The Effectiveness of Challenge-Based Learning in Developing Some Analytical Thinking Skills of STEM Students in the Faculty of Education

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Abstract

This research describes the application of Challenge Based Learning to STEM students. The overall goal is to identify the effectiveness of challenge-based learning in developing some analytical thinking skills among students of STEM education program in the faculty of Education. To achieve this goal, the current research sought to answer the following main question: **What is the effectiveness of challenge-based learning in developing some analytical thinking skills of STEM students in the faculty of education?** The researcher prepared research materials and tools represented in the suggested program of biotechnology in the light of

Challenge based learning and analytical thinking skills test. The experimental approach was used, the quasi-experimental design with one experimental group, and the research was applied on a group of first year STEM students at the Faculty of Education, Zagazig University, their number was 30, and the following results were reached: There is a statistically significant difference at the significance level (0.01) between the mean scores of the experimental group students in the pre- test and posttest of the analytical thinking test as a whole and in its sub-skills in favor of the posttest. There is an effectiveness of challenge-based learning in developing some analytical thinking skills among STEM students in the Faculty of Education.

Keywords : Challenge based learning, Analytical thinking, STEM students.

المستخلص

يصف البحث الحالي تطبيق التعلم القائم على التحدي على طلبة STEM . الهدف العام هو تحديد فاعلية التعلم القائم على التحدي لتنمية بعض مهارات التفكير التحليلي لدى طلبة STEM بكلية التربية. ولتحقيق هذا الهدف سعى البحث الحالي للإجابة على التساؤل الرئيس التالي: ما فاعلية التعلم القائم على التحدي في تنمية بعض مهارات التفكير التحليلي لدى طلاب STEM بكلية التربية؟ أعدت الباحثة مواد وأدوات بحثية ممثلة في برنامج التكنولوجيا الحيوية المقترح في ضوء التعلم القائم على التحدي واختبار التفكير التحليلي. وتم استخدام المنهج التجريبي، والتصميم شبه التجريبي بمجموعة تجريبية واحدة، وتم تطبيق البحث على مجموعة من طلاب المستوى الأول STEM بكلية التربية جامعة الزقازيق، وبلغ عددهم ٣٠، وتم التوصل إلى النتائج التالية: توجد فروق ذات دلالة إحصائية عند مستوى الدلالة (٠.٠١) بين متوسطات درجات طلبة المجموعة التجريبية في التطبيقين القبلي والبعدي لاختبار التفكير التحليلي ككل وفي مهاراته الفرعية لصالح

التطبيق البعدي. هناك فاعلية للتعلم القائم على التحدي في تطوير بعض مهارات التفكير التحليلي بين طلبة STEM بكلية التربية.

الكلمات المفتاحية

التعلم القائم على التحدي، التفكير التحليلي، طلبة STEM.

Introduction:

Egypt vision 2030 represents the roadmap towards investing in the preparation of a distinguished and creative generation that have knowledge, skills, and competencies, which makes it able to keep pace with rapid development, face continuous challenges, and enhance Egyptian pioneering. One of its most important objectives is to achieve sustainable development and improve the quality of education in line with global systems through education for citizenship and focus on the intellectually and technologically enlightened learner.

The university phase is the phase of intellectual development of the human mind, during which the individual's capabilities, thinking and analytical skills are enhanced during that phase, and university students need to become good thinkers while passing through university education. They need to leave their educational institutions willing to face the intellectual challenges that are inherent in their lives and require highly skilled people (Esmaiel, et al., 2018; Nelson Laird, 2016).*

STEM (Science, Technology, Engineering and Mathematics) education is one of the recent trends in education in general and university education in particular. It is an educational approach based on integration and linking between the fields of science, technology, mathematics, and engineering, as it aims to prepare for the world of work that has the

*The researcher followed the APA7: (surname, year).

knowledge and skills that enable them to adapt with the labor market, facing challenges in the future, and developing the skills of the twenty-first century (Batdi et al., 2019; Gao et al., 2020).

STEM students also need to be able to prepare scientific projects and be prepared to be ready to face real problems both in daily life and in labor market. Accordingly, they must be able to gather information by analyzing the situation, come up with new ideas, produce a prototype based on these ideas, and then test it to ensure the effectiveness of the proposed solution. All this requires that students have higher order thinking skills. (Evcim & Arslan, 2021).

One of the consequences of the information revolution, the tremendous technological development and the beginning of the Fourth Industrial Revolution, many and varied challenges have emerged, therefore, individuals must be prepared ready to meet these challenges, and this will require modifications to both the current curricula and modern learning approaches, as it has become difficult for individuals in our current era to think and verify the truthfulness of the information available in abundance in various sources. The issue of supporting the development of thinking has become a necessity in the teaching of students of the Faculty of Education, because they are the future teachers who are responsible for developing thinking for learners. Ritchhart and Perkins (2020) stated in the Zero Project at Harvard University that students can master thinking by training and practicing (Beňo, et al., 2020; Conde et al., 2019).

When talking about thinking and its skills, Webb's Depth of Knowledge (DOK) taxonomy comes to the fore, as higher order thinking skills represent the two higher levels of Webb's taxonomy which are strategic thinking that includes analyze and extended thinking that includes evaluate and create. And in our current era, modern societies seek to develop higher order

thinking skills, especially to produce generations with thinking minds capable of achieving sustainable development and competition in the global arena and compatible with the requirements of the labor market. It is the responsibility of educational institutions, so it has become necessary for those in charge of the educational process to provide appropriate opportunities to develop students' higher-order thinking skill **(صيام وآخرون، ٢٠٢٠ ;Holmes, 2012; الحمدان، والجاسم، ٢٠٢٠).**

Analytical thinking is the basic skill for developing higher-order thinking skills, as it is part of logical thinking. Analytical thinking skills in the current decade are one of the most in demand skills in our daily lives and in many jobs. Thus, they must be developed among students during the teaching and learning processes. Analytical thinking skills are an important element for success in the professional and academic workplace, and they have an important role in improving Learning performance for students and helps qualify students with skills necessary to deal in complex work environments. Analytical thinking skills are seen as a crucial tool for university students because they allow them to segment the situation into its components to better understand it and evaluate the situation effectively (Aksu & Eser, 2020; Boontham, 2015; Carroll & Harris, 2020).

Analytical thinking skills were mentioned by Nuroso et al. (2018), (٢٠١٨) رزوقي وسهيل, Yulina et al. (2019), (٢٠٢٠) خليفة وحسن as following:

Attributing: The ability to identify the components of a problem and their general characteristics, Observation: the ability to gather information related to the observed problem using the senses or using tools and devices, Comparison: the ability to identify similarities and differences between two or more phenomena from several angles, Classification: the ability to

organize questions into categories based on common characteristics, Preparation of the standard: the ability to define the standards against which the elements are evaluated., Identifying relationships and patterns: The ability to perceive the ways and methods in which the elements are related, Ordering and determining the priorities: the ability to arrange ideas and prioritize in a hierarchy order, Prediction or expectation: The ability to use prior knowledge to determine expected outcomes for a problem., Determining causes and results: the ability to identify the major causes and consequences of problems and Measurement: The ability to identify relationships between familiar items and similar events in a new situation for the purpose of solving a problem.

These skills enable students to sort and examine their ideas, identify appropriate ideas to develop them to reach a solution to problems and make decisions quickly and efficiently. By mastering them, students can identify problems, develop knowledge that will lead to dramatic changes in the world, so training the learner in analytical thinking skills in university education is necessary (Lane, 2020; Wahyuni & Analita, 2017; Wulandari et al., 2018).

Despite the importance of analytical thinking skills, there are some studies and research that indicate a low level of students in these skills at various educational levels, including: Nur'Aziza et al. (2018), زكي (٢٠١٨), رضا (٢٠١٩), Prawita & Prayitno (2019), Karenina et al. (2020), صالح (٢٠٢١), Saputro & Sunarno (2021), Fiolida & Rohaeti (2021), Yulina et al. (2022) all which emphasized the need to develop learners' analytical thinking skills Through the development of learning methods, where indicated in total the importance of developing analytical thinking skills to prepare individuals capable of keeping pace

with developments and facing the changing environment in various fields.

Egypt was also ranked internationally in the low category in science learning according to the results of the international test Trends of International Mathematics and Science Studies (TIMSS) in 2019, where the average performance of its students in science reached (389) points, and this is less than the specified standard and the decline is due to several reasons, most notably the low level of students in higher-order thinking skills, including analytical thinking skills, and these results indicated the need to develop the professional performance of teachers and use teaching methods that develop higher-order thinking skills (Kelly et al., 2020; Mullis et al., 2020).

The causes of the decline in students' analytical thinking skills are the lack of stimulation in learning and the followed learning style. Traditional learning reduces opportunities for students to enhance analytical thinking skills, but active and student-centered learning can develop individuals with an analytical mindset (Puchumni et al., 2019).

In light of global developments in various fields of life, attention to the quality of education has become a necessity to raise individuals capable of achieving the requirements of the Fourth Industrial Revolution and sustainable development through the preparation of educational programs based on modern learning methods that link learning outcomes with the challenges of society, and given the importance of analytical thinking among STEM students at the Faculty of Education The current research is concerned with the challenge based learning as one of the modern models in teaching that activates university students due to its main dependence on challenge-based learning.

Challenge based learning seeks to prepare individuals with the knowledge, competencies and skills that make them able to face an era full of challenges and prepare graduates capable of international competition. This aims to develop both personal and professional competencies; Personal competencies refer to the knowledge and skills necessary in the learner's life that affect the quality of his professional life, and which must be developed by the learner, while professional competencies refer to the knowledge, values and skills necessary for professional life. (Membrillo-Hernández et al., 2019; Membrillo-Hernández al., 2021).

Tecnológico de Monterry institute (2018) stated that challenge-based learning is based on enhancing creativity and qualifying the learner to be more effective through immersion in interactive learning experiences. Challenges are the heart of core learning, where students participate with their professors and interact with their environment in developing personal and professional skills by solving challenges through which their understanding and knowledge of learning evidence is demonstrated.

In addition, challenge-based learning introduces teaching as a student-centered pedagogical approach where it is integrated in many fields such as humanities and engineering. It provides opportunities for students to engage them more in the learning process, and motivates them and arouses their interest by solving real-world challenges; So that they can see and understand the relationships between educational content and real-life problems, improve student learning, enhance teamwork, gain many personal skills, help them acquire competencies in the digital age, and develop their abilities and skills by reaching a solution using their technical and non-technical knowledge; It is effective in learning environments that support the use of technology;

Because it allows flexibility in bringing about the learning process (Chanin et al., 2018a; Conde et al., 2017; Torres-Barreto et al., 2020).

The results of Suwono et al. (2019) study referred to the effectiveness of challenge-based learning in developing scientific knowledge among students of the Biology Department. Gallagher and Savage (2020) study emphasized the need for higher education institutions to adopt the challenge-based learning approach because of its effectiveness in the educational process. Gonzalez Almagure et al. (2021) explained the application of challenge based learning by augmented reality and virtual reality made students able to process and manage daily situations.

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The researcher found - within the limits of her knowledge - that there is no research concerned with developing analytical thinking skills among university students using challenge based learning, and this is what prompted the researcher to concern with this knowledge gap.

Realizing the problem:

The researcher realized the problem through:

1. Reviewing previous research that showed a weakness in the analytical thinking skills of students in various educational stages, such as the research of (Nur'Azizah et al., 2018; زكي، ٢٠١٨; رضا، ٢٠١٩; Prawita & Prayitno, 2019; Karenina et al., 2020; صالح، ٢٠٢١; Saputro & Sunarno, 2021; Fiolida & Rohaeti, 2021; Yulina et al., 2022).

2. Reviewing scientific conferences, including the Global Forum for Higher Education and Scientific Research for the years 2019 and 2021, where their recommendations are to pay attention to high-quality education in a way that develops analytical thinking skills as one of the skills associated with the Fourth Industrial Revolution to prepare individuals who meet the requirements of the labor market (State Information Service, 2021).

3. The Pilot study: The researcher applied the analytical thinking scale[1] to a sample of students at the faculty of Education, first year, STEM Department, which consisted of (32) male and female students at the end of the second semester of the academic year 2021/2022, and the average percentage of their grades was (36.58%), which indicates the weakness of students of analytical thinking skills**.**

The study problem:

The research problem represented in the weakness of the analytical thinking skills of STEM students, to handle this problem, the current research attempts to answer the following main question:

[1]**Appendix (1) Analytical Thinking Scale**

What is the effectiveness of challenge-based learning in developing some analytical thinking skills of STEM students in the faculty of education?

The following sub-questions were derived from the main question:

1. What are the analytical thinking skills that should be developed among STEM students in the faculty of Education?
2. What is the effectiveness of challenge-based learning in developing some analytical thinking skills of STEM students in the faculty of education?

Aims of the study:

The current study aimed to:

1. Determining the effectiveness of Challenge-Based Learning in developing some analytical thinking skills of STEM students in the faculty of education
2. Interpreting the development of analytical thinking skills among students of the Faculty of Education in STEM department through a suggested program in the light of challenge-based learning.
3. Predicting the development of analytical thinking skills among students of the Faculty of Education in STEM department through a suggested program in the light of challenge-based learning
4. Controlling the development of analytical thinking skills among STEM students of the Faculty of Education through a suggested program in the light of challenge-based learning

Significance of the study:

The current research is useful in:

Theoretical significance:

- The importance and novelty of its subject, which is challenge based learning.
- In response to recent trends calling for the need to develop teaching strategies.

Practical Significance:

- **Entities concerned with the development of university education**: The current research can contribute to the development of pre-service teacher preparation programs by increasing their awareness of analytical thinking skills.
- **Teachers:** SETM teachers may benefit when they see the proposed program, know its information.
- **Researchers:** The Analytical Thinking test may be used in future studies related to research variables.

Definitions of Terms:

Challenge based learning:

An educational approach that actively engages the student in a real and relevant situation to produce and implement solutions (Olivares et al., 2021).

A modern and evolving approach to education that integrates theory and practice with real-world challenges that require creative solutions. (Vilalta-perdomo et al., 2022).

Operationally:

An educational approach that integrates theory and practice focusing on real-life challenges used to teach proposed

program topics in biotechnology to help STEM students develop analytical thinking skills.

Analytical thinking skills:

رزوقي وسهيل (٢٠١٨) define as the ability to observe and examine the elements of the problem and their characteristics, distinguish between the elements, identify the components and compare them, then classify and arrange them, Identifying relationships and patterns skill and predict events through the available information.

Lane (2020) defines it as the ability to simplify and break down a complex idea or task into its components and to determine the relationships between them to solve a problem or achieve a task.

Operationally:

The ability that enables students to observe the problem and divide it into its parts and compare those parts and then arrange them according to a specific criterion with identifying relationships between its parts to reach a solution to the problem. This requires a few skills, including attributing, observation, comparison, ordering and determining priorities, and identifying relationships and patterns. It is measured by the degree that the student obtains on the Analytical Thinking Test.

Limitations of the study:

The current study was limited to:

1. **The objective Limits:**

- A few scientific topics in the field of biotechnology for the suggested program based on challenge-based learning.
- Measuring some analytical thinking skills**.**

2. The human limits:

A non-random sample of STEM students in the Faculty of Education of Zagazig University due to the link between biotechnology and their specialization and their need to construct integrated scientific projects that require developing analytical thinking skills.

3. The spatial limits:

It applied at the Faculty of Education, Zagazig University, because it is the first university institutions in the Arab Republic of Egypt that includes a bachelor's program for the STEM track.

4. The Temporal limits:

The research tools applied in the first semester of the academic year 2023/2024

Instrument of the study:

The current study tool was:

1. Analytical thinking skills test. (Prepared by the researcher).

Materials of the study:

1. The suggested program in biotechnology is in the light of challenge-based learning.

Methodology of the study:

The current study used:

1. **The descriptive method**: to prepare the theoretical framework, inquire about the relevant previous research and studies, prepare the suggested program, and the research tool (analytical thinking test), in addition to analyzing and interpreting the results.

2. **The experimental method**: It was determined through the Quasi-experimental design with a single group, which depends on the pre and post testing of the research variables, due to its relevance to the nature of the current research.

Hypothesis of the study:

There is a statistically significant difference at the significance level (0.01) between the mean scores of the experimental group students in the pre- test and posttest of the analytical thinking test as a whole and in its sub-skills in favor of the posttest.

There is an effectiveness of challenge-based learning in developing some analytical thinking skills among STEM students in the Faculty of Education.

Procedures of the study:

To answer the research questions and verify the validity of its hypotheses, the researcher followed the following procedures:

1. Survey of literature and previous studies that dealt with everything related to challenge-based learning and analytical thinking skills to prepare and write the theoretical framework for the study variables.
2. To answer the first question, which states: What are the analytical thinking skills that should be developed among STEM students at the faculty of Education?

a. A survey of educational literature, research and previous studies that dealt with analytical thinking skills.

b. Preparing a list of analytical thinking skills to be developed among STEM students.

c. Preparing Analytical thinking test.

3. to answer the second question, which states: What is the effectiveness of challenge-based learning in developing some analytical thinking skills of STEM students in the faculty of education?

a. Preparing the analytical thinking test in its initial form and presenting it to a group of arbitrators in the field of curricula and methods of teaching science and mathematics, then reviewing and amending it in the light of their suggestions, and then applying it on a sample of STEM students in the Faculty of Education to ensure its reliability and validity.

b. Preparing the suggested program in light of Challenge based learning through the following steps: Determine the title of the suggested program, preparing the introduction to the suggested program of biotechnology, determine the basis for constructing the suggested program, determining big ideas of the suggested program, selection of the scientific content of the suggested program, determining performance expectations for the proposed program, determining the educational activities and techniques, determining learning resources, and determining assessment methods.

c. Choosing the research group from the STEM students of the Faculty of Education.

d. Pretesting of the analytical thinking test to the study group.

e. Teaching the suggested program in biotechnology in the light of challenge-based learning on the research group.

f. Post testing of the analytical thinking test to the study group.

4. Data processing using appropriate statistical methods according to the sample size and the nature of the variables.

5. Extracting, interpreting, and discussing the results.

6. Submitting recommendations and suggestions considering the results of the research

Literature Review:

Definition of Challenge based learning:

The literature has dealt with the term challenge-based learning from different points of view, mentioned below:

It is a motivational, multidisciplinary, and collaborative approach that promotes the use of available technologies for gaining knowledge and solving real-world issues (Binder et al., 2017).

A learning framework that eliminates the hierarchy between teacher and learner by presenting real-world challenges that require teamwork and motivates students to develop new ideas and solutions to challenges, assesses students throughout the learning process to its end (Chanin et al., 2018a).

It is a multidisciplinary and engaging approach that allows students to use the technology and collaborate with their peers, teachers, and professionals to solve complex challenges and get a deeper understanding of the subjects they are studying (Serrano et al., 2018).

A learning strategy based on problem-based learning in which students work collaboratively in addition to using the internet to find an adequate solution to a challenge (Suwono et al., 2019).

An interactive, challenging and stimulating model in which students engage in solving problems lead to developing their cognitive, engagement and creativity (Susilawati & Suryadi, 2020b).

An educational technique allows students to engage in real-world issues to be capable of applying their knowledge and

abilities, conduct research, discover new information, develop potential solutions to the given issue and enhance competencies (López-Caudana et al., 2022).

A modern and sophisticated approach in education that integrates theory and practice with realistic challenges which call for creative solutions (Vilalta-perdomo et al., 2022).

The studies of Binder et al. (2017), Serrano et al. (2018) and Vilalta-perdomo et al. (2022) agreed that challenge-based learning is an approach while the studies of Chanin et al. (2018a), Suwono et al. (2019). Susilawati and Suryadi (2020b), and López-Caudana et al. (2022) disagreed with them and the studies of Binder et al. (2017) and Serrano et al. (2018) agreed that it is multidisciplinary.

Operationally:

An interactive educational approach based on purposeful challenges in biotechnology topics in which students participate with their peers and instructor and use modern technologies in solving these challenges, to help STEM students develop analytical thinking skills.

The Key Characteristics of Challenge Based Learning (CBL):

It shows from the above that challenge-based learning has characteristics, Ardiansyah et al. (2021), Gallagher & Savage (2020), Gibson et al. (2018), Quweider & Khan (2016) indicated them CBL as follows:

1. Global themes: means the content that is primarily addressed in a CBL approach is within topics of global significance. So, these topics provide opportunities for students to acquire knowledge and skills of global challenges, a global attitude, and the capacity to deal with those challenges on their own,

and global challenges should be addressed locally with applicable solutions.

2. Real world challenges mean using the challenges facing the real world, these challenges seek to make students closer to the world around them and boost motivation and engagement.
3. Collaboration: the students cooperate with each other during a challenge.
4. Technology: is embedded in CBL, it facilitates contact for students with specialists, interaction with the public, research, and access to data. For instructors, it helps in tracking student interactions, creating a forum for sharing course materials collaboratively, assessing student performance, and pinpointing problems related to the students. Additionally, technology options are broad and flexible rather than being tied to a certain procedure and it offers possibilities for students to develop solutions.
5. Flexibility: is a customized and adaptable framework that can be modified to suit the requirements and be used as a guiding pedagogy or integrated with other modern approaches.
6. Multidisciplinary and discipline specificity: CBL uses multidisciplinary approach for implementation. Multidisciplinary is frequently regarded as using professional competencies to supplement academic curriculum. The STEM area was considered as being especially ideal for CBL because STEM courses are multidisciplinary, real world and Technology-rich learning environment which is a significant component of this discipline.

The studies of Gaskins et al. (2015) and Conde et al. (2017) described that challenges in CBL should be related to

real world, Fidalgo-Blanco et al. (2016) asserted that the teacher and students used internet for communications and the teacher follows the student's interactions through technology, the researchers of Ossiannilsson & Ioannides (2017), Gama et al. (2018) and de la O Campos (2019) assured that CBL topics should be have global significance, Bordonau et al. (2017) explained the collaboration occurs during CBL between the students, teachers and experts in the community, da Costa et al. (2018) indicated to the collaboration take places between the students and their peers, Félix-Herrán et al. (2019) also referred that CBL includes the collaboration between all participants, Díaz Martínez (2019) used virtual learning environments to receive assignments and host module resources and Eraña-Rojas et al. (2019) study implemented CBL as multidisciplinary experience which students from law, medicine and marketing were participated.

The significance of challenge-based learning:

EDUCAUSE (2012) explained the significance of challenge-based learning as follows:

1. Involve students in real-world problems and take responsibility for their learning.
2. Students develop the ability to use technology and benefit from it to achieve a practical result.
3. Makes students feel satisfied because of knowing the challenge and being able to develop a solution to it.
4. Students develop professional and social interaction due to their reliance on solving community challenges.
5. It helps to connect the community to the university campus where it identifies the challenge and how the solution can be implemented.

6. It helps students to promote reflection.

In view of the importance of challenge-based learning, many researchers have addressed it, such as Gaskins et al. (2015) pointed out the significance of challenge-based learning in enhancing student learning, achieving higher retention rates, Suwono et al. (2018) mentioned that CBL helps undergraduate biology students in enhancing scientific literacy, Kohn Rådberg et al. (2020) explained CBL helps in expanding the learning experience, a deeper more comprehensive understanding of science, mastering problem-solving skills and enhancing multidisciplinary teamwork skills for students, Susilawati (2020a) explained that CBL implemented through Android applications enhanced Mathematical representation skill and facilitated the process of discovery among students and Rodrigue-Paz et al. (2022) referred to improving disciplinary competences and digital transformation among engineering students through CBL.

And based on the above, the researcher states the significance of CBL in preparing students for the labor market by developing their professional, personal, technology and social skills and fosters curiosity and perseverance among students, improving the ability to ask scientific questions, searching for information from scientific resources, increasing their involvement in the learning environment and preparing them in ways that make learnable and able to apply knowledge.

Implementation of Challenge Based Learning:

CBL is implemented through stages identified by Apple Inc (2011) and Challenge institute (2018) in 3 interrelated stages as follows:

A. Engage stage:

During which students move from a big idea to a challenge through the main question, this stage includes 3 sub steps are mentioned below:

1. **The general big idea:** Students are provided with a set of contemporary problems or are given a topic that is significant to society.
2. **The main question:** the teacher asks the students questions that would help them discover the challenge, it begins with the general big idea is in a specific, contextual form and pertinent for the students.
3. **The challenge:** Students must come up with a solution to the issue raised in the main question. The challenge is put up by a student group or a teacher.

B. Investigate stage:

During which students plan and participate in building the foundation for solutions, this stage includes 3 sub steps are mentioned below:

1. **Guiding questions:** Referred to the knowledge that the students will need to create a solution to the challenge then categorizing and prioritizing these questions. There will be new guiding questions as you go through the experience.
2. **Guiding activities and resources:** The students use all available techniques to respond to the guiding questions created by the learners.
3. **Analysis:** The students analyze the data to put the basis to solving the challenge; at the end of this step the students submit presentation or reports.

C. Act stage:

During which the solution is implemented, and the results are evaluated, this stage includes 3 sub steps are mentioned below:

1. **Solution:** The results made during the investigation stage led to ideas for solutions, the students filter their Solution concepts. Woschank et al. (2021) defined that students may submit a digital solution and according to Colombelli et al. (2022) the students may find technology-based solutions to face the challenge.
2. **Implementation:** The students implement the solution; the depth of the implementation will depend on the age of the students and the number of resources and time available.
3. **Evaluation**: The students examine the efficacy of the solution thus making adjustment if it is needed and time allows.

Moresi et al. (2017) carried out CBL through 10 steps including big idea, essential questions, challenge, guiding questions, guiding activities, guiding resources, identification of solution, implementation and evaluation, publishing and reflection, support CBL process, Santos et al. (2018) indicated the preference for implementing challenge-based learning in technology-rich educational environments, Serrano et al (2018), Detoni et al. (2019) and Vreman-De Olde et al. (2021) followed 3 stages (Engage, investigate and act) in implementation of CBL, Conde et al. (2019) pointed out the applying CBL differs according to the context as it is a flexible framework; they implement CBL through 3 stages represented in engage, investigate and act, Díaz Martínez (2019) applied CBL in mechatronics through 6 steps including (General idea, essential questions, proposed challenge, guiding questions, activities and

resources, solution and implementation and evaluation), Prieto-Magnus et al. (2021) implemented CBL remotely based on IOT(Internet OF Things), and Nguyen et al. (2023) referred to Challenge-based learning is less appropriate for courses that are time-constrained.

It shows from the above that CBL is a flexible approach as it can be carried out remotely, online through different applications or in a real learning environment. Additionally, most of studies that dealt with CBL applied it through nine steps, which are divided into three interrelated stages in addition to a cycle of documentation, reflection, and sharing.

The Evaluation of Challenge Based Learning (CBL):

CBL evaluation includes formative evaluation in addition to summative evaluation; Rubrics were frequently used to evaluate student performance and were typically connected to the overall learning outcomes and competencies of the program (Díaz Martínez, 2019). The evaluation of challenges is based on their importance as well as its temporal and spatial aspect and the most crucial component of a challenge is that it requires students and educator to collaborate to address real-world problems Gudonien˙e et al. (2021).

There are various tools used in evaluation process of CBL show as follows: Gabriel (2014) used peer evaluations, Gaskins et al. (2015) used exams, Malmqvist et al. (2015) used participation in workshops in evaluating student, Conde et al. (2017) developed digital tools to follow up on students' activities and collect learning evidence from students, which are the electronic portfolio (e-portfolio), the educational platform, Moodle Wikis, Moodle Forums and Chats da Costa et al. (2018) used open book exams and Reading reflections of each student, Díaz Martínez (2019) used presentations, portfolio and prototype, Hernández-de-Menéndez et al. (2019) used

conference paper reports and rubric like RSD (the Research Skills Development) Mora-Salinas et al. (2019) used laboratory reports, analyzing student's video, Eraña-Rojas et al. (2019) and Gutierrez Contreras et al. (2021) research report and info-graphic materials presented in conference.

Based on what was mentioned, the researcher demonstrates that the methods of evaluating challenge-based learning are different and varied, and to accurately evaluate students' performance, more than type of evaluation methods must be used so that they are diverse and capable of evaluating all aspects of students' development.

Instructor's role:

Tecnológico de Monterrey (2018) stated that the teacher has an important role in challenge-based learning. These roles are:

1. Go beyond being information specialists to become learning collaborators who help students develop new ways and habits of thinking while actively seeking out new information.
2. Guarantees that the learning objectives, general idea of the challenge and all its stages are clearly related.
3. Integrates the essential competencies that learners will learn through challenges they will encounter.
4. It encourages students to take responsibility for their learning and to be committed to and involved in the development of challenges.
5. Serves as a facilitator throughout the challenge, monitors activities, evaluates team performance and triggering questions but without giving answers.

6. A prepared rubric is used to evaluate students' solutions to the challenge with specialized teachers and assessors.
7. Throughout the learning process, he serves as a mentor, trying to direct the work teams, and give feedback on student proposals.
8. Encourages team members to work together to accomplish a common goal.
9. Resolve disputes and promotes creative thinking that involves experimenting and taking risks.

Also Gibson et al. (2018) mentioned to the teacher's role in defining general big ideas, essential questions as well as resources and evaluation criteria, and consider as the digital learning experience's designer, Díaz Martínez (2019) has shown teacher is an evaluator, mentor, designer and co-investigator, Palma-Mendoza et al. (2019) noted that professors may do one role or more, they works as a coordinator, evaluator, designer, mentor, instructor or advisor, Pepin and Kock (2021) explained that the teacher's role evolves from a knowledge provider to that of a co-experimenter, coach, or a partner in learning and Woschank et al. (2021) determined the role of teacher in mentoring as oversee each student's learning processes and clarify any queries from the students or groups.

Accordingly, the roles of teacher in CBL are representing in a coach (co-researcher, co-learner, co-designer, and coordinator), a learning supervisor (facilitator or an expectation manager), evaluator and adviser in addition to identifying the main big idea and discussion with students in defining the main question and the challenge.

Student's role:

Apple Inc (2011); Chanin et al. (2018a); Gibson et al. (2018); Pepin and Kock (2021) pointed out the role of students as following:

a. Selecting the challenges and acting on the solutions at home, school, or in the community.
b. Searching and gaining information and skills during solving the challenge.
c. Reflecting on the activities and resources that help them to face the challenge.
d. Working collaboratively with their peers to solve the challenge.
e. Selecting resources that they use in solving the challenges.
f. Self-regulation of their own learning resulting in preparing independent learners.

The researcher opines the main roles of the learner in CBL are highlighted below:

Discussion with the instructor in defining the essential question or identifying the challenge, determine guiding questions that lead them to solve the challenge then prioritize them, determine the educational resources that lead them to answer the guiding questions, determine the educational activities that lead them to answer the guiding questions, gathering information about the challenge and guiding questions, analyzing the collected data and finding solutions to the challenge, submitting a presentation, poster, or report about the challenge, sharing the results in an electronic and non-electronic way and reflect on what they know and learned and what they haven't learned.

The main conditions to foster effective learning in challenge-based learning:

Caratozzolo and Membrillo-Hernández (202١), Membrillo-Hernández et al. (2018) referred to the main conditions to foster effective learning in challenge-based learning as following:

1. Students must actively and imaginatively contribute to the problem-solving process.
2. Learning experiences should be designed and organized in a way that encourages students to take responsibility for their own actions and make decisions.
3. Learning experiences ought to involve activities that promote critical analysis and reflection.
4. The learning experience should enhance Students' self-awareness, empathy for their peers, and understanding of the environment and other cultures.
5. The learning outcomes are the basis for future learning.
6. The instructor's duties provide support for students, setting boundaries, and promoting the learning process.
7. All participants must be involved in the experience.

Based on the importance and novelty of challenge-based learning in education, it has been addressed by many studies such as:

Mukarromah et al. (2020) research asserted that CBL influences students' critical thinking skills on the Atmospheric material on the topic of Climate Change and Its Impact on Life. The researchers used pseudo-experimentation with a quantitative approach; this study applied an essay test on 60 high school students in Malang State University to collect data.

Naim et al., (2020) study reported that CBL is better than the Problem Based Learning (PBL) in improving creative thinking skills among students of Chemistry Education in Indonesia although statistically there is no significant difference in gain scores.; the researchers used experimental approach (control group and experimental group) through applying a creative thinking skills test with open essay questions.

The research of Fernández et al. (2021) concluded that CBL develops skills and competences, fosters the motivation for the subject and the propensity to develop a real-life entrepreneurship project. The researchers used qualitative analysis (interviews of 95 students in Spain).

The study of Gutierrez Contreras et al. (2021) referred that CBL has a positive impact on developing competencies in a trans-disciplinary environment because CBL provided the mixture of students, teacher, and the community in addition to giving a chance to students for exploring through a practical challenge. CBL has helped develop respect for diversity, self-appreciation, empathy, the awareness of acquiring new skills and students' abilities in finding and setting chances for creative intervention through research.

The study of Colombelli et al. (2022) aimed to investigate the effectiveness of CBL on entrepreneurial mindset and skills, the results proved that there is a positive and significant impact of CBL on entrepreneurial mindset and skills (creativity, financial literacy, and planning). The sample was 127 university students in Italy and the researchers used a quantitative approach and collected data by questionnaire.

The current research is concerned with preparing a suggested program in biotechnology in the light of challenge-based learning, where its components are combined to work

together in an integrated framework so that analytical thinking skills are developed among students by linking between community challenges and learning outcomes and the researcher benefited from the second axis in preparing the proposed program in biotechnology.

Analytical Thinking skills:

The development of thinking skills in general and analytical thinking skills is one of the main goals of the educational system, is the adaptation of the learner to various social settings, which is expressed in imparting self-confidence. Learners that use analytical thinking can draw conclusions, the conclusion and interpretation of ideas and the connection between the elements that appear in the phenomenon of separation (عبده، وخشب، ٢٠٢٠).

1. Definitions of Analytical thinking:

Analytical thinking like other types of thinking has a variety of definitions in a broader scope, its connotations have varied and a group of definitions of analytical thinking will be presented below:

A directed and purposeful mental activity that enables the individual to compare, find differences, determine causal relationships, determine personal vision, market evidence and evidence, analyze the essential, spatial, temporal, and qualitative components of issues and problems, and analyze error in the thinking of others (إبراهيم، ٢٠١٧).

محمود (٢٠١٧) defined as the ability to analyze the situation into separate parts and collect sufficient information about each part so that it is easy to deal with it and think about it independently to reach the appropriate solutions according to specific criteria.

رزوقي وسهيل (٢٠١٨) defined as the mental ability to observe and examine the elements of the problem and their characteristics, distinguish between the elements, identify the components and compare them, then classify and arrange them, identifying relationships and predict events through the available information.

It is the activities of examining and dividing information into smaller parts through identifying reasons, making conclusions, and finding evidence to support generalizations (Karenina et al., 2020).

Lane (2020) defined as the ability to simplify and break down a complex idea or task into its components and to determine the relationships between them to solve a problem or a task.

The researcher defines it operationally as the mental ability that enables students to observe the problem and divide it into its parts and compare those parts and then arrange them according to a specific criterion with identifying relationships between its parts to reach a solution to the problem. This requires given skills, including identifying the components, observation, comparison, ordering, identifying relationships, and measurement. It is measured by the degree that the student obtains on the Analytical Thinking test.

It is clear from the above that analytical thinking is characterized by a set of characteristics that distinguish it, which will be addressed in the following:

2. Characteristics of analytical thinking (رزوقي ولطيف، ٢٠١٨; عبدالمجيد، ٢٠٢٠ ;حسن، ٢٠١٩):

a. Requires summon of previous experiences related to the problem or situation they are facing.

b. Its degree varies based on the individual's experience, its age and development level.
c. It is thinking based on the practice of mental operations, evidenced by behaviors that appear on the individual.
d. It proceeds according to organized and sequential steps and allow defining criteria for the validity for each step.
e. It breaks down a single task or problem into its elements then uses those elements to understand the main thing.
f. It requires searching for information relevant to the situation or problem to try to find a solution to it.

The researcher believes that analytical thinking is characterized by the following:

a. Combining many disciplines to find efficient solutions to problems.
b. It necessitates scientific methods based on the accessibility of reliable data.
c. Generating conclusions by dividing the available information leads to making rational decisions.

3. Analytical thinking skills:

Analytical thinking is linked to many mental skills practiced by the individual, and many researchers have been interested in identifying them according to their educational orientation. Among these skills, as mentioned in previous research are the following:

a. Identifying traits and characteristics, realizing the relationship of the part to the whole, comparison, prediction, generalization skills (الأشقر، ٢٠١٨)

b. Identifying traits, realizing relationships, comparison, determining cause and result, classification and prediction or expectations skills (رضا، ٢٠١٩).

c. Matching, classifying, analyzing errors, generalizing, and specifying (Yulina et al., 2019).

d. Examining ideas, identifying arguments in addition to identifying reasons and claims (Amaliah, 2020).

e. Description, observation, comparison, classification, identifying priorities, determining cause and result, realizing relationships and conclusion skills (عبده، وخشب ٢٠٢٠).

f. Observations, identifying reasons, identifying relationships and classification skills (صالح، وغالب، ٢٠٢١).

g. Differentiating, organizing, and attributing (Anggraeni & Taufiq, 2021; Heliawati et al., 2021).

h. Identifying a problem, finding, and knowing the pattern of relationships, identifying and evaluating various errors and summing up the main idea (Fadly, 2021).

i. Identifying traits and characteristics, observation, creating a standard, arranging priorities, determining cause and result, predicting and analyzing errors in the thinking of others skills (حسن، ٢٠٢١).

j. Identifying traits, classification, comparison, realizing relationships and generalization skills (الكوري، والمعمري، ٢٠٢١).

The researcher has benefited from previous studies in identifying analytical thinking skills and selecting some of his skills that serve the purpose of the research and are compatible with the subject and sample of the study. The research will address the following analytical thinking skills that the learner can be trained on:

a. Attributing:

أبو جادو ونوفل (٢٠٠٧) defined it as determining the parts or characteristics of something through what he has of the knowledge bases he has stored in him and then working on clarifying the parts that make up the whole.

رزوقي وسهيل (٢٠١٨) defined it as the ability to determine the general characteristics of several things, by identifying the components of things and knowing their properties and qualities.

The researcher defines it operationally as the ability of STEM students to identify components and general features of things by clarifying the parts that make up the whole.

(إسماعيل ٢٠١١) mentioned to the skill of identifying components and ideas represents the starting point for students to change their traditional thinking style and elicit the main ideas from the sub and the characteristics of these ideas and thus follow the ideas of the students in order to extract the important ideas

b. Observation skill:

The ability to choose the appropriate features, tools, and procedures that guide and assist in the process of collecting information (الأشقر، ٢٠١٨).

The mental ability of the learner to enable him to use one or more of his senses to examine something or an event, then describe it and record its results directly, accurately and objectively (رزوقي وسهيل، ٢٠١٨) .

Monitoring for the purpose of collecting as much information as possible that helps to perfect the work in an issue or to realize the forms and types (عباس، ٢٠٢٠).

The researcher defines it operationally as the ability of STEM students to gather information about a situation or a topic through following appropriate procedures and using tools, devices, or senses.

Also, teaching the skill of observation is important; it is helping in gathering information and data related to a situation or task to understand it to solve it.

c. Comparison skill:

Correspondence between two phenomena, two concepts, or two problems, and identifying the similarities and differences between them (إبراهيم، ٢٠١٧).

The ability to compare two things or ideas or more from several angles and see what is present in one and what is missing in the other (الأشقر، ٢٠١٨).

The researcher defines it operationally as the ability of STEM students to examine ideas and compare two or more ideas from more than one angle to identify what is present in one and missing in the other.

Comparison skill is important for organizing information and developing knowledge, and it makes the learner think about two things at the same time. It is also considered as a summary of two or more phenomena or ideas and expresses the learner's possession of critical points of view, so it has a valuable for the learner (محمود، ٢٠١٧ ؛خليل، ٢٠٢٢).

d. Ordering skill and determining the priorities:

صالح وغالب (٢٠٢١) defined it as the ability to place events in a hierarchy based on qualitative values or the order of certain actions according to time.

According to رزوقي وسهيل (٢٠١٨) ordering skill is placing concepts, behaviors, events, situations, or experiences that are related to each other in one way or another in a sequential and sequential context according to a specific standard.

علام (٢٠٢١) referred to ordering skill as setting priorities and making sequences.

The researcher defines it operationally as the ability of STEM students to place ideas in a specific organization and prioritize them according to a specific basis that is carefully chosen.

e. Identifying relationships and patterns skill:

تومانسون وآخرون (٢٠٠٩/٢٠١٣) defined it as the ability to find the extent of the relationship between things and the extent of interaction between them.

The ability to compare ideas and events to determine the type of relationship and system between two or more (صالح، وغالب، ٢٠٢١).

The ability to perceive the ways and methods in which the elements are related (خليفة، وحسن، ٢٠٢٠)

The researcher defines it operationally as the ability of STEM students to recognize the relationships between parts of the topic or challenge and how they are related.

Identifying relationships and patterns skill is a skill that enables the learner to clarify the internal relationships that determine patterns and relationships. Relationships are cause

and effect, a vertical relationship, a temporal relationship, a partial relationship, the relationship of the whole to the part, or a transformational relationship. This skill depends to a large extent on the knowledge of the content by the learner as well as the experience he has gone through, Finding the relationships between the elements and components of the concept is a mental work that requires students to identify the elements to make them more important in the minds of the students and to think about the components of knowledge or the concept helps the learner to identify what must be brought to mind to deal with it Thus, the goal is to summarize the main and sub-ideas and determine the importance of each element , and arranging the concepts from the most general to the least, according to the relations that link them (رشيد، وحمود، ٢٠٢٠ ؛رزوقي وسهيل، ٢٠١٨).

4. Factors that effect on analytical thinking skills:

Beyaztaş and Senemoğlu (2015) showed that in situations where learning environments are based on memorization, surface learning is reinforced, and students move away from deep learning.

The study of AKKUŞ-ÇAKIR and Senemoğlu (2016) indicated that among the factors that affect the development of analytical thinking in higher education are the following:

a. The presence of memorization-based learning in practice.
b. The readiness level of the students, the effectiveness of the education they receive and the learning experiences.
c. Decreased interest in activities, especially extracurricular activities such as seminars and conferences.

Yulina et al. (2022) study also reported that factors that influence developing analytical thinking skills are:

a. The compatibility of media use to learning materials.

b. The role of instructors in the learning process and media use.

c. The suitability of the used media in learning with student circumstances.

5. The roles of teachers in developing analytical thinking:

The teacher has a vital and important role in acquiring and developing analytical thinking these roles mentioned below:

a. Uses activities that develop students' curiosity.

b. Enhances students' openness to new ideas.

c. Facilitates learning for students instead of just assimilation.

d. Provides support and encourages discussions among students, which constitutes a challenge to them and their participation.

e. Helps students build knowledge and solve problems.

f. Provides a constructive learning environment (إسماعيل، ٢٠١٧.

Developing analytical thinking skills requires a teacher with extensive knowledge of methods and strategies, so that he can activate the role of the learner in the educational process through his participation in the search and investigation of information and the acquisition of various skills (صالح، و غالب، ٢٠٢١.

6. Significance of Analytical thinking: (Changwong et al., 2018; Furqan et al., 2016; Wahyuni & Analita, 2017; Yilmaz & Saribay, 2017).

a. Making students able to think logically while reviewing facts in more detail.

b. Facilitating the distinction and separation of the smallest parts of the whole learning material down to the basic principles.
c. Comprehending information comprehensively, correlates between components and comprehend the relationships between these components.
d. Developing new knowledge and creating innovations.
e. Helping students to evaluate and critique their ideas.

Considering the importance of analytical thinking, many studies have covered it, including:

The study of (٢٠١٧) إبراهيم asserted that learners who are adept at analytical thinking can look carefully and wisely at the issues that their society faces, allowing them to assess them accurately making correct judgments and preparing them to deal with the conditions of practical life, the abundance and complexity of information, and face an increasingly complex future full of changes.

(٢٠١٩) حسن study expressed that The importance of analytical thinking is evident in focusing on perceiving a problem and examining it carefully, the relationships between them, collecting the largest amount of information related to the problem, which helps in reaching the appropriate solution to it, and employing these solutions if faced with a problem similar to it, and using solutions also in facing other problems, and flexibility in employing them to suit the problem.

Damyanov & Tsankov (2018) mentioned that students who are adept at analytical thinking may create and sketch mind maps of intricate ideas and facts, understand and analyze them, create many solutions to a problem, and select the best ones.

Karenina et al. (2020) reported that students with high analytical thinking skills could approach problems in a deliberate, independent, and thorough manner and attain the learning outcomes in a better form.

7. Analytical thinking through challenge based learning:

One of the educational approaches that can help fostering analytical thinking skills is Challenge based learning aims to keep up with modern challenges to achieve the overall quality of all educational outcomes, as university students' education faces many challenges in the era of globalization, the Internet, the communications and information revolution, the era of electronics, and the era of smart technology. All of this necessitates selecting the most effective models, entryways, and techniques that support students' thinking and learning.

Because of the importance of this style of thinking, some previous studies sought to develop it by using different models, programs, strategies and methods in various academic levels and subjects, including:

The research of (٢٠٢٠) عافية aimed to identify the effectiveness of a program based on brain-based learning in developing the habits of mind, analytical thinking, and achievement among students of the master; the sample was 27 students from Imam Abdulrahman bin Faisal University in Saudi Arabia. The researcher used the experimental method (control group and experimental group) and applied a scale for habits of mind, a scale for analytical thinking, and an achievement test in the course for gifted people with learning difficulties. The results showed that there were statistically significant differences at the level of 0.05 of the analytical thinking scale, habits of mind scale and achievement test for the experimental group.

The research of Spaska et al. (2021) aimed to using debates as instructional approach to foster the analytical thinking in tertiary students and the results mentioned that debates fosters the analytical thinking skills because it motivates students and engages students in learning better, the research used pretest and posttest measurement on a focus group by applying the test of analytical skills which consists of on12 multiple-choice with 12 situations questions on 22 of tertiary students.

The study of (٢٠٢٢) أحمد واخرون aimed to develop mathematical proficiency and analytical thinking among 6th grade using the mental mathematics program, the research applied analytical thinking test on the sample consisted of (35) students from 6th grade in primary school in Assiut by following quasi experimental approach (control group and experimental group) and the results approved that the mental mathematics program improved the analytical thinking skills and mathematical proficiency.

The research of Hudin & Yi (2022) aimed to determine the impact of impact of Service-Learning on Analytical Thinking, and Cultural Adaptation ,Communication Skills of University Students and reported that Service-learning has a positive impact on analytical thinking skills, this research used the deductive approach, applied a questionnaire which is closed-ended questions rely on the 5-point Likert scale on 129 university students in Malaysia selected by stratified random sampling and this research recommended that universities should incorporate more service-learning projects into their curricula, train instructors more about service-learning, and forge strong partnerships with the society to give students variety of opportunities for improving their analytical thinking

According to Maison et al. (2022) analytical thinking skills among students affected by 52.2% through applying e-modules based on science process, science process skills has a positive effect on analytical thinking skills, the research dealt with random sample consisted of 30 students from senior high school and used assessment questions on temperature and heat material in Indonesia.

It is evident from previous studies that the studies were carried out utilizing various methods and programs to foster analytical thinking at different academic levels. This study supports earlier studies in this regard, I have benefited from literature and previous studies on analytical thinking to identify its skills and choose the appropriate, in addition to knowing its characteristics.

Methodology

1. Preparing the suggested program in the light of Challenge Based Learning:

To achieve the aims of the research, the researcher prepared the suggested program in the light of challenge-based learning, and it was constructed by following the following steps:

a. **Determine the title of the suggested program:**

A suggested program in biotechnology in the light of challenge-based learning, which may be useful in developing analytical thinking skills.

b. **Preparing the introduction to the suggested program in biotechnology.**

c. **Determine the basis for constructing the suggested program:**

The suggested program is in the light of challenge-based learning, the following was considered:

- The nature of biotechnology.
- The nature of technological progress.
- The nature of the students of the Faculty of Education as teachers of the future.
- Logical organization of biotechnology topics.

d. **Determining big ideas of the suggested program:**

A set of big ideas for the program have been defined.

e. **Determining learning outcomes of the suggested program:**

A set of learning outcomes of the program have been defined, considering that the learning outcomes are clear, specific, diversified, achievable and measurable, and the learning outcomes emanating from the big ideas of the program have been prepared by following Depth of knowledge taxonomy.

f. **Selection of the scientific content of the suggested program:**

Topics in biotechnology were chosen for the proposed program for several reasons, which are described in the following:

- Aligning them with the general framework of the Egyptian curriculum to ensure that students acquire the necessary knowledge, skills, and competencies.
- The novelty of the program topics to keep pace with the tremendous developments in the fields of knowledge.

- It contains a set of scientific concepts that suit the level of students and contribute to demonstrating their progress.
- The possibility of applying the challenge-based learning
- The teaching time of the program is sufficient for the researcher to develop analytical thinking skills among students.
- It provides the opportunity for students to ask several questions, which encourages analytical thinking and the development of their skills.

The suggested program in the light of challenge-based learning consists of 6 main challenges:

- The first challenge: Using stem cells in the treatment of leukemia.
- The second challenge: Creating xenobots to collect microplastics from the oceans.
- The third challenge: The formation of epithelial tissue by bioprinting.
- The fourth challenge: Treating Leber's Congenital Amaurosis disease using CRISPR technology.
- The Fifth challenge: Detecting heavy metals by using biosensors.
- The sixth challenge: Using genetic vectors in the treatment of hemophilia.

g. **Determining the educational activities and techniques:**

Considering the student's performance expectations and according to the program and the scientific content, a set of educational activities has been designed that varied between

individual and teamwork activities represented by research and investigative activities.

h. **Determining learning resources:**

A variety of learning resources were used, including scientific books, scientific research published in scientific journals, research papers from scientific conferences, and scientific articles from research sites and foreign university sites in addition to a group of photos and videos were used.

i. **Determining assessment methods:**

Both formative evaluation and summative evaluation were used by the researcher, where evaluation tools were represented in electronic portfolios, rubrics for presentations and reports, electronic posters, and quizzes.

j. **Determining the validity of the program:**

After completing the preliminary form of the suggested program, it was presented to a group of professors at the Faculty of Science and professors in the field of curricula and teaching methods to express their opinions and suggestions about the program and the program has been modified in the light of the group of arbitrators. The suggested program in the light of challenge-based learning in its final form is valid for application.

2. **Preparing the Analytical Thinking test:**

To achieve the aims of the research, the researcher prepared an analytical thinking test, and it was constructed by following the following steps:

a. Determine the aim of the test:

The test aims to measure the development of some analytical thinking skills among students of the faculty of Education in STEM Department.

b. Determine the skills for exam:

To answer the first question of the research questions, which states: What are the analytical thinking skills that should be developed among STEM students at the faculty of Education? The researcher prepared an initial list of analytical thinking skills, which included (16) main skills after reviewing some research literature and previous studies that dealt with the skills of analytical thinking.

Table 1

Specifications of the analytical thinking test according to the relative importance

Comparison	**Observation**	**Ordering and determining the priorities**	**Attributing**	**Identifying relationships and patterns**	**The skills** / **Relative importance**
17.45%	18.08%	18.3%	19.45%	26.71%	Relative importance based on the opinions of the arbitrators
6	6	6	7	9	Number of questions

c. Formulation of test phrases:

By reviewing some of the literature that dealt with analytical thinking skills, a test of analytical thinking was formulated by determining the skills included in the analytical thinking that the research will adopt and then formulating their phrases in the form of more than one type of question; This is due to its relevance to the characteristics of analytical thinking skills.

d. Test Grade Rating:

The test scores were estimated by giving each of the test questions one point in the case of the correct answer and zero in the case of the wrong answer, and the total score became (34) degrees.

e. Submitting the test to a group of arbitrators in the field of curriculum and teaching methods.

f. The pilot experimentation of the Analytical Thinking Test:

After preparing the test, the researcher experimented with the Analytical Thinking Test to ensure its validity, and calculate its reliability and validity, by applying it to a piloting group consisting of (128) male and female students from the first year of the STEM Department at the Faculty of Education, Zagazig University in the second semester of the academic year 2021/2022 AD, to:

Calculating the reliability of the test:

The reliability of the Analytical Thinking test was calculated by calculating Cronbach's (Alpha) coefficient using SPSS program Ver 27.

Table 2

Cronbach's alpha coefficients and correlation coefficients for the questions of the Analytical Thinking Test with the total score of the skills they belong to if the question's score is omitted from the total skill score.

The correlation coefficient for the overall skill score	Cronbach's Alpha	Question number	The skill
0.909**	0.953	3	**Identifying relationships and patterns**
0.857**	0.957	21	
0.913**	0.953	23	
0.839**	0.958	27	
0.895**	0.954	29	
0.858**	0.956	30	
0.858**	0.956	31	
0.802**	0.960	32	
0.913**	0.953	33	
	0.960		The overall skill score reliability
0.867**	0.886	1	**Attributing**
0.913**	0.879	2	
0.892**	0.882	4	
0.724**	0.906	5	

0.755**	0.903	6	
0.755**	0.901	19	
0.715**	0.908	20	
	0.909		The overall skill score reliability
0.912**	0.920	8	**Ordering and determining the priorities.**
0.833**	0.934	9	
0.886**	0.925	10	
0.859**	0.930	11	
0.924**	0.918	12	
0.832**	0.934	13	
	0.938		The overall skill score reliability
0.884**	0.899	22	**Observation**
0.857**	0.904	24	
0.774**	0.921	25	
0.898**	0.896	26	
0.866**	0.902	28	
0.809**	0.915	34	
	0.921		The overall skill score reliability
0.791**	0.842	7	**Comparison**

0.847**	0.824	14
0.712**	0.859	15
0.799**	0.838	16
0.778**	0.841	17
0.725**	0.851	18
	0.866	The overall skill score reliability
	0.949	**The reliability of the test as a whole**

Note. **sign at level (0.01)

As shown in table (2):

1. Cronbach's alpha coefficient for each question is less than the correlation coefficient for the overall skill score, which means that all questions on the test are reliable.

2. All correlation coefficients between each question and the overall skill score which belong to it statistically significant at level (0.01), which indicates the internal consistency and the reliability of all questions of the Analytical Thinking Test.

- **Internal Consistency:**

The internal consistency was calculated using SPSS program. Ver. 27 by calculating the correlation coefficient between the score of each skill of the Analytical Thinking Test and the overall score of the test. This is illustrated in Table (3).

Table 3

Correlation coefficient between the score of each skill of the Analytical Thinking Test and the overall score of the test

The skill	The correlation coefficient of the total score
– Identifying relationships and patterns	0.563**
– Attributing	0.880**
– Ordering and determining the priorities	0.873**
– Observation	0.764**
– Comparison	0.613**

Note. **sign at level (0.01)

As shown in Table (3) that there is a statistically significant correlation at the level (0.01) between the degree of each of the six sub-skills of the Analytical Thinking Test and the total score of the test, where the correlation coefficients extended between (0.563-0.880) and all of them are statistically significant, which indicates internal consistency For the skills of the test, and thus all the questions of the test are reliable. This means that the Analytical Thinking Test has a high degree of reliability, which increases the reliability of its use for the purpose for which it was prepared.

f. Calculating the validity of the test:

- **Content Validity:**

The Analytical Thinking Test was shown in its initial form to a group of arbitrators specialized in the field from among the faculty members to judge the validity of this test and its suitability for measuring what was designed to measure it. Considering the review of the opinions of the arbitrators, amendments were made, and the paragraphs agreed upon by (80%) of the arbitrators were approved.

- **Face validity:**

This was achieved through the clarity of the analytical thinking test questions to the student, and the clarity of its instructions, then verifying the validity of the test's validity by applying it to the exploratory sample.

g. Determining the time of the test:

The time to answer the questions of the Analytical Thinking Test was determined by recording the time that the first student took to answer the questions and was (23) minutes, and the time taken by the last student was (41) minutes, and the average time needed to answer the test was calculated.

- Calculation of the experimental time for applying the test:

  Experimental time = (the time was taken by the first student to finish answering the test + the time was taken by the last student to finish answering the test)/2

  Experimental time of the test = (23 + 41)/2 = 32

- Calculating the experiential mean of applying the test:

  Experimental mean = total scores obtained by students / number of students

Experiential mean = 1564/128 = 12.22

- Calculating the expected mean of applying the test:

  Expected mean = vocabulary number/2

  Expected mean = 34/2 = 17

  Appropriate time = experimental time * (expected mean / experimental mean)

  = 32 * (17/12.22) = 44.5 minutes

- From the above, the time required to apply the Analytical Thinking Test is approximately (45) minutes.

- **Results of the analytical thinking test:**

The validity of the first hypothesis is tested, which states: **There is a statistically significant difference at the significance level (0.01) between the mean scores of the experimental group students in the pre- test and posttest of the analytical thinking test as a whole and in its sub-skills in favor of the posttest.**

To verify the validity of the hypothesis, the SPSS Ver. 27 program was used. The researcher used the paired Samples T-Test to determine the significance of the difference between the mean scores of the students of the experimental group in the pre-test and post-test of the analytical thinking test as a whole and in its sub-skill, and this is illustrated by the table (4), and table (5).

Table 4:

The value of (t) and its statistical significance between the mean scores of the students of the experimental group in the analytical thinking test as a whole and in its sub-skills in the pre-test and post-test.

T- value	Standard deviation (σ)	Mean ($\bar{x}$)	The application (N=30)	The skill
8.55**	3.24	3.23	Pre- test	**Identifying relationships and patterns**
	1.43	8.2	Post-test	
12.34**	1.12	1.9	Pre- test	**Attributing**
	1.22	5.55	Post-test	
10.38**	1.17	1.28	Pre- test	**Ordering and determining the priorities.**
	0.64	4.18	Post-test	
7.09**	2	1.97	Pre- test	**Observation**
	0.82	4.53	Post-test	
7.26**	1.97	2.37	Pre- test	**Comparison**
	0.96	5.37	Post-test	
13.85**	6.55	10.95	Pre- test	**The test as a whole**
	3.66	27.73	Post-test	

It is noted from Table 4:

1. The mean score of the students of the experimental group in the post-test was (27.73) higher than their mean score in the pre-test (10.95) in the analytical thinking test as a whole and for each sub-skill about their mean score in the pre-test.
2. The value of (T) calculated for the test as a whole is statistically significant at the significance level (0.01), reaching (13.85) for the test as a whole.
3. All (T) values calculated for each skill of analytical thinking are statistically significant at the level of significance (0.01), which indicates that the students of the experimental group excelled in the post test of the analytical thinking test over the pre-test.

Table 5

The value of (t) and its statistical significance and the values of the square of (η^2), (dand the size of the impact of the experimental treatment on the development of analytical thinking skills as a whole and its sub-skills for the students of the experimental group in the pre and posttests.

The size of the effect	d- value	η^2-value	degrees of freedom (df)	T-Value	The skill
High	3.18	0.72	29	8.55**	**Identifying relationships and patterns**
High	4.59	0.84	29	12.34**	**Attributing**

High	3.85	0.79	29	10.38**	**Ordering and determining the priorities.**
High	2.69	0.65	29	7.26**	**Observation**
High	2.63	0.63	29	7.09**	**Comparison**
High	5.14	0.87	29	13.85**	**The test as a whole**

It is noted from Table 5:

1. The high value of (η^2) for the skills of analytical thinking and for the test as a whole, as sit ranged between (0.63-0.87).
2. The value of (d) increased, as it ranged between (2.63 – 5.14), which indicates a great effect size of challenge-based learning in biotechnology in developing some analytical thinking skills among STEM students at the faculty of Education.

In the light of the previous results, it is clear that challenge-based learning in biotechnology has a high impact on the development some analytical thinking skills among STEM students at the faculty of Education, Therefore, the first hypothesis of the research is accepted , which states There is no statistically significant difference at the level of significance (0.01) between the mean scores of the students of the experimental group in the pretest and posttest of the analytical thinking test as a whole and in its sub-skills.

The validity of the second hypothesis is tested, which states: **There is an effectiveness of challenge-based learning**

in developing some analytical thinking skills among STEM students in the Faculty of Education.

To verify the validity of the hypothesis, The researcher calculated Blake modified gain ratio to determine the effectiveness of experimental treatment in developing the analytical thinking skills as a whole and its sub-skills among the students of the experimental group in the pre -test and post-test, and this is illustrated by the table (6).

Potency	Blake modified gain ratio	Mean		Degree	The skill
		Post-test	Pre-test		
High	1.4	8.2	3.23	9	**Identifying relationships and patterns**
High	1.2	5.55	1.9	7	**Attributing**
High	1.1	4.18	1.28	6	**Ordering and determining the priorities.**
High	1.4	4.53	1.97	5	**Observation**
High	1.3	5.37	2.37	6	**Comparison**
High	1.3	27.73	10.95	33	**The test as a whole**

It is noted from Table 6:

the values of Blake modified gain ratio for the experimental group in the test of analytical thinking skills as a whole and in its sub-skills are high values ranging from (1.1-1.4

) which are therefore located in what Blake identified for effectiveness, and this means the effectiveness of challenge-based learning of biotechnology in developing some analytical thinking skills Therefore, the second hypothesis is accepted.

- **Discussion and interpretation of the results:**

Examine of tables (4,5,6) shows that There is statistically significant difference at the level of significance (0.01) between the mean scores of the students of the experimental group in the pretest and posttest of the analytical thinking test as a whole and in its sub-skills, in favor of the posttest. Also, the size and strength of the impact of challenge-based learning in developing some analytical thinking skills as a whole and in its sub-skills is high.

This could be due to:

1. The nature of the scientific content of the suggested program, as it includes topics and information closely related to the student's reality, helped his integration with the content, as well as the link of the program activities with his daily life.
2. Students get the chance to use search and information exploration techniques while engaging in program themes, which improves their capacity to analyze.
3. The program contains information that helps students in grasping the connections between many scientific fields which develops the skill of identifying relationships and provides opportunities for positive participation of students to think.
4. The group work of students is one of the factors contributing to the development of analytical thinking, because each student benefits from the experiences of his

colleagues while practicing activities and solving thought-provoking questions.

This result is consistent with the results of the research of: (عافية، ٢٠٢٠; Spaska et al., 2021; أحمد واخرون، ٢٠٢٢ ; Hudin & Yi, 2022; Maison et al., 2022).

Recommendations of the study.

Considering the results of the research, the following recommendations can be made:

a. Holding seminars for teachers and mentors in the field of science education to learn about the foundations of challenge based learning.
b. Directing the attention of the curriculum planners and developers at the various educational phases to a new type of learning, this is challenge-based learning, to include its own activities in the curricula.
c. The necessity of training science teachers on how to apply the challenge-based learning approach.
d. Introducing teachers to the skills of analytical thinking and methods of developing them among students.

Suggestions for the Study.

Based on what the research results indicated, the following suggestions can be made:

a. Building educational programs considering challenge-based learning to develop a number of educational outcomes such as scientific literacy, cognitive curiosity, scientific self-efficacy, and representational competence.

b. Evaluation of biology books in the light of biotechnology at the secondary stage.

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