are all conducted in the same institution. The purpose of the present study is to evaluate the Curriculum dimension, independent from other dimensions, through the eyes of gifted students studying in different institutions.

The purpose of the study

It is a known fact that there is no single educational program that will appeal to every student. However, the more the characteristics of the sample to which the program will be applied are known, the higher the probability that the program will reach its goal. The EPTS (Education Program for Talented Students) Curriculum Model, which was developed by considering the characteristics of the gifted, is currently being prepared and implemented at the EPTS Education and Research Center.

In this research, "What are the opinions of gifted students about the EPTS Unit prepared by the researcher and the lessons taught in this unit?" An attempt was made to find an answer to the question. In order to answer this question, semi-structured interview questions and reflective diaries filled by students were used and analyzed.

The limited number of studies in the literature in which in-depth views are taken and the use of data collection tools mostly in the context of academic development; makes it difficult to look at the situation from the perspective of the sample. This study aims to reveal how gifted students perceive the EPTS Unit, which is prepared on science/matter and heat, by examining in-depth how students perceive it.

METHODOLOGY

Research Method

In the present study, four gifted students who received post-school education at the Potential Gifted Association (PÜYED) in Bursa were asked to express their views clearly about the courses they received in line with the EPTS curriculum model, and in an attempt to implement a more in-depth study, a qualitative research method was adopted and the case study design was utilized. The case study design, enables the researcher to delve into the cause-effect relationship and details of a special situation related to a group (Çepni, 2014). According to Creswell (2013), it is essential to utilize more than one data collection tool in this research design. Semi-structured interviews and reflective diaries were used as data collection tools since this study aimed to develop a deep understanding of the subject and reflect the experience/event from the perspectives of the students.

Research Sample

The participants in this study were 6th grade students who received after-school education at PÜYED in the 2018-2019 Spring semester. Before the study was applied, necessary permissions were obtained from the parents of the students and students were given code names.

Table 1. Participants

STUDENT CODE NAME	GENDER	SCHOOL TYPE	INTELLIGENCE TEST
S1	M	Private school	WISC-R
S2	M	Private school	CAS
S3	F	Public School	CAS
S4	F	Public School	WISC-R

Table 1 illustrates the students' code name, gender, the type of school they attend, and the intelligence test they have taken when being identified.

Data Collection Tools and Process

Semi-structured interviews (Interview)

Interviews can be defined as an oral interview technique in which the in-depth view of the specified target audience on the subject/subjects is sought. In interview types, there is a semi-structured interview technique, which has benefits such as making changes in predetermined questions, creating a wide discussion environment and providing flexibility in order to make the answers more explanatory (Çepni, 2014).

In the present study, semi-structured interview technique was utilized due to the flexibility it offered. The researcher prepared the questions in advance, but during the interview, he had room for flexibility in the questions in accordance with the changing or developing conditions. The researcher conducted two interviews with each student because of the intermittent block lessons. The interview consisted of a total of sixteen open-ended questions;

Table 2. The interview questions

Question number	Question
1	What do you think about the lesson we taught today? Was it different from other lessons? What was the difference?
2	In today's lesson, you did the activities in order. What do you think about the activities in the lesson?
3	If I ask you to comment individually for each activity, what would you say?
4	Which activity do you think was more effective? Why?
5	Was there a topic that you had trouble understanding? Why?
6	Do you think you understand the activities in the lesson?
7	Science courses; How did teaching with the method of using different teaching practices (model, simulation, experimentation) affect your learning / comprehension of the subject? Can you explain?
8	Would you like us to teach our next lessons with these methods again? Why?
9	What do you think is the most effective method for learning a subject?
10	Did you use any equipment while doing the experiment today? Do you think there are more effective ways to learn a subject?
11	Before doing the activity, we did a brain exercise to get into the subject. Do you think this was effective?
12	What do you think is the role of the teacher while doing the activity? Or what was the teacher's role in this lesson?
13	What do you like most in a lesson? Do interesting and fun activities grab your attention?

14	What other activities can we do to learn about the atom? What do you think is the best way to learn about this topic?
15	How much of the lessons given here or in your normal education can you use/do you use in your daily life? Can you to evaluate them individually?
16	What would you do differently if you did the activities here again? Or would there be an activity you would like to change?

The general purpose of these questions was to consult the views of the participants about the content, process, product and learning environments of the lessons taught in compliance with the EPTS Curriculum Model.

Diaries

Student diaries, which provide a reference point about the experiences of the participants during their education, according to Unrau (2008), enable the understanding of how the learning activities develop from the perspective of the participants. Walker (2003) is of the opinion that this data collection tool also enables the participants to get to know themselves. In addition, the diaries written by students have benefits such as being aware of what has been learned (Moon, 2009), facilitating the development of high-level mental skills (Gorlewski & Greene, 2011), and being a learning method that encourages writing (Farah, 2012) (cited in Girgin, 2020).

The participant/student diaries used in this study consist of four blocks. The blocks are What I Know, What I Observed, What I Learned, and My Questions, respectively. The gifted students who made up the participants started to write these diaries from the beginning of the lesson. The researcher collected the diaries at the end of the lesson.

Data Analysis

The semi-structured audio-recorded interviews were transcribed. The most emphasized themes/categories were obtained from these digital texts, and these were created as tables in the results section. The semi-structured interviews conducted after the EPTS Unit was taught were decoded and subjected to thematic analysis.

In the analysis of the diaries, on the other hand, the answers produced by the participants to the sections in the diaries were examined and variables such as whether they were consistent with the semi-structured interview data and their level of comprehension of the subjects, they learned in practice were examined. In this study, which aimed to tap into the views of the participants about the application of this study, the diaries emphasized whether the answers were realistic and sincere. For instance, an issue that the participant said s/he understood in the interview could be evaluated by analyzing the diaries.

Ethical Considerations:

In this study, "Parent Approval Document" was used because we worked with young children. Before the implementation phase of the study, the students' parents were informed and voluntary approval was obtained from them. The confidentiality of the data was ensured by using the code name instead of the real names of the students and a written commitment was made that the audio-visual media files of the students would not at all be used during the study period.

Validity and reliability

In this study, it was aimed to increase the data diversification. Therefore, two types of data (semi-structured audio-recorded interview questions and students' diaries) were collected. Lincoln and Guba (1985) used the "trustworthiness" of a study as the naturalist's equivalent for internal validation, external validation, reliability, and objectivity. The questions of semi-structured audio-recorded interview questions were written by the first author of this paper. The correctness of these questions was validated by three people. One of them was the experienced vice-principal of the Potential Gifted Association (PÜYED) in Bursa. She also has been working with gifted children at this association for years. The second one was a faculty member who had just completed her doctorate on gifted students. The last expert has been working as an associate professor in the faculty of education having a strong science background. These three experts in the field checked the interview questions created by the first author for clarity and made the questions that they thought incomprehensible more understandable in order to increase the internal validity (Whittemore, Chase, & Mandle, 2001) of these questions.

Reliability in qualitative research refers to the stability of responses to multiple coders of data sets (Strauss, & Corbin, 1990). In this research, the first and the second author of this paper coded the interview data independently. They did read the answers of the open ended questions independently, wrote the themes and categories, and students' views, discussed their analyses, and then, continued this process until they agreed on the questions' analysis. It was thought that having two independent coders for interview questions should also be increased the reliability of the current study. In the end, the findings obtained from semi-structured interviews and the students' diaries were compared (Lincoln & Guba, 1985) by the authors.

RESULTS

The findings were gathered under the sub-themes of using the modelling method in science, using the simulation method, using the experimentation method, using what has been learned in daily life, and comparing the lessons taught using the EPTS Curriculum Model with the formal education lessons, finding the lessons interesting and enjoyable and the role of the teacher. Furthermore, the data obtained from the diaries are also included in this section.

Modelling method was used in two lessons taught. The atomic model in one lesson and molecule model in another lesson were prepared by the participants. The students answered the questions asked in the semi-structured interviews as directly quoted in Table 3 below.

Table 3. The categories of the use of modelling method and students' views

Theme	Categories	Students' Views
Use of the Modelling Method	Learning process, use of materials, method.	*"I think it's effective. At least you see what it is, what it looks like." (S4)* *"Yes. We can't see it in real life, but it's better understood when you show it." (S2)* *"We end up learning it. The practice makes it more memorable." (S4)* *"We attended to it touching and feeling in a more three-dimensional way than we attended to it at this computer. It was good." (S3)* *"I like to design and model what I see.." (S3)*

In the answers given by the participants directly or indirectly to the questions about how the modeling method was used in the lessons taught, they emphasized that this method was enjoyable, understandable and effective. These emphases included the dimensions of process, product and learning environment, which were related to the curriculum dimensions in the relevant lessons.

In the semi-structured interview, the students were asked the following questions; "What are the effects of computer-assisted simulation method on learning?" and "How did you find the method of using computer-assisted simulation?" The findings obtained from the answers given by the students to this question are illustrated in Table 4 below.

Table 4. The categories of the theme of the use of simulation method and student views

Theme	Categories	Students' Views
Use of simulation method	Process diversification, teaching speed, exploratory learning, product/evaluation	*"I mean, I think it is more memorable by demonstrating it, rather than saying "when you go home, memorize these and memorize those" (S4)* *"I didn't know before, but I have learnt now, a lot more." (S2)* *"It was quite good. I already like doing things on the computer." (S1)* *"It is better now. We have seen them visually and heard aurally as well. we tried them out." (S3)* *"I think they should not act like our teacher. I mean, for instance, the teacher explains something, then gets us to write it down, then s/he makes us take an oral exam. Then, when we fail, he gives low mark, 40 or does the same thing to those student who are unruly. I don't think this is what it should be like. We can understand better by experimenting." (S4)*

As far as the results in Table 4 are concerned, the students stated that they found the simulation activity visually rich, instructive and catchy. The student coded S2 stated that the lesson they learned and liked the most was "the lesson conducted using simulation". In fact, in another interview where there was no simulation activity, the student coded S3 suggested that "atomic modeling activity can also be learned better with simulation". Moreover, one of the students referred to some of the situations he experienced in the

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educational institution he attended full-time, saying that learning by experimentation enables him/her to understand the subject matter better.

Heat conduction, thermos construction, density and mixtures experiments were conducted in four of the courses designed according to the EPTS Curriculum Model. Gifted students carried out experiments in line with the lesson plan in these experiments and obtained some certain results. In the semi-structured interviews with the students, “What do you think is the most effective way to learn a subject in a Science class?” and “What do you think about the Science course taught through experimentation?” questions were asked. In line with these questions, the answers given by the gifted students are illustrated in Table 5 below:

Table 5. The theme of the use of the experiment method, its categories and students’ views

Theme	Categories	Students’ Views
Use of the experiment method	Learning method, process, learning environment, student centeredness	*“Mr./Mrs., doing it yourself. Not watching it, not reading it. doing it yourself.” (S1)* *“Lecturing the subject visually and by testing it and working on it.” (S3)* *“Doing experiment. If we are lectured first and then do the experiment, we learn it both practically and theoretically; Those students who are good at it can easily understand when they are lectured. But for those with visual intelligence, I think doing experiment is also very plausible.” (S4)* *“.... Since you have done it before, you know what you're doing. You remember it saying, "Wow, I already did that.” (S4)* *“It was nice and enjoyable. We have learnt which materials are better heat conductors and insulators.” (S3)* *“Doing experiment is enjoyable and memorable. At our school, they converted the science lab into a classroom. In fact, there were so many other available venues they could convert...” (S4)*

In Table 5, the answers obtained from the students were analyzed in the form of direct quotations and divided into various categories of curriculum dimensions. Some of the participants examined the advantages of the learning by the experiment method from their perspective, and the student coded S4 stated that the laboratory in the school where she continued her formal education was converted into a classroom.

Table 6 illustrates the students' Views on using the information they obtained related to daily life from the lessons they studied within the scope of the study.

Table 6. The theme of using what has been learned in daily life, its categories and student Views

Theme	Categories	Students' Views
Use of what has been learned in daily life	Being able to transfer what they have learned to daily life, real life problems	*"I can give examples to my classmates. I can also do my project assignments based on what I have learned here." (S3)* *"For instance, if I accidentally confuse the mixtures, I can easily break them down." (S3)* *"For instance, when there is something about atoms next year, I can be 1 step ahead of everyone." (S3)* *"I can use it." (S4)* *"Sometimes when I was a kid, for instance, I didn't use it much, but now sometimes I come across it. I think as I get older I'll come across it more often." (S1)*

The students coded S4 and S1 stated that they did not know how to use the knowledge and skills they acquired within the scope of the study in daily life and that what was learned in the lessons was not often encountered in daily life. S4, on the other hand, stated that when she had a problem with mixtures in daily life, he could easily break them down based on a lesson taught.

The students were asked the following questions; "Is the Science lesson you have learnt here any different from the Science lesson at your school? If so, what is it?" and "Would you like to be taught the following Science lessons with these methods? Why?" and the results obtained from the responses provided by the students to this question are illustrated in Table 7 below.

Table 7. The theme of comparing the courses taught using the EPTS curriculum model with the formal education courses, its categories and students' Views

Theme	Categories	Students' Views
Comparison of the courses taught using the EPTS curriculum model with the formal education courses	Learning method, learning process, interest, diversity	*"...In our normal education, we sit around for forty minutes in class, but we can model and behave freely in these lessons." (S3)* *"I think the activities were good. It is because usually they plainly teach the things that such scientists have achieved. Teachers say 'memorize them, read them, I will make you all take an oral exam'. Even there is oral exam, teachers say 'read it and I will ask you to tell it again'. This is so unnecessary. The lesson is no longer pleasurable this way. Having to memorize it. I just memorize the subjects I love just by taking notes like this. Other than that, it doesn't work for me when teachers say at school 'just memorize it'." (S4)* *"I would want it." (S2)*

The students stated that they constantly sat around and did memorization in the Science classes at their schools and were not satisfied with the teaching style of their teachers. Nevertheless, they were of the opinion that this new lesson style, which included differentiated instruction, was more effective. For this, they indicated the reasons such as flexibility in the lesson and teaching method of the lesson (experimenting, practicing, modeling).

The responses to such questions as "How did you find the lessons you learnt today?" and "Do you find the lessons you learn interesting, enjoyable or pleasant? Why?" are illustrated in Table 8.

Table 8. The theme of finding the lessons interesting and enjoyable, its categories and students' Views

Theme	Categories	Students' Views
Finding the lessons interesting and enjoyable	Interest and attitude, learning methods, content, process, specific expressions	*"It was good Sir/Ma'am., it was fun." (S1)* *"It was pretty good. I already like doing things on the computer." (S1)* *"Si/Ma'am, modeling in 3D was good." (Ö1)* *"They were good lessons. I got informed." (S3)* *"It was a good activity lesson. We've learnt better." (S3)* *"İt was good fine, enjoyable. We learnt which materials were better heat conductors and insulators." (S3)* *"The lessons were fun. They were educationally beneficial." (S2)* *"It is nice to reinforce your learning by doing activities." (S3)* *"Doing experiments is nice and memorable." (S4)* *"The lessons were fun. We learned about density. We learned about the people who discovered the atom." (S3)*

As is clear in Table 8 above, the students expressed their Views about the courses by "giving reasons". During the interviews, the student coded S4 said, "…*For instance, if the lesson is fun, everybody wants to come and join it.*" emphasizing the "importance of the science lesson being fun and interesting". Furthermore, the students generally answered the question 'whether they found the lesson interesting or good' "positively". Specific to the lesson taught, to questions like "……. How did you find your lesson?", the students stated that they found the teaching methods and techniques of density, three-dimensional modeling, computer-based teaching and experimentation effective, enjoyable or interesting.

The students were asked such questions as "What do you think is the role of the teacher in a Science class?" and "What do you think the role of the teacher should be in a Science class?" and the answers obtained were listed. Table 9 below illustrates the theme, categories related to this subject and the responses of the gifted students presented by direct quotation.

Table 9. The theme of the teacher's role, its categories and students' Views

Theme	Categories	Students' Views
Teacher's role	Content, process, product/assessment, learning environment	*"The teacher lectured on the subject first. Later, he conducted activities to make it more memorable." (S3)* *"Each student should be dealt with individually. A student should not lag left behind about a subject so that they can cooperate together. I mean they all have to do it together at the same time. All of them need to learn well. This was the role of the teacher in this lesson.." (S4)* *"For instance, the teacher, I think, should be fun. S/he should teach with more activities." (S1)* *"Lecturing in a way that students can easily understand" (S2)* *"I mean, the teacher teaches the lesson and then helps with the experiment." (S4)* *"First, the teacher should explain what s/he will do, then teach the subject, and finally the conduct the activity." (S3)* *"Making the activity fun and informative." (S1)*

According to a gifted student coded S3, the teacher should ensure that the students are informed about the subject matter and then get the students do activities so that the information is memorable. Another student, S4 said that the teacher should attend to the students and make sure that the students do not leg behind in the lesson, adding that this is the role of the teacher in this lesson. Furthermore, such the responses as 'the teacher should be fun and get the students to do experiments/activities' are those given by the students.

The data obtained from the diaries consisting of what I know, what I have observed and what I have learned sections and of the texts written by the students in these sections are illustrated in Table 10.

Table 10. Findings from diaries

Diary Section	Sample Text Written by the Students
what I know	*S4: Matter consists of particles.* *S1: Substances other than gas cannot be compressed.* *S3: Solid vibration, liquid and gas substances perform all the movements.* *S2: Substances can melt, freeze, sublimate, condense.*
what I have observed	*S4: I think the practice activity is enjoyable and It will be easily memorable (I have learned molecules in the other 3D activity).* *S3: Molecule making game is just like Subway Surf game. We are trying hard.* *S1: (The student did not write anything here).* *S2: I have mixed oil with water, put play dough in it. I think it will sink. The play dough sank.*
what I have learned	*S4: Atoms are made up of neutrons, electrons and protons.* *S3: Representation of molecules* *S1: Elements combine to form molecules.* *S2: I have learned the symbols and models of some elements.*

It was observed that the gifted students who participated in the study wrote down, grade independently of the study, the knowledge and information they had learned in the sixth in the "What I Know" section of the diary. In the "what I have observed" section, on the other hand, in the practice activity implemented within the scope of the study, the student coded S3 mentioned that he tried very hard in the activity; the student coded S2, on the other hand, expressed his predictions and results while he was doing the experiment. Finally, it was apparent that the students talked about the seventh-grade topics and concepts added to the unit within the scope of acceleration in the "What I have Learnt" section.

DISCUSSION AND CONCLUSION

As far as the semi-structured interview findings are concerned, the gifted students though positively about using the methods of doing experiments, simulation and modeling. They concluded that the use of these methods affected learning positively and that it was good to participate actively by doing practice. Furthermore, they stated that such activities appealed to their visual and intelligence, and that such activities were not used at their own schools. Johnson, Boyce, and VanTassel-Baska (2013) stated that it can be more instructive for students to be personally involved in the work by doing and living in the lesson. Similarly, transforming, arranging or recreating the materials used in the lessons into a new product by the students also serve this purpose. It is possible to say that the courses enriched by the inclusion of Practical Ability skills (using experience effectively, planning the workload, concentration, aiming at a goal, taking responsibility, etc.), which are among the EPTS Curriculum Components, into the EPTS Unit, as a result of identifying the teaching methods suitable for these skills, increases the satisfaction, in-class activities, attitudes towards learning and motivation of the gifted students, who are the target audience. In such courses, which are aimed at gaining skills such as practical, analytical and creative abilities, there are similar studies that show that the lessons taught create a positive attitude towards the field/course in students and that this attitude may continue in the future (Stake & Mares, 2001; Tyler-Wood, 2000; Waiyarod, 2007). It is possible to say that the gifted students who took part in the study found the lessons they learnt regarding content, process, product/assessment and learning environments, which were among the curriculum dimensions (Maker, 1982), successful.

In the 2018 science curriculum of the Ministry of National Education, there is the acquisition of "…investigating, criticizing, questioning, curious, identifying problems and looking for creative solutions to them like a scientist in their own lives…". This acquisition envisages the use of the learned information in daily life. With regards to the theme of putting what has been learned into practice in daily life, one of the gifted students said that s/he could easily break down the mixtures in daily life, referring to the lesson s/he took on the subject of "mixtures" within the scope of the study. Some of the other gifted students also said that they could use what they had learned in their exams and project assignments. Similar to this research, in the study that Girgin (2020) conducted, learning experiences of the gifted children through project-based learning approach were determined via reflective journals. The findings of the research indicated that gifted children have an advanced level reflective writing ability. In the same study, it was also observed that participants grounded their projects with real-life problems and made inter-disciplinary connections in their reflections. However, despite the limited responses, it turns out that clearly the students were unable to foresee how they will transfer what they have learnt to daily life. The reason for this can be attributed to the fact that the study consisted of subjects that we could not experience in real life, such as the movements of atoms, molecules and matter particles within the scope of the subject area of "Matter and Heat".

Another theme transpired as the comparison of the lesson taught using the EPTS Curriculum Model with the school the students attended within the scope of formal education. The gifted participants referred to their dissatisfaction with the learning process, product/assessment, learning environment (laboratory), and content dimensions in the schools where they attended for their formal education. Nevertheless, they made positive comments about the lessons taught within the scope of the study. From this point of view, it is possible to conclude that the reason for these particular results was that no lesson plans were prepared for the educational needs of the gifted students in the institutions where they continued their formal education and the evaluation of these students did not address their different intelligence types. As far as the content and presenting this content was concerned, a student's complaint that the existing teaching method was based on rote learning supports this argument. Furthermore, even though the semi-structured interview findings were divided into themes, it is a noteworthy result that the students stated that they found the lessons taught within the scope of the study in almost every theme interesting and enjoyable. These particular findings may be justified by the reasons that the analytical, practical and creative ability components of the EPTS curriculum enriched the teaching, thus increasing gifted students' motivation and provided them with educational satisfaction with the inclusion of advanced subjects.

There are studies (Ryu, Lee, Kim, Goundar, Lee, & Jung, 2021) in other countries that have similar findings with the current research. For example, in the book chapter cited above, the current status of STEAM education for gifted students in South Korea is presented. In addition, there are studies that investigates positive relationships between gifted education and STEAM education (An & Yoo, 2015). Specifically, in this chapter, the journey of how

South Korea has incorporated STEAM education within gifted education was explained in detail. The same researchers highlighted that gifted education has seen significant investment in the further expansion and development of specialised programs and curriculum of the STEAM education model. In their study conducted in 2015, Gündüz and Akın expressed many problems regarding the education of special education students, such as the lack of appropriate environments in public schools.

The teacher dimension, which was one of the components of EPTS, was one of the themes that transpired as a result of the transfer of the Views of gifted students. The gifted students who participated in the study expressed their Views that the teacher was the person responsible for the learning of all students, that s/he should be fun, that the lessons should be planned with appropriate teaching methods, and finally stating that this was the very role of the teacher in the sample lesson within the scope of this study as well. The findings of the research conducted by Kanlı (2011) show that accelerating in the field of science causes positive reflections on gifted students. Similarly, in Sak (2011)'s study, which found the social validity of the EPTS to be high, the fifth "Courses taught in the EPTS are interesting." and the sixth item, “The EPTS, courses are taught in different ways.” coincides with their propositions. Despite the fact that only the curriculum model was used without using the other components of the Gifted Education Program, similar results show how important the curriculum dimension is.

The possible results that can be deduced are that the teacher should be more effective in managing such processes as a requirement of the lessons taught according to the EPTS Curriculum Model, and if this came true, the students were satisfied with this situation. Furthermore, the fact that the student coded S4 made a comparison with the teacher at her own school in Table 7 can illustrates that she was sensitive about this issue.

The EPTS Evaluation Scale (EPTSES) is utilized in order to reveal the Views of gifted students participating in the EPTS program model after they were included in the program and identify whether they were satisfied with being included in the program (Sak, 2011a, 2013). While creating the items in the EPTSES, the United States National Association of Gifted Children (NAGC, 2010) standards were used and it consisted of items that included the content, process, product/assessment, learning environment and teacher dimensions of the curriculum (Sak, 2017, cited in; Avcı,2015). From this point of view, it would be useful, within the context of EPTSES, to discuss the students' Views on the EPTS Unit, which was prepared according to the EPTS Curriculum Model in the subject area of "Matter and Heat" in the Science course.

In a study his study he conducted with 84 gifted sixth grade students attending EPTS program the scope of after school, in an attempt identify the social validity of the Education Program for Gifted students, Sak (2011) found that the social validity of the EPTS model was high. In this study (Sak, 2011), in which 12-item EPTSES was used as a measurement tool, the items such as (4) The knowledge and skills learned in this program, to this effect, were also useful in daily life. (5) The courses taught in this program were interesting. (6) In this program, lessons were taught by different methods. (7) The teaching staff working in this program consisted of people who were qualified to teach gifted students.” were the items support the results of the present study. As far as the direct quotations from the semi-structured interviews are concerned, it is obvious that the students expressed this clearly.

Among the findings obtained from diaries, which was another data collection tool, the fact that the student coded S3 explicated one part of the lesson as *"The game of making molecules is just like the game of Subway Surf. We are trying hard"* can be an indication of the fact that there was abstractness and complexity of the EPTS Unit prepared within the scope of this study in terms of content dimension and, it possessed the exploratory learning and reasoning sub-dimensions for the student in question regarding the process dimension. Similarly, in the 'What I observe' section, the that the fact that the student coded S3 noted down the predictions and results of the experiments she conducted is likely to resulted from the inclusion of EPTS analytical skills in the relevant unit and the efforts to teach the students the required skills. It is clearly observed that the concepts or subjects that the gifted students took notes of in the "what I have learned" section of the diary consisted of seventh grade subjects included in the unit within the scope of acceleration; It is possible to conclude that the acceleration method attained its objective.

SUGGESTIONS

The fact that the number of participants in the study was small and the study was carried out in a single subject area from the field of science course in a limited period of time can be mentioned as the limitations of the present study. Despite these limitations, the emerging results of this study supported those of similar studies in the relevant literature and it was found that the students had positive views on the subjects such as learning process, learning method, product/evaluation and motivation/interest about the lessons taught according to the EPTS Curriculum Model. In this respect, it is recommended that the teachers who teach the science classes of gifted students develop a lesson/unit plan based on the EPTS Curriculum Model and use it in their lessons. Furthermore, due to the time and student limitations in this study, future researchers are recommended to conduct studies with more students, in longer time periods and in different subject areas of the science course.

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