Online Science Education Journal http://dergipark.gov.tr/ofed

2024; 9(2): 30 - 43.

Traffic Light Tiered Assessment: Examples from STEM

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To cite this article: Örnek, F., Alaam, S., Fateel, M., & Almalki, F. (2024). Traffic light tiered assessment: An example from STEM. *Online Science Education Journal, 9*(2): 30-43.

Article Info

Article History

Received:
14 May 2024

Accepted:
17 September 2024

Keywords

Colors;
Colored tiered assessment;
Differentiation;
STEM
Tiered assessment

Abstract

With rapid changes in the world, educational systems for the 21st century need to adapt by not just teaching any subjects by utilizing any approaches to students. The significant changes affect school curricula, which require more inclusive and diverse approaches for students. Based on these changes, and additionally, in reviewing the results of PISA (OECD, 2018) and TIMSS; OECD Future of Education and Skills 2030: OECD Learning Compass 2030 (OECD, 2019); Bahrain SDGs 2030; and 2022 CAEP standards, teachers should know how students differ in their approaches to learning and create instructional opportunities to provide equitable and inclusive learning experiences for all students. The authors are inspired to develop a traffic light colored tiered assessment in STEM using traffic light colors: green (tier 1), yellow (tier 2), and red (tier 3). In this study, we reviewed several types of tiered assessment integration in different fields such as math and science, to develop a model for tiered assessment using traffic light colors in STEM, in accordance with the available models and practices in different fields. In this paper, the traffic light colored tiered assessment provides some examples in the STEM curriculum as a guide to help further developments of these kinds of questions. Additionally, this paper attempts to provide guidance on how to write traffic-colored tiered questions in STEM to demonstrate how students can be inclusive in assessment. Furthermore, this paper recommends increasing the number of traffic light-colored tiered assessments in STEM to support classes in being more inclusive and differentiated.

INTRODUCTION

The 21st century educational systems need to adapt to the rapid changes happening in the world. It is no longer sufficient to teach subjects to students using any methodology. The significant changes in society also mean that educational curricula should be more inclusive and diverse, requiring teachers to have a broader understanding (OECD, 2019). To ensure equitable and inclusive learning experiences for all students, teachers should be aware of the differences in students' learning styles and employ differentiated instruction strategies. This means recognizing that some students may be exceptional learners, such as those who are gifted, have learning difficulties, or have physical or mental disabilities. Differentiated Instruction (DI) provides a framework for addressing diverse student needs by adapting teaching methods. Within this context, tiered assessment emerges as a practical approach to differentiate evaluation based on students' varying levels of readiness, interests, and learning profiles. This study develops a model for tiered assessment using traffic light colors in STEM education, integrating DI principles to enhance student engagement and learning outcomes. According to Tomlinson (2001, p. 3),

"Differentiated instruction is a teaching philosophy based on the premise that teachers should adapt instruction to student differences. Rather than marching students through the curriculum lockstep, teachers should modify their instruction to meet students' varying readiness levels, learning preferences, and interests. Therefore, the teacher proactively plans a variety of ways to 'get at' and express learning."

Differentiated instruction does not mean that students will learn different content. Although students can learn in different ways, such as through visual learning, the main skills and content they learn will be the same. In other words, students can take different pathways to reach the same destination (Tomlinson, 2001). Students are motivated to learn through a variety of teaching strategies that are tailored to their interests, needs, and skills. This allows them to acquire knowledge and communicate their learning in different ways (Al-Shaboul, Al-Azaizah, & Al-Dosari, 2021). Numerous studies have shown that this approach boosts students' motivation and achievement, enhances their performance, fosters their creativity, and improves the quality of education (Al-Shaboul, Al-Azaizah, & Al-Dosari, 2021; Herner-Patnode & Lee, 2021; Koeze, 2007; Mavidou & Kakana, 2019). Furthermore, differentiated instruction has a significant impact on students' critical thinking, communication skills, attitudes, and problem-solving abilities (Al-Shaboul, Al-Azaizah, & Al-Dosari, 2021; Mizell, 2010; Morgan, 2014; Idrus, Asri, & Baharom, 2021). Based on the literature and our teaching experiences, differentiated instruction has a positive impact on teaching and learning. So, the question arises: how can instruction be differentiated? Tomlinson (1999) answers this question by stating that teachers can differentiate the learning environment, content, process, and product based on students' readiness, interests, and learning profiles. Even though students may be the same age, they have different levels of readiness, interests, and learning styles, as they come from diverse backgrounds and have different experiences and socioeconomic statuses (Ginja & Chen, 2020).

The following is a description of the essential components of differentiated education.

Key Elements of Differentiated Instruction

Differentiated instruction consists of four components: content, method, product, and learning environment, all of which can be tailored to meet individual student needs. Teachers have the ability to differentiate instruction through content, process, product, and learning environment based on a student's readiness, interests, and learning profile, as depicted in Figure 1. The following sections will provide a detailed description of each component.

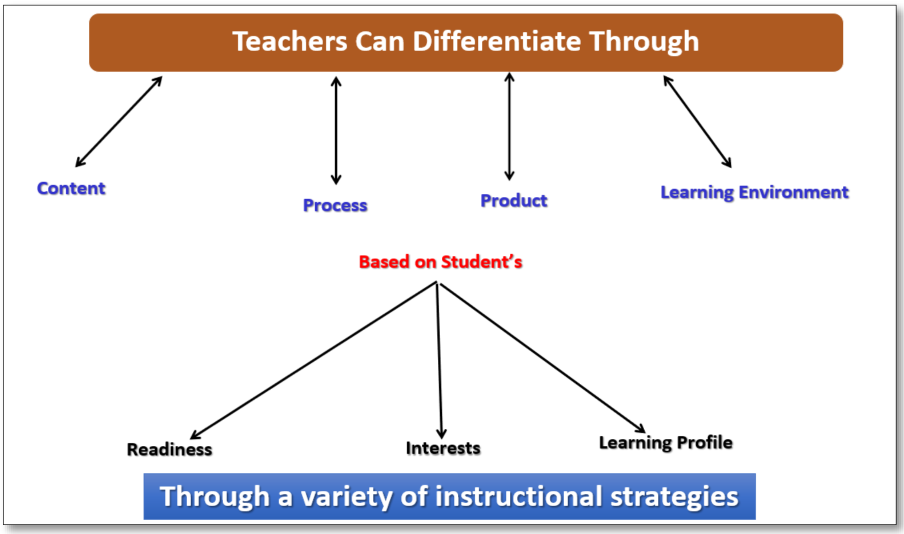


Figure 1. Differentiation process

Content

Content refers to the knowledge, understanding, and skills (KUD) that students must acquire (Tomlinson & Imbeau, 2010). In other words, it is related to what students will learn and the materials that represent the learning. It is important to note that learning objectives for the content will be the same. What will be differentiated are the methods that students use to comprehend the topic. For example, students may use multiple textbooks, articles, supplementary resources, varied online resources such as computer simulations, and varied visual resources such as videos, animations, and pictures. Teachers offer suitable scaffolding when working with content to address the needs of each student, as some students may require more support. For instance, teachers can provide certain students with the opportunity to learn the required material, allow more advanced students to skip ahead in class, or modify the course material for specific students according to their individual levels (Tomlinson & Imbeau, 2010).

For example, students can acquire knowledge about atoms in physics or chemistry courses by observing teachers' demonstrations, engaging in small group discussions, using videos and visuals, and utilizing computer simulations. As seen, the content is the same, but tools are differentiated to ensure all levels of students can comprehend the topic of atoms. Some students may learn best through watching videos, while others may prefer listening to the teacher.

Process

According to Tomlinson (2014), "process describes activities designed to ensure that students use key skills to make sense of, apply, and transfer essential knowledge and understandings" (p.18). Differentiating the process involves practicing the content. When teachers differentiate the process, they teach the same concept or skill in a way that allows each student to understand it. Therefore, teachers should provide a variety of activities for students to comprehend the concepts or acquire the skills. They can determine the best approach based on their students' readiness levels, interests, or learning profiles. For example, some students may prefer working with technology, such as computer simulations that are compatible with mobile devices. These students can use their smartphones or tablets to complete activities. Others may prefer hands-on or minds-on activities. Teachers can group students or assign individual tasks based on these preferences. To illustrate, during a lesson on length, area, and weight, teachers can create different tiered groups based on students' interests. In this activity, students choose their groups and then begin the task. They are instructed to find 10 items in the classroom. The first group finds the length of the items, the second group finds the area, and the third group finds the weight. All groups create a table to present their findings.

Product

According to Tomlinson (2014), "products are vehicles through which students demonstrate and extend what they have learned" (p.18). Products allow students to demonstrate whether they have learned the key concepts and skills in a course and to apply what they have learned to solve problems. Different students can create different products based on their readiness levels, interests, and learning preferences (Tomlinson, 2001). Students should have a variety of products to demonstrate mastery of their learning. Additionally, students can work alone, in small groups, or in pairs on their prouducts. Of course, the products should be related to real-life problems. The products should not be used just for summarizing concepts or ideas, but they should encourage students to analyze and synthesize.

Tiered assignments, tiered assessments, lab experiments/activities with reports, and computer simulation activities with activity worksheets can be examples of products (Hogan, 2009; Lewis & Batts, 2005; Pozas et al., 2020). Moreover, 3D models and project work provide opportunities for students to work on different ideas that relate to the curriculum objectives. When working in groups, each group will produce a different model or project that addresses the same content but has different products that demonstrate their comprehension. When differentiating by product, teachers give students options to demonstrate what they've learned (Wormeli, R., 2023). For example, after finishing Newton's laws of motion, some students may be able to show their learning by completing a worksheet while working on computer simulations about Newton's laws of motion. However, other students may prefer to demonstrate their learning through creating a PowerPoint presentation with videos, animations, or pictures, or by applying Newton's laws of motion to real-life scenarios. Product is one of the key elements that we will focus on in this paper to create several traffic light-colored, tiered assessments in STEM.

Learning Environment

Students come to class with different emotions and feelings, which are created by their past experiences and their reactions to their current experiences (Mänty et al., 2020). These emotions and feelings influence how students view themselves and their motivation to learn and collaborate with their peers. As a result, all of these factors play a crucial role in students' learning process (Boekaerts, 2010). For example, we differentiate based on students' emotions and feelings when we provide alternative options for shy students who do not like to work in groups (Tomlinson & Imbeau, 2023). Another example is when we need to modify the learning environment for students who have difficulty sitting still for a certain amount of time. We should make it possible for them to move around the room to help them concentrate on their tasks. Additionally, some students cannot handle noise during classes or while working in groups, even in their own homes. In these cases, we should provide alternative options such as earplugs or an iPod with music, as some students find it helpful to complete tasks while listening to music.

Differentiation Based on Students' Readiness, Interests, and Learning Profile

Teachers can differentiate content, process, product, and learning environment. However, how can teachers differentiate? Based on what? These four key elements can be differentiated by students' readiness, interests, and learning profiles. The following sections provide answers to these questions.

Readiness

According to Tomlinson (2014), "Readiness is a student's entry point relative to particular knowledge, understanding, or skills" (p.18). Teachers are required to differentiate based on students' readiness levels to evaluate prior knowledge, ascertain what students know, and determine their level of proficiency (Tomlinson, 2001). Once a teacher has this information about students' readiness - through questionnaires or diagnostic tests - they can use it to differentiate content, process, or product (Tomlinson, 2001). If students have lower readiness, they need more assistance, practice opportunities, and structured guidance for activities (Tomlinson, 1999). On the other hand, students with advanced readiness often need less practice and can handle more challenging and abstract tasks. They do not require scaffolding and support (Tomlinson, 1999). For example, in mathematics, students who have mastered the basic operations on whole numbers will find it easier to learn basic operations on integers, while students who struggle with multiplication and division of whole numbers might require more support and guidance during class activities to learn basic operations on integers.

Interests

Interest is related to one's preferences and curiosity; it can pertain to a specific subject or a broader topic (Tomlinson, 1999). Teachers can capture students' attention and involve them in class by incorporating their interests (Tomlinson, 2001), as students enjoy working on subjects that interest them. Teachers can offer examples that align with students' interests. For instance, if some students are particularly intrigued by driving and cars, teachers can provide examples related to driving cars in rainy conditions while teaching about force and friction.

Learning Profile

Learning style preferences, intelligence preferences, and preferences for group size, culture, and gender can all have an impact on students' learning profiles (Tomlinson, 2001). Learning styles refer to the various ways in which students learn. A student's preferred method of comprehending, processing, comprehending, and retaining information is known as their learning style, such as visual learners or auditory learners. Intelligence preferences are outlined by Howard Gardner (1983). According to him, each student may have different intelligence, so lessons should incorporate various intelligence activities. For instance, for linguistic intelligence, teachers can utilize storytelling or word games. Grouping preferences (working alone or with others) and gender preferences are related to the social aspect of learning and the disparities in learning between males and females (Koehler, 2010). Additionally, culture impacts students' learning. In order to identify students' learning profiles, all aspects of the learning profile should be taken into account by using questionnaires such as MI and VARK surveys.

Why Tiered Assessment?

Instruction is derived from assessment. Assessment occurs at the beginning, throughout, and at the end of the unit. Pre-assessment, formative assessment, and summative assessment are regular components of the teaching and learning cycle. Assessment helps the teacher/instructor plan for the next class and understand the progress of the diverse student population. It is an integral part of instruction, and differentiated assessment can inform instructional decisions and show student progress (Mohammad & Kaur, 2014). Assessment should be inclusive of all students, including low achievers and high achievers. It should not be a one-size-fits-all approach, but rather differentiated to match students' readiness, interests, and learning profiles.

Tomlinson (1995) suggests that in a heterogeneous classroom, teachers use tiered assignments to meet the various needs of their students. Tiering assessments is particularly helpful when teachers want to ensure that students with different levels of learning proficiency are working with the same core concepts and essential knowledge and skills. In other words, tiering assessment is based on a readiness-based strategy. Readiness refers to knowing where students are in their learning journey, recognizing their current knowledge and skills. For example, a student struggling with abstract concepts in science or abstract thinking still needs to grasp important concepts and principles in a given question, phenomena, or situation. On the other hand, a student who is well advanced beyond grade expectations in the same subject needs to be challenged and engaged at a higher level when working with the same essential content. Therefore, a one-size-fits-all assessment is unlikely to benefit struggling or high-level students in comprehending key concepts. By using tiered assessments that vary in complexity, abstractness, open-endedness, and independence, all students can focus on fundamental knowledge, understanding, and skills. The teacher increases the likelihood that each student will achieve important skills and understanding by maintaining the assessment's focus and offering varying degrees of difficulty.

Tiered instruction and activities provide an effective way to address the different levels of students while building on and deepening fundamental skills and knowledge. This has been found to support better student performance across subjects (Galloway, 2018; Suarez, 2007). Studies have shown that when students have good performance in tier 1, they will need less extra support and instruction in tiers 2 and 3 (Galloway, 2018). This approach focuses on the necessary skills for students to achieve mastery while allowing them to set higher goals to reach more complex levels of mastery, and as they are exposed to different tiers, students can develop a complex set of skills ranging from memorization to designing, analyzing, reasoning, and justification; in addition to its positive impact on students' understanding and achievement, using tiered assessments also supports their emotional development by empowering them to make their own choices, which boosts their confidence and autonomy in the learning process, further motivating them to tackle more challenging tasks and enhancing their sense of being addressed by the teacher in terms of their needs and interests, further elevating their motivation and confidence (Suarez, 2007). This approach focuses on the necessary skills for students to achieve mastery while allowing them to set higher goals to reach more complex levels of mastery, and as they are exposed to different tiers, students can develop a complex set of skills ranging from memorization to designing, analyzing, reasoning, and justification; in addition to its positive impact on students' understanding and achievement, using tiered assessments also supports their emotional development by empowering them to make their own choices, which boosts their confidence and autonomy in the learning process, further motivating them to tackle more challenging tasks and enhancing their sense of being addressed by the teacher in terms of their needs and interests, further elevating their motivation and confidence (Suarez, 2007).

Furthermore, the usage of tiered assessments and tasks can positively impact teachers, who feel that they are meeting their students' needs while addressing curriculum standards and allowing for deeper learning (Suarez, 2007). When teachers design tiered assessments, they feel more confident in challenging their students' needs while providing opportunities for success in achieving and exceeding the standards (Levy, 2008; Suarez, 2007).

Three-tiered assessment is found to be more reliable than two-tiered and one-tiered assessments in determining students' comprehension and lack of knowledge, and it can effectively highlight students' alternative conceptions, especially when using open-ended questions; it serves as an effective tool for educators to assess prior-to and post-instruction, allowing them to effectively plan and teach different concepts (Cetin-Dindar & Geban, 2011). Considering these benefits, traffic light-colored tiered assessment can be advantageous for both teachers and students.

Colored Tiered Assessment

"The term traffic light refers to an automatically turned-on colored light that helps control traffic" (Munna 2021), meaning traffic light colors can be used for tiered assessments and activities. It has been shown that the use of color in educational materials is important for evoking a range of emotions and grabbing students' attention (Chang, Xu & Watt, 2018). With the aid of color, students may pay more attention to specific information, which increases the likelihood that the information will be retained in long-term and short-term memory (Dzulkifli & Mustafar 2013). For instance, warm colors like red, orange, and yellow have been identified as the best colors to draw students' attention and encourage their active involvement in lessons (Wilson 1966). In other words, cool colors (such as green, blue, and purple) soothe, and warm colors (such as red, orange, yellow) stimulate (Clarke & Costall 2008). Furthermore, due to earlier color experiences or presumptions about colors connected to cultural norms and life events, learners may interpret colors differently. On the other hand, traffic light colors have the same meaning worldwide. Green color: the driver can start driving or keep driving; Yellow color: the signal is about to turn red, and the driver needs to be prepared; Red: the driver has to stop. Therefore, these colors can be used for differentiated assessment for different cultures too. Green, yellow, and red colors have the following meanings similar to traffic light colors as seen in Table 1. In traffic lights, green means go or pass (no stress); yellow means be careful and maintain your attention in case red lights turn on; red means stop (need to be on alert). In actual traffic light usage, yellow also transitions from red to green, this role is utilized in our tiered assessment model to maintain a clear and straightforward progression of difficulty and vice versa.

Traffic lights are helpful because they assist in the development of students' self-reflection skills. They serve as an excellent tool for creating personal development plans that enable students to actively engage and participate based on their individual abilities and knowledge. The traffic light model encourages self-learning responsibility, which is crucial for cognitive and emotional growth, and promotes a proactive learning culture (Munna, 2021).

Table 1. Meanings of green, yellow, and red colors (adapted from psychology of colors, 2020)

GREEN	YELLOW	RED
Enhance focus Create calmness Improve memory Relieve stress	Encourage creativity Maintain attention Create positive feelings Boost mood Increase joy	Encourage creativity Inspire action Grab attention Increase alertness

In terms of tiered assessment, a question will have three levels. The first level is the green level, in which students will be calm and not feel any stress because the problem-solving tasks and questions are very basic and appropriate for this level. The use of the color green has been found to be physically relaxing and encourages positive feelings of calmness and comfort (Kexiu, et al., 2021). At this level, students' success depends on their understanding and application of the required basic knowledge and skills. They can easily focus, and this level can make them feel confident in their ability to solve the problem and pass this question. Green level problems fulfill a thorough grade level proficiency standard.

The second level is the yellow level. At this level, students need to be creative and attentive. They will feel positive and joyful because they have already solved the problem/question at the green level. The color yellow has been found to increase motivation and intellectual activity (Al-Ayash, et al., 2016). Furthermore, students often report feeling more relaxed, cheerful, and alert when exposed to the color yellow (Al-Ayash, et al., 2016). Problem/question solving tasks are advanced and complex, though not as much as at the red level. Students' success depends on applying and expanding their skills to solve complex question or problems.

The third level is the red level. Students need to be more creative, have inspiration, pay more attention, and be more alert to be able to solve the problem/question at this level. Some students might become anxious at this level and pause for some time because problem/question-solving tasks are advanced and complex. Students’ success depends on their ability to apply their creativity and extend their skills.

In general, the colors green, blue, and black are used for differentiated assessments or activities. Green (low level), blue (middle level), and black (high level) are used for tiered assessment (Suarez, 2007). However, we propose using traffic light colors because they are more attractive, attention-grabbing, and relatable to students' daily lives, as explained above.

Designing Traffic Colored Tiered Assessment (product)

The following questions in STEM are designed based on a differentiation framework using traffic-light-colored tiered questioning. In some questions, it may not be possible to integrate all subjects of STEM; sometimes only math and science or science and technology. As mentioned above, we will use the color green for the low level, yellow for the middle level, and red for the high level. Teachers can decide on the distribution of points for each level question. For example, let's consider question 1 on page 8: Teachers can assign points to each level according to the level of complexity (see example in Table 2). If a question is harder, it will receive more points. Of course, partial credits can also be used for grading. On the other hand, sometimes it is better to do the opposite because it can improve struggling students' motivation. They can feel that they have competence and can develop themselves more, which can lead to positive attitudes towards the subject matter.

Table 2. Point distribution example for question 1

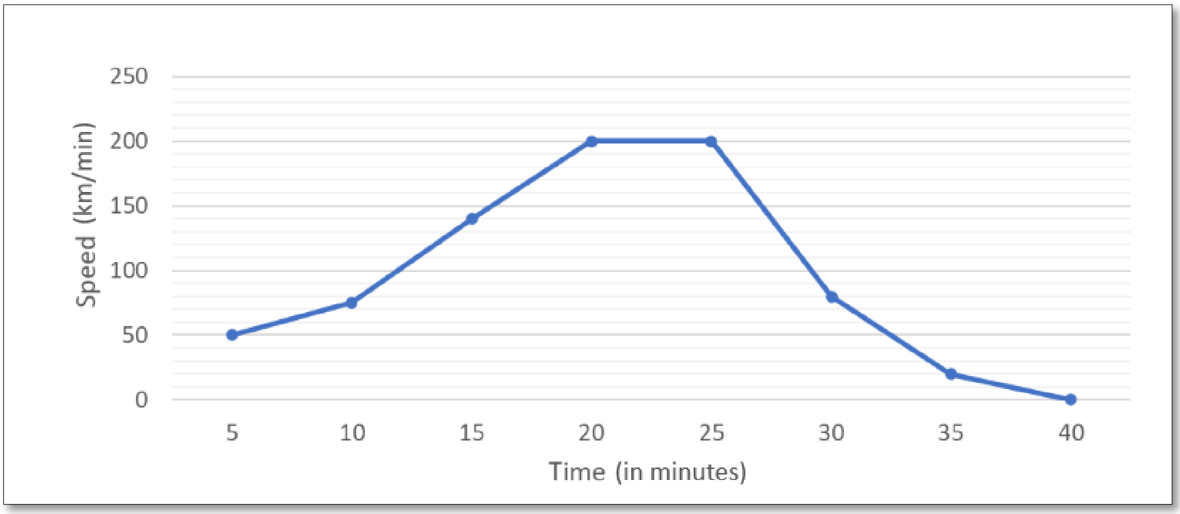
Total	**Green**	**Yellow**	**Red**
12	3.5	4	4.5
12	4.5	4	3.5

There is a misunderstanding among teachers who are not very familiar with tiered assessment. They think that students should choose one of the questions, such as a green level or a red level. However, tiered assessment requires students to answer all questions at different levels. Another important point is that teachers should not administer these questions separately.

They should be a part of a series of regular questions. For example, Question 1 (not tiered), Question 2 (tiered), Question 3 (not tiered).

Question 1 (Math, Science, Technology)

Your sister and you are coming home from shopping, and you have a physics exam tomorrow. You want your sister to help you study topics and practice a couple of questions together. You are driving, and your sister is sitting in the car. She decides to start helping you by pulling out her tablet and opening the "numbers" app to record data during your road trip. Based on the data, she then creates a nice graph for you to practice some questions.



Green	**When did the car reach the speed of 50km/min?**
Yellow	**What is the time interval where speed is positive?**
Red	**When did the car acceleration reach zero? Justify your answer.**

We provide detailed examples from STEM activities to demonstrate the practical application of traffic light-colored tiered assessments in STEM education. For instance, in a physics lesson on motion, a tiered assessment might include:

- Green Level: Basic questions assessing fundamental concepts (e.g., 'When did the car reach a speed of 50 km/h?')
- Yellow Level: Intermediate questions requiring deeper understanding and application (e.g., 'What is the time interval where the speed is positive?')
- Red Level: Advanced questions involving critical thinking and problem-solving (e.g., 'When did the car acceleration reach zero? Justify your answer.')

These tiered questions not only assess different levels of understanding but also encourage students to engage with STEM concepts at varying degrees of complexity, thereby supporting differentiated learning and assessment.

Question 2 (Math, Science, Technology)

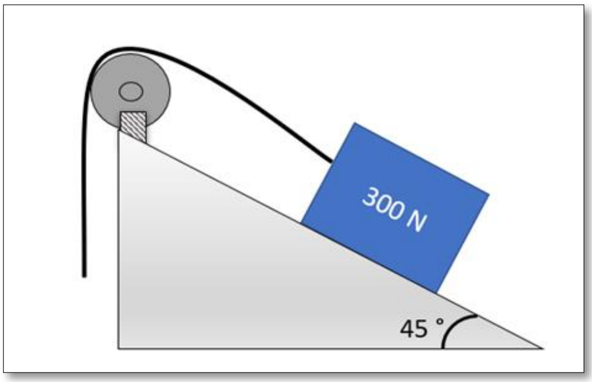
One month ago, you conducted an activity with plants in the science lab. You exposed mint and coriander seeds to red and blue lights. Each week, you measured the length of the plants using the "measure" app on your smartphone. You recorded all the data in your tablet using the "numbers" app, as shown in the table below. The table displays the length of 2 mint plants and 2 coriander plants that were placed under red and blue light for 3 weeks.

length / plant	Mint plant		Coriander plants	
	Red light	Blue light	Red light	Blue light
1 week	4 cm	4.5 cm	3 cm	3.4 cm
2 weeks	5 cm	6 cm	4.1 cm	5.3 cm
3 weeks	6 cm	8 cm	5.1 cm	8.5 cm

Green	Which plant grew more in 3 weeks?
Yellow	Specify the dependent, independent and control variables in this experiment.
Red	Draw the best graph to represent the changes in the plants.

Question 3 (Math, Science, Engineering)

You have a box filled with your old books that weighs 300 N. You want to create a pulley system on an inclined plane to transport the box to a higher level in your home using a rope and a pulley. After obtaining all the necessary materials, you have successfully designed the pulley system on the inclined plane (please refer to the figure below). While working on this project, your sister asked for your assistance with her physics exam. Since you are already immersed in physics due to designing the system, you decided to ask your sister questions to help her practice for her exam.



Green	**What are the forces acting on the box in the system? Please show them in the figure.**
Yellow	**How much force is needed to move the box? Please show all your work.**
Red	**How can you design a system that can carry the box with less force? Please draw it and justify your answer.**

The activities carried out in this study were designed to create a practical framework for implementing traffic light-colored tiered assessments in STEM education. The activities included:

We developed a series of tiered questions across different STEM subjects. These questions were categorized into three levels (green, yellow, and red) to align with the traffic light metaphor. Each level of questions was designed to address varying degrees of complexity and cognitive demand, ensuring that students at different levels of understanding could engage with the material meaningfully. The tiered questions were used in a classroom setting during a post-graduate course. Teachers were provided with training on how to administer these questions and collect feedback from students. The feedback was used to refine the questions and ensure they were appropriately challenging and accessible.

One of the authors conducted a teaching session with participating teachers to discuss the implementation process, share best practices, and address any challenges encountered. This session was instrumental in refining the approach and ensuring that teachers felt supported throughout the implementation. These practical steps could be implemented to effectively develop traffic light-colored tiered assessments in STEM education.

DISCUSSION AND RECOMMENDATIONS

This paper aims to provide examples of traffic light-colored tiered questions for students at various grade levels that incorporate all the components of STEM education. This approach emphasizes the importance of differentiation and the theoretical framework of tiered assessment. Despite its many advantages in building students' fundamental skills and allowing for more complex thinking (Richards & Omdal, 2007). This paper focused on creating tiered assessment tasks that align with STEM education principles. STEM education emphasizes the integration of science, technology, engineering, and mathematics to prepare students for the challenges of the modern world. Our tiered questions are designed to promote critical thinking, problem-solving, and application of interdisciplinary knowledge.

For instance, in the plant growth activity, students applied scientific methods and mathematical analysis to understand biological processes, integrating technology for data collection and analysis. In the pulley system design challenge, students used engineering principles and physics concepts to solve a practical problem, fostering an understanding of how these disciplines intersect in real-world applications.

Research indicates that integrating STEM education through differentiated instruction can enhance student engagement and achievement, particularly in developing higher-order thinking skills and preparing students for future STEM careers (Bahrain SDGs 2030). By incorporating tiered assessments, we aim to provide all students with opportunities to engage in meaningful, challenging, and relevant learning experiences, regardless of their starting points.

Nonetheless, there is still some reluctance and resistance to adopting tiered assessments. Teachers, especially new ones, may experience difficulties when preparing tiered assessment tasks (Roberts, & Inman, 2023). Challenges include formulating questions that address different levels, grading, and administering them effectively (Richards & Omdal, 2007). Some teachers might think students should choose only one of the three questions.

In this paper, we have developed several traffic light-colored tiered questions in STEM to help illustrate how teachers can design, grade, and administer these types of questions. We believe that implementing tiered assessment, especially in STEM, may require additional teacher training to effectively prepare teachers. Research indicates that targeted professional development can significantly enhance teachers' confidence and competence in implementing differentiated instruction (Al-Shaboul et al., 2021; Richards & Omdal, 2007; Tomlinson, 1995).

One way to support teachers in implementing tiered assessment in STEM is through Post-Graduate Diploma Education programs, many of which include differentiation courses. These programs provide teachers with a solid background in differentiation and differentiation practices that can be applied in their teaching. These programs help enhance teachers' knowledge and skills (Al-Shaboul et al., 2021; Richards & Omdal, 2007). Another way to support teachers is by conducting workshops on differentiation in schools. These workshops can provide a hands-on opportunity for teachers to examine their practice and develop their own tiered assessment tasks. Additionally, creating professional learning communities that provide support, sample tiered assessment tasks, and resources for teachers can help eliminate some of the reluctance towards implementing differentiation and tiered assessment (Tomlinson, 1995).

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Online Science Education Journal *http://dergipark.gov.tr/ofed*

2024; 9(2): 44 - 60.

Evaluation of the Teaching Methods and Techniques Used by Science Teachers in Science Classes [1]

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To cite this article: Sidekli, D., & Aykaç, N. (2024). Evaluation of the teaching methods and techniques used by science teachers in science classes. *Online Science Education Journal, 9*(2), 44-60.

Article Info

Article History

Received:
6 November 2024

Accepted:
24 December 2024

Keywords

Science teacher
Teaching methods and techniques
Use of teaching methods and techniques

Abstract

The purpose of this study is to reveal the teaching methods and techniques used by science teachers in their classes and the reasons for their use of these methods and techniques. Explanatory sequential design, one of the mixed methods research designs, was used in the current study. The study group from which the quantitative data of the study were collected consisted of 50 science teachers working in public schools in Muğla province and 600 7th-grade students attending these schools. The study group from which the qualitative data of the study were collected consisted of 15 science teachers working in public schools in Muğla province. In the selection of the participants, the convenience sampling method was used. The data of the study were collected by using the "Science Lesson Method-Technique Determination Teacher Questionnaire", the "Science Lesson Method-Technique Determination Student Questionnaire" and a "Semi-Structured Teacher Interview Form". In the analysis of the quantitative data, the SPSS program package was used. The frequency, percentage, arithmetic mean and standard deviation values were calculated for the methods and techniques preferred by the teachers. The qualitative data of the study were analyzed using the content analysis method. As a result of the study, it was found that the most preferred method-technique by the science teachers is the question-answer method, and the least preferred method-technique is the aquarium technique. It was concluded that while the science teachers are choosing their teaching methods and techniques, they pay most attention to class size, objectives and class hours. It was also found that the science teachers prefer traditional methods and techniques more and active methods and techniques less. The reasons why the science teachers prefer traditional methods more include crowded classes, insufficient class hours and their lack of knowledge of some methods and techniques.

INTRODUCTION

Science is ubiquitous in our daily lives, permeating everything from the living organisms that surround us to our own bodies and the air we breathe. Science encompasses the knowledge gained through observations, experiments, hypothesis formation, and scientific

[1] This study is derived from the master's thesis titled "Evaluation of Teaching Methods and Techniques Used by Science Teachers in Science Classes"

methods to understand the world around us and even the universe (Akçay, 2019). Engaging in science helps individuals develop their thinking skills, creativity and ability to interpret information. The main goal of science education is to make individuals conscious and responsible people in the future (Topsakal, 2005). Teachers are the key to successful science education as they are the ones who implement the science curriculum.

The most important reason for differences in achievement among students at the same school and grade level is the methods, techniques and approaches used by teachers (OECD, 2009). The teaching methods and techniques used in science classes are tools for fully achieving the course objectives. Therefore, for the learning and teaching process to occur effectively, teachers need to choose their instructional methods and techniques carefully. In addition, it is very important for the teacher to have mastery of the selected method and technique, because teachers choose the appropriate method and technique for the lesson and subject they will teach and plan the learning-teaching process accordingly. In this respect, it is very important to use the methods and techniques in the right place and in the right way. Implementing the methods in a student-centred manner is of great importance for students to learn effectively.

Science classes can equip students with skills such as inquiry, problem-solving and analytical thinking, in addition to teaching them about science. In addition, science education aims to provide opportunities for individuals to improve their quality of life and overcome their problems (Akçay, 2019). For effective science education, it is very important to know the teaching methods and techniques that teachers use in the classroom. In order to achieve the objectives of the science curriculum, student-centred methods and techniques must be used. Notwithstanding curricular reforms, empirical evidence suggests that these changes have frequently failed to translate into practice, with teachers exhibiting limited capacity to achieve the stated objectives of the new curriculum (Avcı, 2006; Bulut, 2010; Güven-Yıldırım, Köklükaya & Ayoğdu, 2016; Saraç, 2015; Şimşek, Hırça & Coşkun, 2012; Taşkaya & Sürmeli, 2014). Furthermore, it has been observed that there is a discrepancy between the teaching methods and techniques preferred by teachers and the objectives of the curriculum. While there is abundant research on teachers' preferences for methods and techniques, there is a scarcity of studies that delve into the reasons behind these preferences.

Science education is also crucial for raising a country's economic prosperity. Effective science education is possible by using methods and techniques that are in compliance with the goals and objectives of the curriculum and that keep students active in lessons. As seen in the literature, there are a number of problems related to the use of methods and techniques and the achievement of curricular goals in our country, including physical deficiencies in schools and teachers' preferences for methods and techniques (Avcı, 2006; Doğru & Aydoğdu, 2003; Kılıç et al., 2004). Teachers who are not well trained in methods and techniques cannot use correct and appropriate methods because they do not make effective and correct choices (Demirel, 1994).

Research in the literature has revealed that factors such as school physical conditions, class size, dense curriculum and the examination system hinder teachers from using active methods (Bulut, 2010). Research has found that science teachers do not use methods that make students active as required. The research conducted by Binler (2007) also revealed that teachers are incompetent in using methods and techniques that require individual skills. In the study conducted by Saraç (2015), it was determined that teachers adhered to traditional methods and could not use active methods well. This shows that there are problems with the training of science teachers. Therefore, science teachers' lack of knowledge about methods and techniques causes problems in science education. For this reason, it is very important to determine which methods and techniques science teachers use and to reveal the reasons why they prefer these methods and techniques.

Purpose of the Study

The purpose of the current study is to determine the teaching methods and techniques used by science teachers in science classes and to reveal the reasons for using these teaching methods and techniques. To this end, answers to the following questions were sought:

- What methods and techniques do science teachers use?
- What are the teaching methods and techniques most frequently used by science teachers?
- What are the reasons why science teachers prefer the methods or techniques they use most frequently?
- What are the issues that science teachers pay attention to when choosing different teaching methods and techniques in science classes (objectives, economic conditions, physical conditions, etc.)?

METHOD

Study Design

The current study employed a mixed research model. The mixed research model involves collecting quantitative or qualitative data in a single study and analyzing and interpreting these data together (Leech & Onwuegbuzie, 2009, p.266). The mixed method design was defined by Tashakkori and Teddlie (1998) as a research design based on pragmatist philosophy. The mixed research model acts as a bridge between qualitative and quantitative research models (Leech & Onwuegbuzie, 2004, p.15).

In the current study, the explanatory sequential design, one of the mixed method research designs, was used. In the explanatory sequential design, data are first collected and analyzed with quantitative methods. Based on the analysis of the quantitative data, qualitative data are collected and analyzed. Then, quantitative and qualitative data are interpreted together and inferences are made (Creswell, 2021). This model is useful for better understanding the phenomenon being studied and developing different perspectives (Baki, Gökçek, 2012, p. 1-21).

Study Group

In the study, the convenience sampling method, one of the non-random sampling methods, was used in the selection of the participants. Convenience sampling involves selecting participants who are readily available to the researcher (Christensen, Johnson & Turner, 2020, p.172). While collecting the quantitative data of the study, the study group was composed of 50 science teachers who teach 7^{th} grade students from among the teachers who teach science courses in public schools in Muğla province and 600 7^{th} grade students who are taught by these teachers. While collecting the qualitative data constituting the second part of the study, the study group consisted of 15 science teachers who had previously participated in the survey study.

Data Collection

The “Use of Teaching Methods and Techniques in Science Classes-Teacher Questionnaire” developed by the researcher consists of 36 items. For the validity and reliability studies of the questionnaire, expert opinions were received from two curriculum development experts, four science teaching experts, one measurement and evaluation expert and one Turkish teaching expert, and then a pilot study was conducted with the participation of 20 science teachers. In light of the expert reviews and pilot application, the necessary corrections were made and the questionnaire was given its final form.

The "Use of Teaching Methods and Techniques in Science Classes-Student Questionnaire" developed by the researcher consists of 36 items. For the validity and reliability studies of the questionnaire, expert opinions were received from two curriculum development experts, four science teaching experts, one measurement and evaluation expert and one Turkish teaching expert, and then a pilot study was conducted with the participation of 20 7^{th} grade students. In light of the expert reviews and pilot application, the necessary corrections were made and the questionnaire was given its final form. The questionnaire items were about methods and techniques accompanied by explanations to ensure understanding by both the teachers and students.

The science teacher semi-structured interview form prepared by the researcher consists of 8 items. These items aim to elicit data about what teachers pay attention to when choosing the methods and techniques they use in their lessons, whether they choose a method appropriate for the objectives of the science curriculum, and their knowledge of methods and techniques. For the validity and reliability studies of the interview form, expert opinions were received from two curriculum development experts, four science teaching experts, one measurement and evaluation expert and one Turkish teaching expert, and then pilot interviews were conducted with the participation of 5 science teachers. In light of the expert reviews and pilot applications, the necessary corrections were made and the interview form was given its final form. The interview form, which initially consisted of 12 questions, took its final form of eight questions after the necessary revisions were made.

Data Analysis

While analyzing the quantitative data of the study, the SPSS program package was used. While determining the methods and techniques most frequently preferred by the science teachers, frequency (f), percentage (%), arithmetic mean (X) and standard deviation values were calculated. The content analysis method was used in the analysis of the qualitative data. While analyzing the qualitative data of the study, the interview records were listened to and transcribed by the researcher. The data obtained from the interviews were read by the researcher and analyzed using content analysis. Codes were created from the analysis of the transcriptions. Similar codes were combined to create themes. With the themes created, it was made easier for readers to understand and interpret (Yıldırım & Şimşek, 2021). The data obtained are presented with direct quotations in the findings section.

FINDINGS

In the findings section, first, the arithmetic mean, frequency, percentage and standard deviation values obtained from the questionnaires completed by the teachers and then the teachers' opinions elicited through the semi-structured interview form are presented.

Findings on the Frequency of Science Teachers' Use of Teaching Methods and Techniques

Findings on the teaching methods and techniques used by the teachers in science classes are given in Table 1.

Table 1. Science teachers' frequency of using instructional methods and techniques

Methods & techniques	Never	Rarely	Sometimes	Usually	Always	$\bar{X}$	Ss
Question-answer	-	-	1.9	31.5	67.5	4.61	.51
Lecturing	3.7	3.7	22.2	44.4	25.9	3.85	.97
Discussion	-	7.4	24.1	40.7	27.8	3.88	.90
Buzzing	22.2	42.6	22.2	7.4	5.6	2.31	1.07
Opposite panel	24.1	42.6	22.2	7.4	3.7	2.24	1.02
Panel	16.7	40.7	22.2	14.8	1.9	2.51	1.11
Conference	40.7	42.6	14.8	1.9	-	1.77	.76
Debate	20.4	46.3	22.2	9.3	1.9	2.25	.95
Aquarium	51.7	29.6	13	3.7	1.9	1.74	.95
Experiment	9.3	7.4	16.7	38.9	27.8	3.68	1.22
Observation	1.9	7.4	27.8	3.33	29.6	3.81	1.37
Trip	11.1	31.5	29.6	20.4	7.4	2.81	1.15
Brain storming	-	9.3	16.7	37	37	4.01	.96
Cooperative learning	1.9	13	25.9	44.4	14.8	3.57	.96
Opinion development	22.2	35.2	27.8	11.1	3.7	2.58	1.07
Six thinking hats	50	29.6	9.3	5.6	5.6	1.87	1.15
Talking circle	31.5	37	18.5	11.1	1.9	2.14	1.07
Case study	3.7	3.7	24.1	35.2	33.3	3.90	1.03
Drama	18.5	29.6	29.6	13	9.3	2.64	1.19
Dramatization	31.5	31.5	25.9	5.6	5.6	2.22	1.12
Scenario-based learning	48.1	29.6	14.8	1.9	5.6	1.87	1.09
Tell-show-do	1.9	9.3	20.4	40.7	27.8	3.83	1.0
Demonstration	-	1.9	11.1	29.6	57.4	4.42	.76
Project	5.6	18.5	27.8	33.3	14.8	3.33	1.11
Problem solving	1.9	16.7	22.2	38.9	20.4	3.59	1.05
Fishbone	27.8	25.9	18.5	14.8	13	2.59	1.38
Role-play	25.9	29.6	25.9	11.1	7.4	2.44	1.20
Creating a story	37	31.5	24.1	5.6	1.9	2.03	1.0
Station	13	25.9	22.2	27.8	11.1	2.98	1.23
Educational game	22.2	33.3	24.1	11.1	9.3	2.51	1.22
Digital story-telling	25.9	24.1	22.2	12	14.8	3.16	1.38
Inquiry-based learning	1.9	-	18.5	29.6	50	4.25	.89
Snowball	38.9	33.3	20.4	3.7	3.7	2.0	1.04
Concept cartoons	42.6	29.6	7.4	14.8	5.6	2.11	1.26
Concept map	1.9	11.1	14.8	38.9	33.3	3.90	1.05

The frequency of use of teaching methods and techniques by the science teachers participating in the study is given in Table 1. As seen in Table 1, 1.9% of the science teachers sometimes use the question-answer method and 49.6% usually or always use it ($\bar{X}$=4.61).

It was seen that 3.7% of the science teachers never use the lecturing method, 12.95% rarely or sometimes use it and 35.15% usually or always use it ($\bar{X}$=3.85). It was also seen that 15.75% of the science teachers rarely or sometimes use the discussion method while 34.25% usually or always use it ($\bar{X}$=3.88).

It was observed that 9.3% of the science teachers never use the experimental method, 12.05% rarely or sometimes use it and 33.35% usually or always use it ($\bar{X}$=3.68). It was also seen that 19% of the science teachers never use the observation method, 17.6% rarely or sometimes use it and 33.35% usually or always use it ($\bar{X}$=3.81). It was seen that 13% of the science teachers rarely or sometimes use the brainstorming technique while 37% usually or always use it ($\bar{X}$=4.01).

It was seen that 1.9% of the science teachers never use the cooperative learning method, 19.45% rarely or sometimes use it and 29.6% usually or always use it ($\bar{X}$=3.57). It was also seen that 3.7% of the science teachers never use the case study method, 13.9% rarely or sometimes use it and 34.25% usually or always use it ($\bar{X}$=3.90). It was seen that 1.9% of the science teachers never use the tell-show-do technique, 14.85% rarely or sometimes use it and 34.25% usually or always use it ($\bar{X}$=3.83).

It was seen that 6.5% of the science teachers rarely or sometimes use the demonstration method while 43.5% usually or always use it ($\bar{X}$=4.42). It was also seen that 5.6% of the science teachers never use the project method, 23.15% rarely or sometimes use it and 24.05% usually or always use it ($\bar{X}$=3.33).

It was seen that 1.9% of the science teachers never use the problem solving method, 19.45% rarely or sometimes use it and 24.05% usually or always use it ($\bar{X}$=3.59). It was seen that 1.9% of the science teachers never use the concept map technique, 12.95% rarely or sometimes use it and 36.1% usually or always use it ($\bar{X}$=3.90). It was seen that 1.9% of the science teachers never use the inquiry-based learning method, 18.5% rarely or sometimes use it and 39.8% usually or always use it ($\bar{X}$=4.25).

It was seen that 22.2% of the science teachers never use the buzzing technique, 32.4% rarely or sometimes use it and 6.5% usually or always use it ($\bar{X}$=2.31). It was seen that 40.7% of the science teachers never use the conference technique, 28.7% rarely or sometimes use it and 1.9% usually or always use it ($\bar{X}$=1.77). It was seen that 51.7% of the science teachers never use the aquarium technique, 21.3% rarely or sometimes use it and 2.8% usually or always use it ($\bar{X}$=1.74).

It was seen that 50% of the science teachers never use the six thinking hats technique, 38.9% rarely or sometimes use it and 5.6% usually or always use it ($\bar{X}$=1.87). It was seen that 18.5% of the science teachers never use the drama method, 29.6% rarely or sometimes use it and 11.15% usually or always use it ($\bar{X}$=2.64). It was seen that 13% of the science teachers never use the station method, 24.05% rarely or sometimes use it and 19.45% usually or always use it ($\bar{X}$=2.98). It was seen that 22.2% of the science teachers never use the educational game method, 28.7% rarely or sometimes use it and 10.2% usually or always use it ($\bar{X}$ =2.51).

It was seen that the teachers use the question and answer ($\bar{X}$=4.61) and lecturing methods ($\bar{X}$=3.85) the most, and the aquarium ($\bar{X}$=1.74) and six thinking hats techniques ($\bar{X}$=1.87) the least.

Findings on the Instructional Methods and Techniques Used by the Science Teachers in Science Classes according to the Students

Findings on the methods and techniques used by the teachers in their classes according to students are given in Table 2.

Table 2. Frequency of use of teaching methods and techniques by science teachers according to 7th grade students

Methods & techniques	Never	Rarely	Sometimes	Usually	Always	$\bar{X}$	Ss
Question- answer	1.2	3.1	18.9	41.0	35.8	4.07	.88
Lecturing	1.2	1.5	3.5	14.9	78.8	4.68	.72
Discussion	11.7	17.2	30.7	23.7	16.7	3.16	1.23
Buzzing	51.2	24.3	16.1	5.5	2.9	1.84	1.06
Opposite panel	63.4	18.4	11.5	4.0	2.6	1.63	1.0
Panel	48.2	23.2	14.9	9.5	4.0	1.97	1.17
Conference	65.7	13.7	10.3	5.2	5.1	1.70	1.15
Dispute	59.4	19.2	12.1	5.7	3.5	1.74	1.09
Aquarium	72.2	13.2	7.8	4.5	2.3	1.51	.97
Experiment	28.3	20.7	26.6	14.0	10.4	2.57	1.31
Observation	15	20.9	27.6	20.6	15.4	2.99	1.28
Trip	55.8	19.0	12.7	7.4	5.1	1.86	1.19
Brain storming	15.2	16.9	23.8	23.8	20.3	3.17	1.34
Cooperative learning	37.2	21.2	17.1	13.1	10.9	2.38	1.38
Opinion development	50.8	16.0	18.1	8.4	9.7	2.10	1.36
Six thinking hats	81.6	5.8	4.5	4.1	4.0	1.43	1.03
Talking circle	64.8	11.7	10.8	6.1	6.6	1.78	1.24
Case study	19.5	18.7	24.6	19.0	18.1	2.97	1.37
Drama	55.3	18.0	12.3	7.2	7.2	1.93	1.26
Dramatization	66.8	12.6	10.0	6.1	4.5	1.68	1.14
Scenario-based learning	66.4	14.4	8.4	5.5	5.2	1.68	1.15
Tell-show-do	17.8	20.3	26.3	22.0	13.7	2.93	1.29
Demonstration	15.2	13.7	23.8	23.5	23.8	3.27	1.36
Project	23.0	20.7	22.7	18.6	14.9	2.81	1.37
Problem solving	18.6	18.3	21.0	21.7	20.4	3.07	1.39
Fishbone	54.1	19.8	12.0	8.6	5.5	1.91	1.22
Role-play	63.0	14.4	8.9	8.6	5.1	1.78	1.21
Creating a story	66.4	11.8	10.1	5.8	5.8	1.72	1.20
Station	41.5	20.6	19.7	10.6	7.7	2.22	1.29
Educational game	49.6	15.4	14.6	10.6	9.8	2.15	1.38
Digital storytelling	65.6	13.7	9.7	6.5	4.6	1.70	1.15
Inquiry-based learning	12.0	17.2	23.2	23.8	23.8	3.30	1.32
Concept cartoon	65.9	14.4	7.5	6.1	6.0	1.71	1.20
Concept map	22.3	15.4	21.0	18.7	22.6	3.03	1.46

The findings obtained from the opinions of the 7th grade students who participated in the study regarding the methods and techniques used by their teachers in science classes are given in Table 2. As seen in Table 2, according to the 7th grade students who participated in the study, 1.2% of the teachers never use the question-answer method, 11% rarely or sometimes use it and 38.4% usually or always use it ($\overline{X}$=4.07). According to the students, 1.2% of the teachers never use the lecturing method, 2.5% rarely or sometimes use it and 46.85% usually or always use it ($\overline{X}$=4.68).

According to the students, 11.7% of the science teachers never use the discussion method, 23.95% rarely or sometimes use it and 20.2% usually or always use it ($\overline{X}$=3.16). According to the students, 15.2% of the science teachers never use the brainstorming technique, 20.35% rarely or sometimes use it and 22.05% usually or always use it ($\overline{X}$=3.17). According to the students, 28.3% of the science teachers never use the experimental method, 23.65% rarely or sometimes use it and 12.2% usually or always use it ($\overline{X}$=2.57).

According to the students, 15.5% of the science teachers never use the observation method, 24.25% rarely or sometimes use it and 18% usually or always use it ($\overline{X}$=2.99). According to the students, 37.8% of the science teachers never use the cooperative learning method, 19.15% rarely or sometimes use it and 12% usually or always use it ($\overline{X}$=2.38). According to the students, 15.2% of the science teachers never use the demonstration method, 18.75% rarely or sometimes use it and 23.65% usually or always use it ($\overline{X}$=3.27). According to the students, 17.8% of the science teachers never use the tell-show-do method, 23.3% rarely or sometimes use it and 17.85% usually or always use it ($\overline{X}$=2.93).

According to the students, 23% of the science teachers never use the project method, 21.7% rarely or sometimes use it and 16.75% usually or always use it ($\overline{X}$=2.81). According to the students, the science teachers never use the problem-solving method, 18.6% rarely or sometimes use it and 19.65% usually or always use it ($\overline{X}$=3.07). According to the students, 12% of the science teachers never use the inquiry-based learning method, 20.2% rarely or sometimes use it and 23.8% usually or always use it ($\overline{X}$=3.30).

The students stated that 22.3% of the science teachers never use the concept map technique, 18.2% rarely or sometimes use it and 20.65% usually or always use it ($\overline{X}$=3.03). According to the students, 51.2% of the science teachers never use the buzzing technique, 20.2% rarely or sometimes use it and 4.2% usually or always use it ($\overline{X}$=1.84). According to the students, 65.7% of the science teachers never use the conference technique, 12% rarely or sometimes use it and 5.15% usually or always use it ($\overline{X}$=1.70).

The students stated that 72.2% of the science teachers never use the aquarium technique, 10.5% rarely or sometimes use it and 3.4% usually or always use it ($\overline{X}$=1.51). According to the students, 81.6% of the science teachers never use the six thinking hats technique, 5.15% rarely or sometimes use it and 4.05% usually or always use it ($\overline{X}$=1.43). According to the students, 49.6% of the science teachers never use the educational game techniques, 15% rarely or sometimes use it and 10.2% usually or always use it ($\overline{X}$=2.15). According to the students, 41.5% of the science teachers never use the station method, 20.15% rarely or sometimes use it and 9.15% usually or always use it ($\overline{X}$=2.22). According to the students, 55.3% of the science teachers never use the drama method, 15.15% rarely or sometimes use it and 7.2% usually or always use it. According to the students, the science teachers use the lecturing ($\overline{X}$=4.68) and question-answer methods ($\overline{X}$=4.07) the most, and the six thinking hats ($\overline{X}$=1.43) and aquarium techniques ($\overline{X}$=1.51) the least.

Findings on the Reasons for the Science Teachers' Preferences for Methods and Techniques

Interviews were conducted with science teachers to determine the reasons behind their preferences for the most frequently used methods and techniques. As a result of the analysis of the interviews, various themes and codes were created. Table 3 shows the themes and codes.

Table 3. Reasons for science teachers' preference for instructional methods and techniques

Themes	Codes
Physical structure of the school	Insufficiency of materials Crowded classes Lack of laboratories
Characteristics of the course	Class hours Objectives Characteristics of the subject
Characteristics of the method	Ease/difficulty of implementation Time-consuming Cost
Student	Readiness Level of students
Teacher	Classroom management Knowledge of methods and techniques Whether taking in-service training

As seen in Table 3, the science teachers expressed their opinions regarding the reasons for their choosing the methods and techniques they use in their classes. As a result of the interviews, 5 themes were created regarding the reasons for the teachers' choice of methods and techniques: "physical structure of the school", "characteristics of the course", "characteristics of the method", "student" and "teacher" and 15 codes gathered under these themes were created. The teachers' opinions on the themes and codes are given below.

For the theme of the physical structure of the school, three codes were created: "insufficient materials", "crowded classes" and "lack of laboratories". Teachers' opinions on these themes and codes are as follows:

> *"I pay particular attention to materials, class size, and learning outcomes. Unfortunately, materials are insufficient, and our classes are very crowded, making it difficult to conduct experiments and similar activities." (ST-4)*

> *"If materials are available, I conduct all activities; however, we face issues arising from time constraints. In classes with a large number of students, I do demonstration experiments." (ST-3)*

When the opinions of the science teachers, it was seen that the majority of them indicated that class size, lack of materials and the physical conditions of the school are influential in their choices of methods and techniques. They stated that crowded classes and insufficient materials negatively impact their choice of methods and techniques. They stated that they conduct fewer experiments because the classes are crowded and the materials are not sufficient for students. The factor that affects teachers the most in terms of method and technique is crowded classes and inadequate materials. They also stated that they could use different methods and techniques if sufficient material and physical conditions were provided.

For the theme of the characteristics of the course, 3 codes were created: “class hours”, “objectives” and “characteristics of the subject”. Some of the teachers’ opinions on these themes and codes are as follows:

> *“I pay attention to objectives, but the distribution of objectives is unbalanced. For example, 6th graders have a lot of topics, so I usually use lecturing to cover everything in time.” (ST-3)*

> *“I pay attention to objectives and content because they are the key points that students need to learn.” (ST-5)*

> *“The method I use should enable me to deliver the objective effectively; I try to choose methods that make the most efficient use of time.” (ST-4).*

When the opinions of the science teachers were examined, it was seen that almost all of the teachers stated that they pay attention to the objectives when making their choices for methods and techniques. Teachers indicated that the primary purpose of education is to ensure students acquire the specified objectives. Therefore, they emphasized the importance of aligning instruction with these objectives.

In addition, teachers stated that they pay attention to the characteristics of the subject when choosing a method. They stated that not every method is suitable for every subject. Consequently, they make a conscious effort to select and apply methods and techniques that are most suitable for the specific content being taught. Another point that teachers highlighted is the limited amount of class time. Teachers indicated that there are too many objectives to cover in the limited class time available, leading them to prioritize methods and techniques that can efficiently deliver these objectives. As can be understood from these opinions, teachers pay attention to the objective, characteristics of the subject and class hours when choosing methods and techniques.

For the theme of the characteristics of the method, 3 codes were created: “ease/difficulty of implementation”, “time-consuming” and “cost”. Some of the teachers’ opinions about the codes and themes created are as follows:

> *“The question-answer and lecturing methods are easier for students and us and are preferred more because they are easier to evaluate.” (ST-1)*

> *“It takes a lot of time and has little applicability, for example, it is difficult to call an expert for the conference method, and the expert does not want to leave his/her work and come. The permissions, correspondence procedure take a long time and are also costly, which is why we cannot prefer these methods.” (ST-3)*

"I prefer these methods, which are easier to implement, due to lack of materials, large class sizes, and insufficient class hours. In addition, class time is wasted with activities such as mock exams, centralized written exams, etc., and it becomes difficult to spare enough time for the objectives." (ST-5)

When the opinions of science teachers were examined, it was seen that teachers pay attention to the characteristics of the method when choosing methods and techniques. Teachers stated that they do not prefer methods that are difficult and costly to implement. The majority of the teachers stated that they prefer easy-to-apply methods that do not require preparation due to lack of time. They also stated that they use methods such as trips and conferences less due to economic reasons and permission procedures. It was observed that reasons such as lack of materials and insufficient time allocated for preparation also affect teachers' method and technique preferences.

For the student theme, two codes were created: "readiness" and "level of the student". Some teachers' opinions on the determined themes and codes are given below:

"Science can be a difficult subject for students, particularly when they lack the foundational knowledge required to understand the concepts. In such cases, I use the lecturing method more frequently." (ST-9)

"Most children cannot express themselves. I've seen this in the open-ended exams I've given. Instead of making sentences, they answered with keywords. These techniques require self-expression and since children have difficulty with this, I prefer easier methods. It is difficult to explain the method and teach the lesson at the same time." (ST-9)

In the interviews conducted with the teachers, it was seen that some of the teachers make their choice by paying attention to the students' level of readiness, age and intelligence when choosing a method or technique. Teachers also stated that science lessons are sometimes difficult for students, so they choose methods that could help them understand the lesson. They stated that it is particularly difficult to explain contemporary methods and techniques to students and to make them understand the subject using these methods and techniques.

For the theme of teacher, 3 codes were created: "classroom management", "knowledge of methods and techniques" and "whether taking in-service training". Some opinions on these themes and codes are as follows:

"I don't know every method and technique, but I am open to learning new methods and techniques." (ST-2)

"I participate in in-service training, but I still cannot say that I am qualified for all methods." (ST-4)

"The large class size makes it difficult to manage the classroom; therefore, I prefer the lecturing method because it allows me to maintain better control of the class." (ST-12)

"There are times when I feel inadequate. I participated in a TÜBİTAK applied education project in 2016, but I haven't had the chance to participate in another one since then." (ST-5)

When the opinions of the teachers are examined, it is evident that their mastery of methods, classroom management skills and whether they have received in-service training significantly influence their preferences for methods and techniques. It was determined that teachers prefer methods and techniques that allow them to maintain classroom control more easily. Although some teachers have received in-service training on methods and techniques, they do not see themselves as competent enough. It was also found that the number of teachers participating in activities such as the ones organized by TÜBİTAK and similar events is low. It was observed that teachers who have participated in projects or have a higher level of education diversify the methods and techniques they use.

CONCLUSION and DISCUSSION

In the study, the methods and techniques used by science teachers were examined. Based on the data collected through the questionnaires administered to the teachers and students, it was found that the most preferred methods by the teachers are the question-answer and lecturing methods, while the least preferred techniques are the aquarium technique, the six thinking hats technique, and the field trip-observation method. When the literature is reviewed, many studies reporting results consistent with the results of the current study can be found. In the study conducted by Bulut (2010), it was concluded that teachers use the question-answer method the most, and the field trip-observation method and the aquarium technique the least. In the study conducted by Saraç (2015), it was seen that teachers use the question-answer method the most. Ergani (2010) conducted a study on social studies teachers and concluded that social studies teachers prefer the question-answer method the most and the trip-observation method the least. The difference in the results obtained from teachers and pre-service teachers indicate that there are other factors affecting teachers' preferences for methods and techniques (Bulut, 2010; Gülnaroğlu,2019; Kaptan & Korkmaz, 2001; Saraç, 2015). In addition, Talaz (2013) concluded that active methods are used more in classes with less than 30 students. The similarity of results obtained in the current study and in the literature suggests that teachers' preferences for methods and techniques may be resistant to change or that updates made to the curriculum have little impact on teachers' choices of methods and techniques.

In the current study, it was found that teachers prefer the question-answer and lecturing methods the most, followed by the demonstration technique, inquiry-based learning method, brainstorming technique, discussion method, problem-solving method, experimental method, project method and cooperative learning method. However, it was observed that they use methods such as experiments and observations and cooperative learning, which would contribute the most to the development of the skills included in the science curriculum, relatively less. Yıldırım (2011) concluded that methods and techniques that tend to make students passive are used more frequently in science classes. To explore the reasons behind the findings collected with the questionnaires administered to the teachers and students, interviews were held with teachers. In the interviews conducted, teachers stated that they prefer the lecturing and question-answer methods for several reasons, including their being time efficient, the ease of application in classes with a large number of students, the need to allocate time for solving tests due to an exam-centred system, and class hours being insufficient to cover everything. Avcı (2006) concluded that teachers prefer the question-answer and lecturing methods because they activate students and facilitate the rapid transfer of a large amount of information.

The method most preferred by teachers after the question-answer method is the lecturing method. Many studies in the literature indicate that the lecturing method is highly preferred (Avcı, 2006; Bulut, 2010; Saraç, 2015). They also stated that they prefer the lecturing method for teaching topics that are difficult for students, as well as for teaching topics that involve principles and conceptual knowledge. The fact that teachers prefer the lecturing method when teaching concepts, factual knowledge, or theoretical topics indicates that traditional methods still have their place. As can be understood from here, the subject and objectives also affect the method and technique preferences of teachers. In the traditional lecturing method, the student is in a passive position. Teachers need to activate students by supporting the lecturing method with body language and various materials (Yulu, 2014).

Teachers participating in the study also stated that their preference for the lecturing method may vary depending on the grade level they teach. They stated that they prefer the lecturing method more in classes with relatively less successful students. One striking result from the study is that, while the lecturing method was the second most frequently used method according to the teacher questionnaire, it ranked first in the questionnaire conducted with the students. This indicates that the responses given by the students and teachers to the questionnaires differ. The reason for this may be that teachers are reluctant to admit that they frequently prefer the traditional lecturing method. Similar to this finding of the current study, in a study by Karamustafaoğlu et al. (2014), teachers reported using the lecturing method at a moderate frequency, whereas interviews with students and observations indicated that the lecturing method was used more frequently. This may be because teachers tend to avoid acknowledging their use of traditional methods.

The questionnaire results showed that teachers occasionally prefer contemporary instructional techniques such as brainstorming, case studies, educational games and demonstration. It is believed that teachers choose these methods and techniques to engage students, make the lesson more interesting, encourage students to generate new ideas, promote group work, and foster long-term learning. However, from the data obtained from the interviews, it was concluded that these methods are difficult to implement due to the large class sizes and inadequate lesson hours. Şahin and Güven (2016) concluded that teachers' method and technique preferences are limited due to reasons such as physical conditions and class size.

It was concluded that the experimental method was not used sufficiently by teachers. In the interviews conducted with teachers, it was concluded that the most important reasons for the experimental method being less preferred are insufficient materials, lack of physical conditions, lack of laboratories in schools and crowded classrooms. Karamustafaoğlu et al. (2014) found that although teachers conducted their lessons in the laboratory, they conducted few experiments and only included demonstration experiments. They explained that the reason for this is the lack of materials and inadequate physical conditions. In the study conducted by Bulut (2010), the rate of those who use the laboratory sometimes was found to be the highest. The similarity of results in the current study and in the literature suggests that the lack of materials, inadequate physical conditions and crowded classrooms in schools have not been addressed adequately.

Another reason why the experimental method is not adequately used in science classes appears to be the activities included in textbooks. Teachers noted that there are more activities than experiments in textbooks and that the number of experiments has been reduced in textbooks. For this reason, the experimental method is not used as frequently as it used to be. Bayır and

Kahveci (2022) examined science textbooks in terms of scientific process skills. They concluded that the terms “activity” and “science, engineering and entrepreneurship applications” were used instead of experiment in the textbooks examined at all the middle school levels. In the literature, it is stated that the use of the experimental method causes students to develop a positive attitude towards science classes, to eliminate misconceptions, and to increase their academic success (Taşkoyan, 2008; Telli et al., 2004; Uluçınar et al., 2008).

Some of the teaching methods that have an important place in science teaching are the problem-solving, project and cooperative learning methods. According to the results of the current study, teachers use these methods less in their classes than traditional methods. The reasons for this situation are shown as insufficient lesson hours, crowded classes, and the difficulty for students to understand the methods and techniques to be applied. From the opinions expressed by teachers, it was concluded that the use of the project method has increased with the changes made in the 2018 science curriculum, but it is still not preferred much. Similar results have been reported by Kayabaşı (2012), Karamustafaoğlu et al. (2014), Sözbilir et al. (2006) and Çepni (2010).

In the study, the least preferred methods and techniques by teachers were found to be the aquarium technique, the six thinking hats technique, the conference and the station technique, respectively. Teachers stated that the reason why they prefer techniques such as conference, six thinking hats, station, and aquarium less is that not every subject in science is suitable for using these techniques and it is difficult to explain these techniques to students. As can be understood from this finding, not every method and technique is suitable for every subject. Thus, it can be concluded that the characteristics of the subject are taken into consideration when choosing methods and techniques. It is also one of the results that methods such as aquarium, six thinking hats and conference are not preferred because of the cost and length of the procedure required for their implementation. As can be understood from the results, although it is emphasized in the curriculum that students should be at the centre and be active, it is thought that the necessary efforts have not been made to increase the use of the methods and techniques that can make students more active. In addition, some of the teachers stated that they did not have much knowledge about techniques such as the six thinking hats technique and the aquarium, and therefore could not use these techniques. Thus, it can be concluded that the knowledge and skills possessed by teachers in relation to methods and techniques can be influential in the selection of methods and techniques.

When the results of the study are examined, it is seen that among the factors affecting teachers’ method and technique preferences are factors related to teachers and students. Many teachers expressed that they do not have the required competence for the effective use of some methods and techniques and indicated that they do not know how to implement some of them. A similar result was also reported by Tunga et al. (2021). According to the results obtained from the interviews conducted with the teachers, most of the teachers stated that they need to receive training on teaching methods and techniques and that the courses given at the undergraduate level are not sufficient. It can be concluded that teachers are willing to participate in in-service training on methods and techniques, but they cannot find enough opportunities to do so.

According to the results obtained in the current study, teachers generally use traditional methods more, but the reason for this is not their own preference but the physical conditions of the school, crowded classes, inadequate class hours and the fact that they have to teach in an exam-oriented system. In addition, it was concluded that in-service training on methods and techniques is insufficient. It was determined that teachers sometimes prefer contemporary and student-centred methods. However, they also stated that they cannot apply some methods due to insufficient materials or crowded classes.

It is concerning that research findings clearly reveal issues such as large class sizes and insufficient class hours. Another notable finding in the study is that teachers do not feel confident in their knowledge of methods and techniques. It was also concluded that the in-service training provided is insufficient. The limited availability of in-service training on learning-teaching methods and techniques, which are one of the most important elements of the curriculum, is thought to hinder the effective implementation of the curriculum.

SUGGESTIONS

In light of the results of the study, the following suggestions can be made.

- The science curriculum should be updated, and the number of science class hours should be increased.
- Materials used in science classes should be maintained continuously. Materials that are depleted or damaged should be replaced.
- Class sizes should be reduced to allow active methods and techniques to be implemented.
- In-service training should be provided for science teachers on teaching methods and techniques so that they can use these methods and techniques more effectively.
- The content of the teaching methods and techniques courses given in university teacher training programs should be enriched and a more practice-based learning process should be structured.

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