

Constructivist Approaches in STEM Education

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Chapter Highlights

This chapter summary provides the reader with a quick and general overview by summarizing key points about constructivist approaches to STEM education.

- Fundamental components of STEM education - integration of science, technology, engineering, and mathematics; problem-based learning, project-based learning and collaborative learning.
- The role of constructivist approaches in STEM education – Evaluation of cognitive, social and radical constructivist perspectives on learning knowledge.
- 21st century skills and STEM education - The contribution and impact of transversal competencies on STEM education
- Advantages and limitations of the constructivist approaches – Positive and negative aspects of constructivist approaches from the teachers' and students' point of view
- Future Directions and Recommendations – Integrating technology into the educational environment, providing teacher training on STEM education and the application of constructivist methods, and providing the necessary infrastructure.

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Introduction

In the 21st century, which is in a constant state of technological development and change, it is crucial to utilize methods in education that include skills like creative thinking, critical thinking, problem solving, and constructing information by processing it in collaboration with peers, instead of traditional teaching methods in which students passively receive information. As is well known, in traditional teaching methods, individuals learn information as it is conveyed to them and are passive in this process (Jonassen, 1991; Amirova, 2025). STEM (Science, Technology, Engineering, and Mathematics) education and constructivist approaches also include skills that will help the individual keep up with this changing situation and not fall behind the times. When considered in this context, these approaches, which see learning as a process and advocate active learning, are based on 21st century skills (Amirova, 2025).

“21st century skills” has a broad meaning in terms of content. Vista (2020) also expresses this term as a very broad set of skills. Ananiadou & Claro (2009) describe 21st century skills as the use of higher-order cognitive skills like analysis and reasoning to understand and solve events that one enjoys. Individuals with 21st century skills will develop different perspectives on events, situations and problems, enabling them to better align to the rapidly changing technological world and the conditions in which the individual finds herself/himself. In addition, an individual with 21st century skills can take on a guiding role in society by looking at events from a critical and innovative perspective and producing solutions appropriate to the needs and requirements of the society in which she/he lives. Based on this, it can be stated that 21st century skills are in a close relationship with STEM education.

STEM education is an approach that brings together the disciplines of Science, Technology, Engineering and Mathematics, and interest in STEM education is increasing day by day. One of the main reasons for this situation is that students are prepared for the changing world in every field (Tytler, 2020). Because STEM education enables individuals to find various, distinctive solutions to the problems that they encounter (Altunel, 2018). By doing so, STEM education promotes positively to the advancement of creativity by empowering the individual to think analytically. Additionally, in STEM education, the individual looks at problems that are intertwined with daily life with a critical eye and approaches them with a problem-solving perspective, allowing them to look at events from different perspectives. With STEM education, individuals have the prospect to put their knowledge

and skills into practice (Salinger & Zuga, 2009). Therefore, these features in STEM education need to be addressed and supported with a modern/constructivist approach. Considering all these skills, it can be said that STEM education and constructivist approaches have fundamentally similar features. Because in both STEM education and constructivist approaches, the individual is active in the process of processing information, making sense of it, constructing information, and focusing on problem solving.

In this chapter, constructivist approaches in STEM education, their basic principles, philosophical and psychological foundations, constructivist teaching models used in STEM education, and student - teacher characteristics are discussed in detail. Additionally, the advantages, limitations and challenges of implementing STEM education and constructivist approaches in educational settings were discussed. Finally, in line with the main intention of the study, the measurement and evaluation process of constructivist approaches in STEM education was examined.

What is constructivism?

Since the end of the 20th century, the philosophy of constructivism has increased its importance. It is possible to talk about various reasons for the increasing popularity of constructivism. For instance, in parallel with the development of technology, individuals are expected to have various skills such as being more creative and having better problem-solving skills in business life. Similarly, Arslan (2007) states that one of the most important philosophies affecting educational practices is constructivism. He cited the primary reason for this as a desire to find solutions to the qualitative problems in countries' education systems. Because developed societies no longer require individuals to have only in-depth knowledge. On the contrary, they require individuals to possess high-order skills such as constructing and interpreting information, analytical thinking, and problem-solving. The constructivist approach also bolsters the advancement of 21st-century competencies, like problem-solving, critical thinking, and creativity, which are at the core of STEM education (English, 2016).

In the age of information and technology we live in, it is not expected for individuals to be passive recipients. Both the social structure in which the individual lives, technological developments and the changing business life have made it necessary for the individual to learn actively, to have problem-solving skills and an innovative perspective, and to construct new knowledge by making sense of the information in the learning process. All these necessities have made it necessary to abandon the understanding of

education to approaches in which knowledge is constructed rather than traditional models and methods.

Constructivism can be expressed as the individual learning new information by associating it with his/her existing knowledge and thus new learning occurs in the individual (Gömleksiz & Elaldı, 2011; Sherman & Kurshan, 2005; Noureen, Arshad & Bashir, 2020; Daley, 2001). In this process, Bhardwaj et al. (2025); Duffy and Cunningham (1996) define learning as a process in which a person actively creates meaning from their experiences and builds on the knowledge she/he has. In short, the constructivist approach is meaningful learning by constructing students' own learning (Gao et al., 2013; Kouicem & Nachoua, 2016). In the epistemological context, the constructivist approach argues that the individual does not receive knowledge directly, but goes through a mental process and constructs it depending on the individual's experiences (Prawat, 1992). In this context, learning is a phenomenon that subjectively expresses continuity for the individual. In this process, knowledge is not certain but subjective. In other words, knowledge does not represent absolute truth; it is the individual's way of making sense of and interpreting the world.

Even though constructivism became popular in education from the late 19th century onwards, its history dates back to Socrates in the 5th century (Brooks & Brooks, 1999; Busbea, 2006). Other prominent pioneers of constructivism are Giambattista Vico (1668-1744), Jean-Jacques Rousseau (1712-1778), Immanuel Kant (1724-1804), Jean Piaget (1896-1980), John Dewey (1859-1952), Bruner (1915-2016), Vygotsky (1896-1934) and Ernst von Glasersfeld (1917-2010). Hanley (2005) stated that Giambattista Vico was a philosopher who attributed similar meanings to modern constructivism and brought a new standpoint to epistemology with his work "De antiquissima Italorum sapientia"; he stated that individuals can only comprehend what they construct and that "an individual knows to the extent that he can explain it" (as cited in Arslan, 2007).

Kant (1960) expresses two views regarding knowledge. These are: knowledge developed through logical analysis of actions and objects; knowledge resulting from the individual's experiences. According to the first view, knowledge is formed after learning experience; according to the second view, knowledge is formed together with experiences. According to both views, it is necessary to have a knowledge base in order to construct new knowledge. The existing knowledge possessed by the individual influences his/her interpretation of the knowledge to be acquired later, making sense

of it and constructing it (as cited in Busbea, 2006). With these views, Kant stated that individuals are not passive recipients in the process of acquiring knowledge, but rather interpret knowledge as a consequence of their experiences, thus sharing the same thought with Giambattista Vico and expressing today's constructivist approach. Because, in both the theory of Giambattista Vico and Kant, as well as in today's constructivist approach, in order to acquire new knowledge, there must be a pre-existing, existing knowledge base.

One of the most important pioneers of the constructivist approach in the 20th century was Jean Piaget. He served a leading role in the enhancement of constructivist philosophy and in transcending the traditional paradigm of how individuals acquire knowledge. From an epistemological perspective, many thinkers have answered questions such as “*What is knowledge?*” and “*Is knowledge certain?*” from a universal perspective regarding the acquisition of knowledge, and within this framework, they have thought independently of the “*human subject*”. Instead of these conventional questions, Piaget asked the more pragmatic question, “How does an individual manage to learn something called knowledge?” (von Glasersfeld, 1998). Piaget was more interested in how knowledge is created and formed. In other words, Piaget's understanding of constructivism is related to cognitive theory (Arslan, 2007; Busbea, 2006). “*Cognitive constructivism*” advocates the thesis that individuals construct knowledge through their own experiences. According to cognitive constructivism, individuals process information but cannot use the incoming information directly. Piaget (1950) states that knowledge is not obtained ready-made from the outside world, but that the individual creates knowledge by associating it with existing knowledge and filtering it through his or her own mental filter; and that as the individual grows older or develops mentally, his or her mental structure also develops.

Another sort of constructivism is “social constructivism,” of which Vygotsky is considered the founder. Vygotsky places more emphasis on the social dimension of learning. In this respect, it differs from Piaget, who did not associate learning with social interaction (Raza et al., 2023). Vygotsky (1978) pay attention to the close interrelation between learning and development; states that social interaction helps children progress by keeping their development always alive. In social constructivism, the individual can learn phenomena that she/he cannot learn alone through her/his social and cultural environment (Kouicem & Nachoua, 2016). In other words, it can be stated that learning is a social process rather than an individual process. Vygotsky (1978) argues that individuals learn through

social interaction and thus changes occur in individual behavior over time. He also suggests that it is possible to refine students' problem-solving skills through social interaction. In this context, social constructivism offers individuals the opportunity to evaluate the information they obtain from different perspectives. The "*Zone of Proximal Development (ZPD)*" has an important place in social constructivism. Vygotsky (1978) delineates the zone of proximal development as the development of underdeveloped or deficient skills by individuals who are better at these skills under the guidance or in cooperation with competent individuals. However, students should be guided by adults in this process (Busbea, 2006). Namely, cooperation or guidance is important in this process. To sum up, social constructivism argues that individuals develop the skills they lack by observing competent individuals through social interaction (Zhou, 2020).

Another significant constructivist philosopher is Bruner. According to Bruner's constructivist view, students are actively involved in the instructional process and develop their own solutions to the problems they encounter (Barth, 2015). Like Piaget, Bruner also states that knowledge is configured through active involvement by the individual. During the process, instead of directly receiving the information given by the teacher, the student first groups the information and then organizes and reconstructs it (Zhou, 2020). According to Bruner (1960), children learn information in three ways: action-based, visual-based, and language-based. In action-based learning, the child learns by experiencing, doing and living; in visual-based learning, the child learns with pictures and visuals; in language-based learning, the child learns with words, concepts and symbols. Bruner's constructivist theory expresses how students learn and how knowledge is represented by students (Liu & Matthews, 2005). When we examine Bruner's constructivist theory, the student is basically active. The student produces new concepts and ideas using the representation of the information presented to her/him, and this process is affected by culture (Zhou, 2020). In this respect, we can say that Bruner's theory of constructivism has both a cognitive aspect and a social aspect.

"*Radical constructivism*" developed by Von Glasersfeld can be expressed as the fact that knowledge does not reflect objective reality from an ontological perspective, but rather the arrangement and organization of the world in which the individual creates knowledge through experiences (Von Glasersfeld, 1984). Here, the individual constructs the world without realizing it. Von Glasersfeld characterizes radical constructivism as a break from traditional epistemology. In this context, in radical constructivism, knowledge is not

certain; knowledge is constructed by the individual through experiences during the developmental process.

To summarize cognitive constructivism, social constructivism, constructivist learning and radical constructivism:

Table 1. Comparison of cognitive, social, constructivist learning and radical constructivism

Cognitive Constructivism (J. Piaget)	Social Constructivism (L. Vygotsky)	Constructivist Learning (J. Bruner)	Radical constructivism (E. Von Glasersfeld)
- The individual constructs knowledge through his/her own experiences. - There is a cognitive process. - Knowledge is not certain, it is subjective. - Assimilation and adaptation are important. - The teacher guides the student in the process of constructing knowledge.	- Knowledge is built through social and cultural interaction. - The zone of proximal development (ZPD) is important. - In cases where the individual is deficient, he/she can correct the deficiencies by observing competent individuals. - The teacher acts as a guide.	- The learner take an active part in the instructional process. - There are three basic features in learning information: Action (Enactive) based, visual (Iconic) based, language (Symbolic) based - A teacher is someone who facilitates student learning. - Social environment is also efficacious in learning.	- The formation of knowledge depends on the individual's personal experience. - The individual processes and interprets the raw information coming through her/his senses in the mental process. - There is a constant change and development of information.

Constructivist Teaching Models Used in STEM Education

In the 21st century world, which is rapidly developing and changing in every field, it is a necessity for individuals to constantly follow the changes and developments. However, due to these rapid developments, it is not possible for individuals to know and keep in mind everything. Under these circumstances, it is significant for the individual to “*learn how to learn*” rather than knowing everything. “*Learning to learn*” is only possible with the active engagement of students in the instructional process. There are various teaching models that enable individuals to learn actively. Some of these are: Problem-Based Learning, Project-Based Learning, and Collaborative Learning.

Problem-Based Learning

Problem-based learning (PBL) is one of the active learning methods in

which students solve realistic and complex life problems in collaborative groups under the guidance of the teacher (Allen et al., 2011). In PBL, instead of simply learning information, students are encouraged to work in small groups to develop their skills and attitudes positively (Woods, 2008). Therefore, PBL is theoretically based on a constructivist approach.

PBL was developed in the medical field in the late 1960s (Wood, 2008). It was first used by Howard Barrows at McMaster University in Canada (Barrows & Tamblyn, 1980) and later at the University of New Mexico. Afterwards, It has been utilized in a variety of fields like engineering and architecture (Keenahan & McCrum, 2020).

It is possible to mention six basic features of the problem-based learning approach. These are:

- Problem-based learning is learner-focused.
- Small groups are formed by teachers during the students' learning process.
- Teachers are guides and have a facilitating role in the instructional process.
- Problems in the instructional process encourage students to learn.
- Through problems, students gain problem-solving skills.
- In instructional process, students take responsibilities for learning and learn new things (Mayer & Greeno, 1972, as cited in Jaganathan; Bhuminathan, & Ramesh, 2024).

When the given basic features are examined, in PBL, the individual actively constructs knowledge during the problem-solving process. In addition, they have the opportunity to learn cooperatively in small groups. This situation plays a positive role in both the learning and socialization of the individual. The fact that teachers act as guides in the learning-teaching process allows students to assume responsibilities for their own learning and decide what, when and how they will learn. In this way, individuals will gain self-confidence in real life and will be more successful by finding different solutions to the problems they encounter.

Kaptan and Korkmaz (2001) list the process steps in problem-based learning as follows:

- Recognizing and defining the problem
- A complete statement of the problem
- Determining information about the problem
- Determining the necessary resources
- Identifying the alternative solutions

- Analyzing the identified solutions
- Presenting the solution

In problem-based learning, the problems presented to students must have certain characteristics. Duck et al. (2001) list these features as follows:

- Problems should be interesting to students.
- Problems should encourage students to learn.
- The problem should be devised in a way that learners can solve it cooperatively in groups.
- Problems must be interconnected.
- Problems must be intertwined with real life.

In problem-based learning, the teacher is in a position to learn with the students and guide them, rather than presenting ready-made information. In this process, he/she is in a position to facilitate the process for the students and motivate them when it's necessary. In this process, the teacher assigned a task or scenario to the students. In this process, students try to solve the problem presented to them in small groups. At the outset of the task, students do not have any idea about the issue. Afterwards, students conduct in-depth research on the problem presented to them and produce solutions to the problem (Kaptan & Korkmaz, 2001). In this process, the student acquires high-ordered cognitive skills by actively participating.

Project-Based Learning

Project-based learning (PjBL) approach is a method that provides permanent learning for the individual. As the name suggests, this method prioritizes the individual's thinking, imagining, analyzing, and developing projects or designs. PjBL is an approach that places the learner at the central position in the instructional process, includes real-life problems, and provides the student with high-ordered cognitive skills. In this respect, it appears as a method that prepares the individual for social life. In this approach, student's involvement in the instructional process is of utmost importance.

In project-based learning, projects can be expressed as intricate assignments based on questions and problems that challenge learners (Mergendoller & Thomas, 1999). In this respect, PjBL has an important place in helping students acquire higher-ordered cognitive skills such as analysis and synthesis. In this process, students can work individually or in groups.

PjBL is closely associated with the philosophy of pragmatism and progressivism in education. Because in both PjBL and pragmatism and

progressivism, the student is involved with real-life problems. Progressivism argues that education is life itself (Vatansever Bayraktar, 2015).

In order for a project to be defined as “Project Based Learning”, it must have certain characteristics. Thomas (2000) expresses these features as follows:

- PjBL projects are at the centre of the curriculum, not at the periphery. What is meant here is that PjBL projects ought to occupy a central position in the instructional process and that projects cannot be complementary activities to the learning process.
- PjBL projects focus on questions and problems that challenge students to contemplate the core basics and concepts of a discipline. To put it differently, learners acquire basic concepts and principles not only by reading but also by experiencing them through projects.
- Projects engage students in a constructive inquiry process. Research, on the other hand, is purposeful and enables students to learn actively through activities such as questioning, creating knowledge and finding solutions.
- Projects are significantly student-centered. PjBL projects offer students greater autonomy. Students freely plan their projects, deciding what to do, how to do it, and when. In short, the student is fully responsible for the entire process.
- PjBL projects should be relevant to real life, not school settings. Projects should facilitate learners with genuine life exposure.

Advantages and Disadvantages of Project-Based Learning

The PjBL approach helps students acquire various higher- ordered cognitive competencies like problem solving and data analysis (Dori & Tal, 2000). Öztürk and Ada (2006) express the advantages of PjBL as follows:

- It enables students to improve their learning skills.
- It provides lifelong learning.
- Working in groups supports cooperative learning.
- It allows students to use different dimensions of intelligence.
- It provides feedback on student performance.
- It helps students develop problem-solving skills.
- It contributes students with the avenues to apply the knowledge and competencies they have learned with PjBL in different subjects.
- It provides students with various competencies like the ability to use technology, cognitive process skills, various life skills, and self-control skills.

In addition to these advantages, they also stated their disadvantages as follows:

- The teacher's responsibility and workload increases.
- The time allocated for learning may increase.
- If the boundaries of the research are not well defined, there will be deviation and dispersion in the subject.

Collaborative Learning

Cooperative learning can be defined as a group of learners work as a team to accomplish a certain target. In cooperative learning, students in small heterogeneous groups help each other learn, and in this way, positive engagement develops among students and positive development occurs in students' communication and social skills (Watson, 1992). At the same time, as a result of students working in groups, the focus of cooperative learning is on students' ability to make observations, to display appropriate attitudes and behaviors within the group, to establish social interactions with group members, and to develop friendships (Cartwright, 1993). Johnson, Johnson and Taylor (1993); Panitz (1999) also stated that the cooperative learning approach improves students' self-esteem, allows students to take an active role in the teaching-learning process, and is an alternative evaluation method for evaluating students.

Cooperative learning was first written by Deutsch in 1949. Pioneers of cooperative learning include Stuart Cook, Millard C. Madsen and Spencer Kagan, Robert Slavin, Jerome Bruner and J. Richard Suchman, and Frederic Skinner. In addition to these researchers, David W. Johnson and Roger T. Johnson established the "*Center for Collaborative Learning*" at the University of Minnesota (Kılbaş et al., 2022). Their main purpose in establishing the center is to conduct research on collaborative learning.

The cooperative learning approach offers various academic, social, and psychological benefits to the individual. Şimşek et al. (2006) list these benefits as follows:

- It improves the student's thinking skills.
- It encourages critical thinking and allows students to express their ideas freely during the discussion process.
- It contributes learners with the avenues to reveal their talents both inside and outside the classroom.
- It assists students in enhancing their oral communication competencies.
- Collaborative discussions improve students' recall of text content.

- It contributes learners with an exploratory and active learning environment where they can take responsibility for their learning.
- It ensures that students do not see teachers as the sole source of information.
- It helps students think creatively and do research rather than making them compete.

Social benefits of cooperative learning:

- Cooperative learning helps students develop their social interaction methods.
- It gives students a positive understanding of finding answers to problems.
- It helps students acquire a sense of responsibility towards each other and creates different meanings between students and teachers.
- It assists students acquire a sense of empathy.
- It enables learners to come together and form teams to solve problems.
- It helps students develop their leadership skills.
- It helps students establish social relationships with each other.

Psychological benefits of cooperative learning:

- It helps student develop self-esteem and become a qualified individual.
- It encourages students to seek help when needed.

Traditional-Constructivist Classrooms and Teacher-Student Roles

In the 21st century, as traditional methods gave way to constructivist understanding in the education process, a radical change occurred in the roles of students and teachers in the constructivist classroom environment. As is known, in conventional classrooms, the teacher presents information to the learners in depth and students memorize this information by taking notes. With constructivism, the classroom environment has become a place where important ideas are investigated and examined in depth (Prawat, 1992). In other words, constructivist classrooms are an environment where information is constructed rather than memorized. We can compare the constructivist classroom with the traditional classroom in the following way.

Table 2. Comparison of a traditional classroom and a constructivist/modern classroom (Chaika, 2024)

Traditional Classroom	Constructivist/Modern Classroom
• Focuses on memorizing information. • The teacher is positioned at the core of instructional process. • Textbooks, course materials are the main resources. • There is a structure with hierarchy and discipline. • Courses are held according to a fixed curriculum. • The value given to higher-order thinking skills is quite limited. • There is monotony in learning. • The integration of technology in the classroom is very limited. • Standardized exams and tests are used to evaluate students.	• The student is at the center of education. • There is interaction among students in the classroom. • The teacher provides an environment that develops students' creativity and independent thinking during the teaching process. • Encourages students to learn individually. • There is a flexible program. • The teacher integrates technology into the lesson. • Focuses on practical skills. • Process is important in student assessment; projects, presentations and group work are frequently used.

In the constructivist approach, the choice of classroom, in other words, the educational setting is of utmost importance. Because the process of students assimilating, interpreting and constructing information is shaped in this environment. If a suitable learning environment is not provided or created for students, this situation may have negative repercussions on students. In constructivism, where each individual is special, students' interests and needs vary, so students' levels should be prioritized in classroom organization. Cunningham, Duffy, and Knuth (1993) stated that constructivist learning environments should serve the following seven purposes:

- It should provide students with experience and life in the process of constructing knowledge. Students must decide for themselves how they will study the topics they are studying and which methods and strategies they will use in the problem-solving process. The main role of the teacher in this process is to help students in this process.
- Different perspectives and ideas should be taken into consideration. Generally, there is more than one solution to the problems we encounter. Therefore, an environment that provides opportunities for students to evaluate different solution methods should be

designed in a constructivist learning environment.

- Learning should be carried out in real-life contexts and in contexts appropriate to real life. Here, it is stated that the problem-solving activities that students engage in during the learning process at school should be adapted to real-life problems. In other words, it means reflecting a skill that a student learns in the classroom into his or her daily life.
- Students ought to be promoted to take responsibility in the instructional process and to express their own ideas openly. This statement emphasizes that constructivist learning is student-centered and that teachers should counsel and guide students throughout the process.
- The learning process should be supported by social experiences. An individual's rich social life is exceedingly important for his or her mental development. For this reason, students should be in constant interaction with both their teachers and their friends, and the instructional space should be set up in this way.
- Learners ought to be encouraged to access information in different ways and formats. Therefore, using a variety of tools and materials is crucial in the instructional process. Learners ought to be encouraged to learn the subject from different perspectives rather than just written or verbal expression. The learning process should be supported by various materials and tools such as images and videos.
- Students should be encouraged to gain self-awareness in the process of constructing knowledge. In a constructivist environment, it is essential not only for the learner to learn the information but also why and how she/he learns it. Here, it is more important how the student reaches the result, in what way, and by using which strategies, rather than reaching the result of a problem. Therefore, the learning environment should encourage students to gain self-awareness (as cited in Honebein, 1996).

Bada and Olusegun (2015) express the aims of constructivist classes as options for critical and creative thinking, appreciation of practicing diverse teaching approaches, collaborative learning, active role of students, realistic-based activities, exploration of possible solutions and construct knowledge. Raza et al., (2023) also created a symbolic shape for these items.

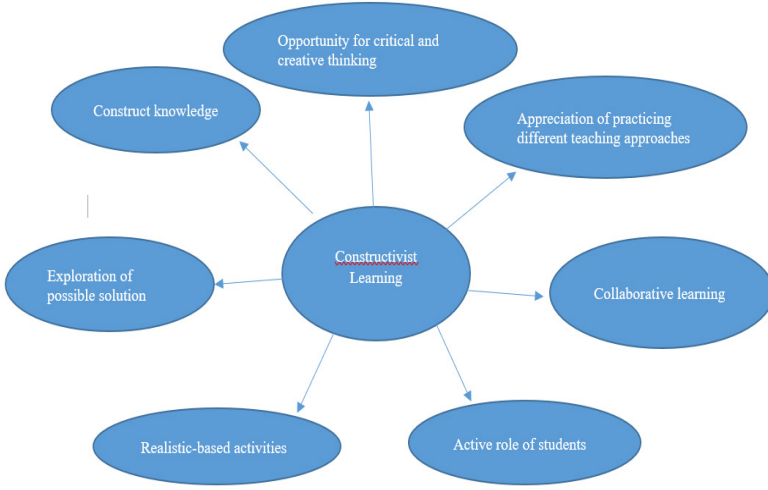


Figure 1. The aims of the constructivist classroom

In traditional methods, there is a teacher-focused situation where the educator is at the center of knowledge (Alam, 2023; Alessa & Hussein, 2023; Chaika, 2024). With constructivism, this situation has turned into a situation where the teacher is more in a guiding (Mishra, 2023) position, associating students' new learning with previous learning (Gömlüksiz & Elaldı, 2011; Arslan, 2007; Naylor & Keogh, 1999). In other words, the learning process has become an environment shared by both educators and learner. In this process, the teacher creates a learning environment by taking into account the individual differences and interests of the students. In this learning environment, various teaching strategies such as cooperative learning and drama are applied to help students develop different perspectives on events and situations (Wilson, 1997). Additionally, the educator promotes students' active engagement in the instructional process, ask questions, and learn in depth (Zajda, 2018).

Brooks and Brooks (1999) list the basic characteristics that teachers who adopt the constructivist approach should have as follows: Teachers ...

- care about their students' opinions.
- prepare classroom activities that will challenge students' assumptions.
- create meaningful problems that develop students' interests and curiosity.
- create a classroom environment where students can develop and

ascribe personal meaning.

- organize lessons around “core/primary concepts” and “big ideas.”
- view student assessment as part of the process. In other words, assessment is not separate from the activities implemented in the classroom, but rather is a part of them.
- assist learners assume responsibilities for their own learning.
- provide students with real-life tasks.
- do not transfer knowledge to students, but help students construct knowledge.
- encourage learners to be responsible for their own learning and helps them construct knowledge subjectively.
- help students make interdisciplinary connections.

In an environment where the constructivist approach is adopted, it is certainly unthinkable for the student to remain passive and be content with only what is presented to her/him. In contrast, in constructivist education, there is sharing of responsibility in a collaborative environment. Constructivism offers individuals the opportunity to construct their own learning (Alam, 2023; Mondal & Khare, 2023; Noreen, Arshad, & Bashir, 2020; Juvova et al., 2015). In addition, in constructivism, which enables students to approach situations with a critical perspective, it is extremely important to create an environment in which students will take an active role in the learning process and to motivate them for active learning (Mir & Jain, 2015). In constructivist teaching, student characteristics can be listed as follows:

- Students are active in the instructional process.
- Learning is his/her responsibility.
- The student is primarily responsible for constructing knowledge during the learning process.
- Students construct learning subjectively by asking questions to the teacher.
- Students have a researcher, inquisitive and curious personality.
- Students make self-assessment.

Measurement and Evaluation in the Constructivist Approach

In the constructivist approach, student assessment does not consist of paper-and-pencil or test exams as in traditional methods. Because in these types of assessments, students must memorize and recall information. In other words, traditional methods direct students to memorize. In this assessment, it is not possible to measure any higher-ordered cognitive skills

of the student. In addition, students may not be able to fully demonstrate their knowledge in the exam due to various reasons (illness, being late for the exam). However, the evaluation that is consistent with the basic philosophy of the constructivist approach is that it is performance-based or process-based. In other words, assessment isn't a quick process; rather, it's an observation of a student's progress over a period of time or the creation of a product. For instance, a student might be asked to prepare a project or give a presentation. Additionally, student self-assessment, peer assessment, and portfolio preparation can be given as examples of the types of assessment used in constructivism. In all of these types of evaluation, the student's development is evaluated and in this process, the student has the opportunity to learn from the mistakes she/he has made.

Advantages and limitations of the constructivist approach

It is possible to talk about many advantages of using constructivism in the teaching process since it has a student-centered structure. However, it is also possible to mention some limitations. Alam (2023) listed the advantages and limitations of constructivism as follows:

Table 3. Advantages and limitations of constructivism (Alam 2023)

Advantages	Limitations
• The individual has the opportunity for personalized learning. • The individual constructs her/his own learning. • The learning process is individual. • It helps the individual to have different perspectives on any subject. • Encourages individuals to work cooperatively. • Active learning is involved. • It enables the individual to learn the subject in depth. • It provides an interesting environment for students. • It provides the individual with critical thinking, problem-solving and interdisciplinary skills. • It helps learners improve their communication skills.	• In a constructivist classroom, the educator spends much time and effort preparing appropriate materials and classroom environment. • Evaluating students is difficult because learning is individual and specific to the student. • Due to the flexible nature of constructivism, it may cause confusion in students who expect clear instructions and directions from the teacher.

Bada and Olisegun (2015) express the benefits of constructivism as follows:

- Students learn more and have fun when they take an active part in the instructional process.
- Constructivist approach allows individuals to learn to think and understand. In other words, the constructivist approach teaches individuals how to think.
- The constructivist approach helps individuals transfer the knowledge and competencies they have acquired to daily life.
- The connection of the activities in the learning process to real life encourages students' participation in the process in a positive way.
- It contributes to the development of students' social and communication skills.

Steakley (2008) also states one of the advantages of constructivism is that learners take an active part in instructional process. Similarly, Li (2025) expresses its advantages as follows: it affects students positively both emotionally and socially, it allows students to learn independently and collaboratively, and it is flexible and adaptable. Besides the advantages of the constructivist approach, Gordon (2009) also points out that teachers need to be pedagogically experts as a limitation. The number of learners in the classroom is essential for constructivist methods to be used effectively in education and serve their purpose. It can be said that it is difficult to apply constructivist methods in crowded classes.

Discussion

In the 21st century, the rapidly developing technology has also changed society's expectations from individuals. The 21st-century world expects individuals to be competent in all areas, to possess high-ordered cognitive competences like interdisciplinary and critical thinking, to have collaboration and communication skills, to keep up with the changing world by following developing and changing technology (Binkley et al., 2010; Kyllonen, 2012); and to have the skills to solve such complex problems when faced with information pollution, misinformation and intertwined problems (Tsai et al., 2023). For these reasons, schools should be institutions that prepare individuals for life, rather than simply being institutions where knowledge is transferred.

STEM, which is formed by combining the first letters of the words Science, Technology, Engineering and Mathematics, is based on an interdisciplinary approach that enables individuals to solve problems, acquire critical thinking

competencies, and learn via practical and experiential activities. When considered in this context, constructivist approaches appear to overlap with both 21st century skills and STEM education objectives. The constructivist approach is based on the individual's learning by doing and experiencing, acquiring high-ordered competencies like problem-solving skills in a collaborative environment, and actively constructing knowledge for himself/herself, rather than being passive recipients. For these reasons, building STEM education on constructivist approaches will contribute positively to the development of various 21st century competencies such as creativity, problem-solving skills, critical thinking, and taking responsibility.

When the literature is examined, it is shown that constructivist learning environments lead to a positive increase in students' motivation and academic success (Tsai, 2023; Do et al., 2023). Syamsuddin (2024) concluded in his study that innovative and constructivist-based learning strategies notably increased both students' motivation and academic achievement. The use of project and design-based learning methods in a constructivist learning environment will contribute positively to the development of students in STEM education. Students' active participation in the learning process, collaborating in small groups to produce solutions to problems, and conducting in-depth research (Alam, 2023; Bada & Olisegun, 2015; Steakley, 2008) will prepare them for real life and support their survival in the ever-evolving technological world order.

In STEM education, two or more disciplines are combined in a single teaching unit (Toma et al., 2024). Some difficulties may arise in the process of interdisciplinary integration in STEM education. These challenges can be listed as follows: time and planning (Lin et al., 2025), integrating the STEM curriculum (Yang & Oh, 2024), inadequate teacher training (Yang & Oh, 2024); difficulty in interdisciplinary integration (English, 2016); lack of support from school administrators in encouraging student collaboration in STEM education (Murata, 2002); inflexible course schedules, compulsory courses, and standardized exams (Lesseig et al., 2017). The constructivist approach, which allows individuals to construct their own learning, has some limitations like other approaches. Alam (2023) and Gordon (2009) state that the possibility of the teacher not being able to create an environment based on constructivist learning and not having the necessary pedagogical competence is a limitation in the learning-teaching process. Guzdial (1997), on the other hand, states that learning occurs in the individual's own mental process and in his or her own world of meaning, regarding the constructivist learning process. Based on this, he states that the mental structure of

the individual cannot be directly observed, that is, it cannot be tested by experimental means. For this reason, he stated that constructivism is a philosophical approach rather than a scientific and theoretical one. Therefore, he offered a critique of the constructivist approach (as cited in Şimşek, 2004). Similarly, Çetinkaya (2023) states that the constructivist approach is an approach with more philosophical intensity and that there are some question marks about its evaluation as a theory. Çetinkaya (2023) states that it cannot be tested experimentally and is far from scientific evidence. In addition to these statements, it's worth noting that the effective use of constructivist methods and techniques is extremely effective in preparing students for social life. However, using constructivist methods in crowded classrooms is quite challenging.

Conclusion

Constructivist approaches in STEM education offer individuals the opportunity to construct their own learning by providing active participation in the learning process (Ghaour, 2018; Mir & Jain, 2015). Constructivist approaches help individuals acquire higher-ordered cognitive competencies like problem solving, critical and creative thinking (Almulla, 2023). In the constructivist approach, knowledge is subjective, knowledge is not inherent in humans, the individual is active in the learning process, and constructs knowledge subjectively.

Another feature of constructivist approaches is that students construct knowledge by doing and experiencing. During this process, they create solutions to real-life problems or design projects with their friends in small groups. Thus, students have the opportunity to work flexibly in a collaborative environment. Additionally, while working with a group, individuals gain a sense of responsibility and socialize. The teacher is in an important position in preparing and designing a constructivist learning environment (Mir & Jain, 2015). Because the role of the teacher in providing the materials students need, arranging the environment, encouraging students to research and learners' active engagement in the instructional process is of primary importance (Brooks & Brooks, 1999).

Recommendations

The following suggestions were made regarding the use of constructivist approaches in STEM education:

- In classes where constructivist approach is used, appropriate environments and materials should be arranged according to student

interests and needs.

- In constructivist classes, the teacher should organize the learning process flexibly and encourage students to do research.
- Since STEM education is important for the development of both the individual and society, STEM education should be included in the curriculum starting from primary school.
- Schools should encourage students to pursue STEM education and support them in developing their critical thinking and creativity.
- Educators ought to be provided with in-service training on STEM.
- Schools should create special classes and laboratories suitable for STEM education and constructivist approaches.
- Teachers should be careful to keep class sizes small in classes where constructivist methods are applied.

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STEM and Mathematics: Understanding and Developing Students' Fractions Knowledge through a Radical Constructivist Lens

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Chapter Highlights

This chapter emphasizes the central role of mathematics within STEM education by positioning radical constructivism as a unifying theoretical framework applicable across STEM disciplines. It examines how mathematics education researchers employ radical constructivism to investigate learning processes, with a particular focus on fraction knowledge. Through an illustrative case study on children's understanding of fractions and pedagogical recommendations for supporting older students, the chapter bridges theory, research, and instructional practice.

- **STEM and Mathematics** – Examining the foundational role of mathematics as a core integrative component of STEM education.
- **Radical Constructivism as a Lens for STEM Education** – Introducing radical constructivism, contrasting it with the emergent perspective, and discussing its adaptation to classroom contexts.
- **Children's Fraction Knowledge** – Exploring how children develop an understanding of fractions, supported by an in-depth case study grounded in radical constructivist principles.
- **Older Students' Fraction Knowledge** – Offering instructional goals and pedagogical strategies to support and extend fraction understanding among older learners.

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