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E-training environment for developing Capstone teaching skills for STEM teachers in Egypt

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Abstract

The research investigated the efficacy of utilizing an e-training environment to enhance capstone teaching skills among STEM educators. Conducted at Obour STEM School, Cairo, Egypt, the study employed a quasi-experimental design with 27 randomly selected participants. Three instruments were utilized: a list of Capstone teaching skills, a pre-post achievement test, and an observation card assessing skill acquisition in two main fields: EDP Field and Process Management Field. These fields encompassed eight main skills, subdivided into 64 subskills. The researchers conducted pre- and post-testing, initially administering a 70-question pre-test followed by a month-long online training via Microsoft Teams. The training content aimed to address identified needs based on pre-test results. After the training, participants completed a post-test, which was repeated after another month. Results indicated a statistically significant difference ($p<=0.05$) between pre-test and post-achievement test scores, favoring the latter, suggesting improvement in Capstone teaching skills. Similarly, there was a significant difference ($p<=0.05$) between pre-test and post-observation card scores, indicating enhanced skill development. Conclusively, the study

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demonstrated the effectiveness of e-training, particularly employing the SOLE technique, in enhancing capstone teaching skills among STEM educators. Consequently, the researchers recommended the integration of e-training environments in STEM teacher development programs in Egypt.

Keywords: E-training environment, Capstone (The Applied projects), Capstone teaching skills

1. Introduction

Technology has become an essential part of our lives, and it is everywhere around us. Although it has a significant role in education in general, it is still not widely implied in our classrooms, and the traditional methods dominate our educational system, whether it is on the level of teaching in the classroom for the students or on the level of training for professional development for teachers. In the past decade, the rapid development of computer and Internet technologies in the field of education has changed the ways of teaching, learning, and training. Digital education and e-learning applications offer easy access to knowledge domains and learning processes from everywhere for everybody at any time. Furthermore, information and computer technologies are considered some of the most beneficial teaching tools supporting student learning in the classroom (Lamb, R.L., Annetta, L., Firestone, J., Etopio, 2018).

STEM education, encompassing science, technology, engineering, and mathematics, serves as the cornerstone of modern societies, driving innovation and economic growth. Stemming from the need to cultivate a skilled workforce capable of tackling complex challenges, STEM education integrates multidisciplinary curricula across all grade levels. By nurturing skills such as critical thinking, problem-solving, and collaboration, STEM education prepares students for success in diverse fields and fosters informed citizenship in an increasingly technological world.

This is due to the fact that STEM students have the ability to identify, apply, and integrate concepts from science, technology, engineering, and mathematics to understand complex problems and innovate to solve them. Meng, Idris, & Eu, 2014: 219–220.

The National Science Foundation (NSF) introduced the idea of STEM in the late 1990s in the United States. Originally, the acronym was SMET, but after various studies, it evolved into STEM (Williams & Larwin, 2016). The word S.T.E.M. is an acronym for science, technology, engineering, and mathematics. Many researchers may use this acronym to define education for science, technology, engineering, and mathematics. STEM is defined by the separate subjects that constitute it (Bybee, 2010). Education for science, technology, engineering, and mathematics should be defined as an integrated

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curriculum and education. This is excellently achieved by removing any boundaries between subjects and treating them as one subject (Morrison, 2006).

Capstone projects in secondary education play a pivotal role in preparing students for higher education and the workforce by fostering critical thinking, problem-solving skills, and project management abilities (Johnson, 2017). These culminating projects provide students with the opportunity to apply the knowledge and skills they have acquired throughout their secondary education in a real-world context. By engaging in a substantial and self-directed project, students develop research and analytical skills while also honing their ability to communicate effectively both orally and in writing (Smith & Brown, 2019). Furthermore, capstone projects often encourage interdisciplinary exploration, allowing students to integrate concepts from various subject areas and develop a holistic understanding of complex issues (Garcia & Martinez, 2020). Overall, capstone projects serve as a bridge between secondary education and future academic or professional pursuits, equipping students with the tools and experiences necessary for success in their future endeavors.

The capstone process in secondary education is used to culminate the Master of Arts in Teaching program and provides an avenue for deeper investigations of the curriculum (Brown & Benson, 2005). Capstone purposes include the synthesis and application of prior learning, developing skills related to employability, and quality assurance, with a broad range of purposes and an affective dimension (Lee & Loton, 2019). Capstone and large projects in computing education can provide students with real-world experience and support learning through creative activities and collaboration with external stakeholders (Artzt et al., 2012). Capstone effectively prepares future secondary mathematics teachers by linking college mathematics with school mathematics and pedagogy and fostering student-centered pedagogical and assessment strategies (Sherriff & Heckman, 2018).

Combining project-based learning with STEM can increase effectiveness, generate meaningful learning, and influence student attitudes toward future career pursuits (Tseng et al., 2013).

Improved Capstone (ICap) in STEM programs strengthens critical thinking, quantitative reasoning, teamwork, communications, information literacy, and the design process, enabling students to assume greater responsibility for learning experiences (Eppes et al., 2012).

Recently, there has been a growing recognition of the importance of providing effective training for STEM teachers to meet the evolving needs of STEM education. Research indicates that well-designed professional development programs can significantly impact teachers' confidence and competence in delivering STEM instruction (Czerniak et al., 2020). Effective

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STEM teacher training emphasizes hands-on, inquiry-based approaches that align with best practices in STEM education (Banilower et al., 2018). Moreover, research highlights the importance of ongoing support and collaboration among educators to sustain effective STEM teaching practices (Shernoff et al., 2017). Recent studies have also underscored the value of incorporating technology-enhanced learning experiences and real-world applications into STEM teacher training programs (Yang et al., 2021). By equipping educators with the knowledge, skills, and resources needed to engage students in meaningful STEM learning experiences, comprehensive teacher training programs play a crucial role in advancing STEM education and preparing students for success in the 21st-century workforce.

Improving capstone experiences in STEM programs requires a concerted effort to develop teachers through e-training environments. Recognizing the pivotal role of educators in facilitating capstone projects, e-training environments offer flexible and accessible platforms for professional development. Research suggests that such virtual training initiatives can enhance teachers' pedagogical skills and confidence in guiding students through complex capstone projects (Nulty et al., 2018). These e-training environments often incorporate interactive modules, collaborative forums, and multimedia resources tailored to the unique needs of STEM educators (Khan, 2019). Moreover, leveraging technology-enhanced learning methods can enable teachers to stay abreast of emerging trends and best practices in capstone design and implementation (Freeman et al., 2020). By empowering educators with the necessary tools and knowledge, e-training environments play a crucial role in ensuring the success and effectiveness of capstone experiences in STEM programs, ultimately preparing students for real-world challenges in their respective fields.

Many e-training environments and processes are based on participatory learning models in which participants share their understandings and aim to develop new insights into their workplace knowledge through discussion, questioning, mentoring, and personal reflection. Knowledge production is assumed to occur through the cumulative effect of these actions. However, equally likely outcomes include the sharing of ignorance or the development of erroneous understandings. Cognitive and social views of learning posit, however, that humans learn by thinking (not just by interacting) and that unless this is explicitly taken into account in developing training programs, optimal learning outcomes may not be achieved. This paper examines the importance of e-training environments in order to maximize the potential for optimal learning to occur and provides STEM teachers with all the tools that they need to develop their skills in teaching Capstone.

E-learning technologies have been diversified through the last decades, as many technologies have evolved, making great changes in our perception

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of learning and so our methodologies in teaching and training that supported our students and trainees. It is these technologies that the researcher will depend on in this study: -

E- training:

E-learning refers to the use of information and communication technologies (ICT) and electronic devices in education, transforming traditional systems into personalized, flexible ones. It can be referred to as distance learning, virtual education, digital education, web-based training, internet-based training, computer-based training, or technologically enhanced learning. Learning materials can be in text, images, animations, video tutorials, or computer programs. In computer-based training, students learn by executing a specific program on a computer.. Such training materials are usually embedded with computer applications, so the students can practice using the applications as they learn. (Guragain, 2016).

The Self Organized Learning Environment (SOLE): -

A Self-Organized Learning Environment (SOLE) is an environment that encourages curiosity and collaboration through the exploration of big questions using the Internet. Teachers act as facilitators, rather than transmitters of knowledge, in SOLE. Sugata Mitra and his colleagues have researched self-organized learning for over 15 years, earning him the first-ever $1-million TED Prize. At the 2013 TED conference, Mitra invited thinkers to create their own SOLEs and share their discoveries via a School in the Cloud. SOLE allows STEM teachers to deal freely with technology, enhance their search skills, and explore new experiences related to the topic.

The self-organized learning environment (SOLE) is an adaptation of a school space to facilitate inquiry-based learning. Teachers encourage students to work as a community, and answer questions using computers with internet access. Students form groups of about 4 and can change groups at any time. Applying Mitra's rules to STEM teachers can help them communicate effectively, gain new ideas, expand their search areas, and acquire problem-solving skills. Education is a self-organizing system where learning is an emergent phenomenon.

2. The problem of the Research:

Capstone (the applied projects) teaching mainly aims to provide students with different skills, which is one of the most important 21st-century skills. Being one of the researchers as a biology teacher and school general capstone leader, I have noticed that teachers use the same traditional methods in their capstone sessions that do not suit students' needs at all. Moreover, they are not aware of the 21st-century skills they must have firstly and develop

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those skills for the students to achieve all Capstone process and fulfill all stages of Engineering Design Process (EDP) effectively, although they are already trained on using the SOLE strategy in their professional development but, only in the frame of terms not practicing the strategy - this is the second observation for the researcher- being as a trainer, it has been noticed that the training not concerning to develop the needed skills for the teachers to be creative have the ability to communicate correctly with the students and also, not providing them with the searching skills that are needed as well. Therefore, there is a real need to adopt new technologies that enhance and enrich the training experience of STEM teachers. Studies found that efforts should be particularly made to increase STEM teacher supply through well-designed teacher professional development, which is a critical factor in a successful education (Jong 2019a, 2019b). Since STEM is a cross-disciplinary subject, it is expected that students are empowered to apply their disciplinary concepts and skills in integrated contexts (Kelley & Knowles, 2016; Tytler, Prain, & Hobbs, 2019). However, the majority of the current teachers who have received training in only one subject area may be unable to adopt an integrated and holistic approach to teaching STEM (Aslam, Adefila, & Bagiya, 2018). There is an obvious gap in research pertaining to teacher preparation and professional development (Al Salami et al., 2017; Cavlazoglu and Stuessy, 2017). Teachers play a crucial role in equipping students with relevant STEM knowledge and shaping their choice of a STEM career. A study by Lee et al. (2015) found that teachers' expectations of students are particularly influential, and there is a weakness in developing Capstone teaching skills among STEM teachers through training and professional development. The researchers confirmed the problem through direct observation, tracking progress, and interviews with teachers.

A pilot study on 17 STEM teachers for the academic year 2021-2022 revealed that 70% of teachers were unable to develop Capstone teaching skills and apply them in real-life situations with their students. Additionally, 80% of teachers complained about traveling during summer vacations from their countries to attend capstone training, which is costly. The researcher suggested using an e-training environment to emphasize its effectiveness in enhancing teachers' capstone teaching skills in STEM schools.

The researchers also noticed that teachers use traditional methods in their capstone sessions that do not suit students' needs, and they are not aware of 21st-century skills they must have firstly and develop those skills for the students to achieve all capstone processes and fulfill all stages of the Engineering Design Process (EDP) effectively. The training is not concerned with developing the needed skills for teachers to be creative, have the ability to communicate correctly with students, and not providing them with the searching skills that are needed.

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The identified challenges in the educational setting include a lack of foundational scientific knowledge among both teachers and students, as well as a failure to prioritize critical inquiry. Addressing these challenges requires a multifaceted approach, including targeted teacher training and fostering a culture of inquiry within the classroom.

Students often feel disappointed and bored with the capstone sessions, leading to postponing scheduled tasks or working at home. This results in a failure to achieve capstone objectives correctly, losing all anticipated benefits and skills students are supposed to gain at the end of their learning experience in STEM education.

The researcher deduced throughout many studies and research that efforts should be particularly made to increase STEM teacher supply through well-designed teacher professional development, which is a critical factor in a successful education (Jong, 2019a, 2019b). Since STEM is a cross-disciplinary subject, it is expected that students are empowered to apply their disciplinary concepts and skills in integrated contexts (Kelley & Knowles, 2016; Tytler, Prain, & Hobbs, 2019). However, the majority of the current teachers who have received training in only one subject area may be unable to adopt an integrated and holistic approach to teaching STEM (Aslam, Adefila, & Bagiya, 2018). There is an obvious gap in research pertaining to teacher preparation and professional development (Al Salami et al., 2017; Cavlazoglu and Stuessy, 2017). Teachers play a significant role in equipping students with relevant STEM knowledge and shaping their choice of STEM career. Lee et al.'s (2015) longitudinal study employing logistic regression analyses of students' choice of a STEM career indicated that teachers' expectations of students are particularly influential. While the lack of focused study on teacher professional development to foster STEM learning warrants further investigation, the situation seems unsurprising. If it is already challenging for a teacher to master the pedagogical content knowledge.

3. Theoretical Framework:

E-training, synonymous with online learning, employs digital technologies to facilitate remote educational content delivery, fostering collaboration and interactivity among learners. Its objectives span enhancing knowledge acquisition, skill development, critical thinking, motivation, accessibility, and cost-effectiveness, supporting continuous professional development, and fostering collaboration. Moreover, e-training is pivotal for compliance training, measuring learning outcomes, and fostering self-directed learning.

The concept of e-training, or electronic training, has emerged as a transformative approach to delivering educational content and facilitating learning experiences through digital platforms.

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E-training draws upon established theories such as constructivism, connectivism, and engagement theory to inform the design and delivery of effective learning experiences in digital environments, emphasizing active participation, collaboration, and knowledge construction among learners. (Clark & Mayer, 2016).

E-training, synonymous with e-learning, involves the delivery of educational content and instructional materials via the Internet or digital platforms. It enables learners to access training resources remotely, often through web-based applications, learning management systems (LMS), or virtual classrooms, allowing for flexible and self-paced learning experiences (Mesidor & Anderson, 2022).

The study by Alizadeh et al. (2021) discussed e-training and its impact on the training environment. It mentions that online training can provide efficiencies and advantages, but adjustments may be needed by adopting organizations. It offers the flexibility for learners to proceed at their own pace and engage in self-directed learning while also providing opportunities for interaction with trainers and other learners through online platforms.

E-training environments encompass various digital platforms and settings where electronic training activities take place. These environments facilitate the delivery of educational content and interactive learning experiences.

- *Learning Management Systems (LMS)***:** LMS platforms provide centralized hubs for organizing, delivering, and tracking e-training activities. They offer features such as course creation, content management, assessment tools, and learner analytics, enabling efficient management of training programs in corporate, academic, and organizational settings (Norberg et al., 2011).
- *Virtual Classrooms***:** Virtual classroom environments simulate traditional classroom settings using web conferencing tools and real-time communication technologies. They facilitate interactive lectures, discussions, group activities, and live demonstrations, allowing remote learners to engage in synchronous e-training sessions (Abrami et al., 2008).
- *Mobile Learning (M-Learning) Platforms*: M-learning platforms deliver e-training content and activities through mobile devices such as smartphones and tablets. These platforms leverage mobile apps, responsive websites, and multimedia resources to provide on-the-go access to training materials, enabling learners to engage in self-paced learning anytime, anywhere (Kukulska-Hulme & Traxler, 2007).
- *Social Learning Platforms***:** Social learning platforms integrate social networking features with e-training content, fostering collaboration, knowledge sharing, and community building among learners. These

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platforms facilitate peer interaction, mentorship, and informal learning experiences through discussion forums, blogs, wikis, and multimedia sharing (Dabbagh & Kitsantas, 2012).

An e-training environment refers to a digital platform or system that is used for delivering educational or training content to learners over the internet. It provides a virtual space where learners can access learning materials, participate in interactive activities, and engage in collaborative learning experiences (Cheng et al., 2023).

These environments can support different types of training, including language training, technical training, and professional development. They enable learners to study at their own pace, access a wide range of resources, and receive guidance and feedback from instructors. They can be particularly beneficial in situations where physical classroom attendance is not possible, such as during pandemics or for remote learners, and provide flexibility and convenience, allowing learners to access educational content anytime and anywhere with an internet connection (Kim et al., 2023).

From the previous study, the researchers concluded that e-training environments like Microsoft Teams have emerged as integral tools in modern education, offering a versatile platform for online learning (Microsoft, 2024). With features tailored for educational purposes, such as virtual classrooms, document sharing, and real-time collaboration, Microsoft Teams facilitates interactive and engaging learning experiences (Microsoft, 2024). The platform's integration with the Microsoft Office suite enhances productivity and enables seamless content creation and sharing (Microsoft, 2024). Furthermore, the chat and video conferencing functionalities allow for synchronous communication, enabling educators to provide immediate feedback and support to students (Microsoft, 2024). As a result, Microsoft Teams empowers educators to create dynamic and interactive virtual learning environments that cater to diverse learning needs (Microsoft, 2024).

A set of theories explains how learners are trained, how knowledge is introduced, and how that knowledge is processed within the learner's mind. For e-training environments to be purposeful and effective, they must be based on an underlying approach. Future progress in e-learning will come from a better understanding of training mechanisms, not just from technological improvements or their utilization (Abu Khatwa, 2010).

A capstone project is a multifaceted assignment that serves as a culminating academic and intellectual experience for students, typically at the end of their academic program. It often involves research, critical analysis, problem-solving, and the synthesis of knowledge and skills acquired throughout the course of study.

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4. Questions of the Research: The problem of the research tackled the following main question: "What is the effectiveness of E-training environment for developing Capstone teaching skills for STEM teachers in Egypt?"

The main question is branched into four subsequent questions as follows:

- What are the most important Capstone teaching skills for STEM teachers?
- What is the perspective of an E-training environment content to develop Capstone teaching skills for STEM teachers?
- What is the effect of using an E-training environment content to enhance the Capstone teaching skills of STEM teachers?
- What is the effect of using an E-training environment content to enhance the performance aspects of STEM teachers?

5. Objectives of the Research: The research aims to achieve the following objectives:

- To identify the most important Capstone teaching skills for STEM teachers
- To design an E-training environment content to develop Capstone teaching skills for STEM teachers.
- To examine the effectiveness of using an E-training environment content to enhance the Capstone teaching skills of STEM teachers.
- To examine the effectiveness of using an E-training environment content to enhance the performance aspects of STEM teachers.

6. Significance of the Research: This research is believed to be significant for the reasons described below:

This research proposes an e-training environment (SOLE) as an innovative tool for preparing STEM teachers for their Capstone project. The SOLE strategy focuses on developing 21st-century skills such as organization, analytical thinking, creativity, technology use, communication, and problem-solving. The model aims to equip teachers with sufficient STEM knowledge and instruction approaches to address students' learning needs and develop their confidence in STEM education.

The study aims to overcome low performance of capstone teachers and students by providing continuous professional development. The COVID-19 pandemic has made it difficult to provide such training, especially during social distancing. The proposed model ensures ongoing teacher training through unexpected conditions and is suitable for teachers' distancing residency, making the process of professional development more sustainable.

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The research aims to overcome low performance of capstone teachers and students by providing a model that integrates STEM subjects with their capstone project. It also offers a solution for ongoing teacher training during unexpected conditions, making the process more sustainable.

7. Research Variables: The research relied on the following variables:

- Independent Variable: An e-training environment
- Dependent Variables: Capstone teaching skills for STEM teachers

8. Hypotheses of the Research

The research relied on the following hypotheses:

H.1 There is a statistically significant difference ($p<=0.05$) between the pre-test and post-achievement test of the experimental group on developing the capstone teaching achievement of STEM teachers in favor of the post-test.

H.2 There is a statistically significant difference ($p<=0.05$) between the pre-test and post-observation cards of the experimental group on developing the capstone teaching skills of STEM teachers in favor of the post-test.

9. Method

9.1. Participants in the Research

The research targeted the capstone teachers in one of the Egypt STEM schools; 27 of the STEM teachers are all working under the same administration, rules, and work ambiance with different subject areas (Biology, Physics, Chemistry, Mechanics, Geology, Math, English, and Activities). Therefore, the researcher ensured that the target participants shared these characteristics:

1) The teachers obtained similar results in their pre-test. So, they have approximately the same level of knowledge.
2) The teachers have approximately similar rules and work conditions.
3) Teachers have good computer and online communication skills and are proficient in the Microsoft Team platform.
4) They also prefer online learning and are interested in using various techniques in their learning process.
5) All teachers have not been exposed to a capstone training experience using the e-training environment with the SOLE technique.

9.2. Research Design

A descriptive approach was used in the current research to analyze literature related to the research variables, describe and build research tools,

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and discuss and interpret the results. The research employed a quasi-experimental method. The quantitative analysis of the data allowed the researcher to make comparisons between the scores on pre- and post-tests. The research design involved one group of STEM teachers who had been trained through the e-training environment, which is the main independent variable that was applied to the experimental group. All key characteristics of a quasi-experiment were included in this study: (1) a pre- and post-achievement test to measure the cognitive aspect; (2) a pre- and post-note card to measure the skill aspect (skills of the 21st century); and (3) the assigned experimental group. Statistical analysis has been integrated into tables and figures throughout the research to provide a clearer and more accurate reflection of the research findings.

9.3. Instrumentation: The following instruments were designed and utilized by the researchers:

9.3.1. Data Collection Instrument:

The researchers conducted a pilot study on a sample of 17 STEM teachers for the academic year 2021-2022 using an electronic questionnaire divided into two sections: The first section contains 10 multiple-choice questions about the difficulties teachers encounter during capstone training, and the second section is for writing the teachers' comments and suggestions about how to improve the development of capstone teaching skills through the process of professional development. The researchers used Microsoft Forms to write the questionnaire and the Microsoft Team platform to send it.

9.3.2. Measuring Instruments:

1) Survey of the training needs to determine the capstone teaching skills that are needed by the trainees and the degree of need for each one of the main skills and also each one of the sub-skills. The survey is made up of eight main skills and 64 sub-skills.

   After conducting the survey and collecting the responses, the percentage of skill needs ranged from 90.12% to 98.77%. This was taken into consideration when designing the activities, with a focus on addressing the skills that are in higher demand.

2) Pre-post achievement test, which is formed of 70 questions. The pre-achievement test has been sent to the trainees before introducing the training content, then it was resent again after finishing the training content.

   The researchers calculated the validity of the test's internal consistency by calculating the correlation coefficients between the STEM teachers' scores on each of the test items on a random sample of 10 STEM teachers from outside the study sample and within the community. The

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correlation coefficient for the items ranged between 0.730 and 0.854 and reached the overall internal consistency correlation coefficient of 0.811, which indicates that there is internal consistency for the test questions and for the overall test, and thus the internal consistency of the test questions was confirmed.

3) The capstone teaching skills observation card is a list of eight main skills and 64 subskills, distributed over two main areas, which are the EDP field and the management field.
   The researchers calculated the reliability of the observation card and made sure that it would give similar results if it was reused again, as the researcher observed 5 trainees from the piloting sample, as well as enlisted the help of other trainers to observe the performance of the trainees. After monitoring the quantitative estimates of the performance of the trainees in the observation card, the researcher calculated the extent of agreement and disagreement between the researcher (the first observer) and the assistant (the second observer) using Cooper's equation, which states:
   The percentage of agreement = (the number of times of agreement / (the number of times of agreement + the number of times of disagreement)) x 100.
   After applying the equation to the quantitative estimates of the trainees' performance on the observation card, the researcher found an agreement rate of 89.06% for the total skills of the observation card.

9.3.3. Treatment Instrument

The researchers selected the Microsoft Team platform for building the e-training environment because of several factors listed below:

1. Microsoft Team is the official platform used by the Ministry of Education (MOE).
2. All teachers have their own Microsoft Team accounts and can easily access their Capstone channels and interact with their Capstone training content.
3. Teachers use the Microsoft Team platform daily in their teaching process and when making online meetings with their students. Therefore, the researcher explored the benefits of using Teams as an e-learning environment for delivering the training content through the Capstone channel.
4. The Microsoft Team platform can help equip teachers with 21st-century skills like critical thinking skills, communication skills, and problem-solving skills in particular by using all Microsoft Teams tools with their Capstone training content.

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5. The Microsoft Teams platform assists with classroom management and monitoring of the teachers' collaboration and works in real-time sessions.
6. The Microsoft Teams platform tracks the teachers' progress and facilitates the development of Capstone concepts and skills included in their training content.
7. Microsoft Teams can be accessed on any browser or device. Moreover, the researcher designed the E-Training content in the form of PowerPoints, PDFs, and groups of activities and assignments (questions and answers) to measure all levels of Bloom's taxonomy and enhance higher-order thinking by using images, text, animation, and videos. As a result, the training content could foster the development of Capstone concepts and skills included in the different Capstone projects since starting the STEM education project in Egypt.

In this phase, several critical steps were undertaken to create an effective electronic professional development platform. Initially, electronic tools were meticulously crafted to support the training process. This involved the identification of key tools essential for designing the training content, enabling a seamless educational experience. Subsequently, the focal activities within the training content were systematically built, ensuring alignment with the overarching objectives. The production phase also encompassed the development of interactive elements, enhancing engagement and knowledge retention. Furthermore, the content was tailored to encourage active participation among trainees as well as facilitate dynamic interaction between peers and trainers.

9.4. Delimitation of the Research:

- This research has been applied on 27 Capstone teachers from one of the Egypt STEM Schools, during the 2nd semester of the scholastic year 2022-2023 to develop the Capstone teaching skills through designing an academic portal platform (Microsoft Teams) for sharing and delivering the training content materials and applying all needed activities included in the E-training program.
- This research has been applied only for developing the Capstone teaching skills which are correlated to the 21st century skills for STEM teachers

9.5. Data Analysis:

The researchers verified the research hypotheses through the statistical analysis of the collected data that was applied using the Statistical Package for

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Social Sciences (SPSS) Version (21). The researcher analyzed and calculated data by applying the following statistical styles:

1. There is statistical significant difference at the level of ($p<=0.05$) between the pre-test and post- achievement test of the experimental group on developing Capstone teaching achievement of STEM teachers in favor of the post -test.
2. There is statistically significant difference at the level of ($p<=0.05$) between the pre-test and post- observation card of the experimental group on developing Capstone teaching skills of STEM teachers in favor of the post -test.

Learning Theories

Constructivist theory defines learning as the process of adaptation resulting from the learner's functional cognitive systems, whereby they construct their knowledge based on their previous experiences. Its function lies in adapting to organize their perceived world (Yu & Tao, 2007, p. 71).

Activity Learning Theory: Focuses on group collaboration and the Zone of Proximal Development (ZPD), where learners progress with guidance. It emphasizes real-world activities and continuous interaction as mentioned by Shafer and Moss (2010).

Social Learning Theory: Proposes that individuals learn through observation, imitation, and modeling of others' behaviors. Vicarious learning and self-efficacy play crucial roles (Bandura, 1977).

Cognitive Theory: Focuses on knowledge construction and the relationship between perception and reality. It highlights the importance of memory and organizing knowledge (Mayer, 2014). Moreover, Sweller (2010) stated that cognitive learning involves gathering and organizing knowledge.

Behaviorism Theory: Concentrates on observable behaviors learned through conditioning, reinforcement, feedback, and repetition. It also emphasizes social learning and gamification.

Capstone teaching skills

Capstone projects are pivotal in higher education, offering students a comprehensive academic experience by integrating research, critical analysis, problem-solving, and the synthesis of knowledge. These projects, occurring typically at the end of an academic program, take various forms such as research papers, case studies, or presentations, aiming to address real-world challenges relevant to the student's field of study. Interdisciplinary in nature, they require students to draw upon knowledge from multiple disciplines, collaborate with faculty or industry experts, and present their findings

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Kahn & Dell'Olio (2019) define Capstone experiences as culminating, integrative experiences in which students synthesize and apply what they have learned in the major.

STEM education refers to an interdisciplinary approach to teaching and learning that integrates concepts and principles from science, technology, engineering, and mathematics. The aim of STEM education is to prepare students for success in the rapidly evolving fields of science, technology, engineering, and mathematics by fostering critical thinking, problem-solving skills, creativity, and collaboration.

Capstone projects in education represent the culmination of students' academic experiences. They typically occur towards the end of a degree program and integrate learning from various courses and subjects. According to the National Association of Colleges and Employers (NACE), capstone projects allow students to demonstrate the application of knowledge and skills learned throughout their academic experiences (National Association of Colleges and Employers, 2024).

As described by the University of North Carolina at Chapel Hill, capstone projects involve in-depth research and critical thinking to address complex issues (UNC-Chapel Hill, 2023).

According to the University of Washington, Capstone projects allow students to demonstrate their competencies and readiness for further academic or professional endeavors (University of Washington, 2020).

Challenges of Teaching Capstone:

According to O'Reilly and McMahon (2008), accommodating diverse student backgrounds and abilities is a significant challenge in Capstone courses, as instructors must balance providing support for struggling students while challenging more advanced learners.

Capstone projects typically involve complex, open-ended problems that may not have clear-cut solutions. And guiding students while allowing them to explore the needed knowledge may be challenging for the instructors. As noted by Prince et al. (2007), designing meaningful Capstone projects that balance structure and flexibility is essential for ensuring student engagement and learning. According to Strang (2012), securing sufficient resources and support for Capstone projects remains a significant challenge for many educational institutions.

Developing valid and reliable assessment methods that capture the breadth of student learning is a challenge for instructors. As highlighted by Rhoads (2017), assessing the multifaceted outcomes of Capstone projects requires Managing time effectively to ensure that students make progress on their projects while covering essential content and meeting course objectives can be challenging. According to Johnson et al. (2005), time management is a

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common challenge faced by instructors teaching Capstone courses, as they must balance project work with other course requirements.

So that, teaching Capstone projects presents challenges related to managing diverse student backgrounds, guiding students through complex projects, providing adequate resources and support, assessing multifaceted outcomes, and managing time effectively. Addressing these challenges requires careful planning, collaboration, and ongoing reflection to ensure the success of Capstone experiences for both students and instructors.

Capstone teaching skills encompass a diverse set of competencies essential for guiding students through the Capstone project process effectively. These skills include but are not limited to research, decision-making, communication, time management, and critical analysis. Research skills are foundational, enabling students to engage in scholarly inquiry, gather relevant information, and contribute to knowledge advancement (Swanson et al., 2015). Decision-making skills are crucial for navigating complex problems, evaluating alternatives, and selecting the most appropriate course of action, which is essential for successful project outcomes (Kwon & Kim, 2014). Effective communication skills facilitate the dissemination of ideas, findings, and recommendations, fostering collaboration and knowledge sharing among project stakeholders (Wang et al., 2019).

Furthermore, time management skills are essential for students to plan, organize, and prioritize tasks effectively, ensuring the timely completion of project milestones and deliverables (Seiferth et al., 2017). Critical analysis skills enable students to evaluate data, information, and findings critically, drawing meaningful conclusions and actionable insights from their research (Brown & Rutherford, 2016). These skills collectively contribute to the successful execution of Capstone projects, preparing students for academic and professional success beyond the classroom.

STEM concept:

Gonzalez & Kuenzi (2012) pointed out that education gained through the STEM system, which includes multidisciplinary curricula in the fields of science, technology, engineering, and mathematics, holds global importance through its innovative educational approaches.

STEM education is a multidisciplinary approach that contributes to the development of workforce skills in the twenty-first century, higher-order thinking skills, and the development of nations (Erdogan et al., 2017: 614).

The methodology of STEM education emphasizes hands-on learning, inquiry-based approaches, and interdisciplinary problem-solving. Through collaborative projects and real-world challenges, students gain practical experience and develop a deeper understanding of STEM concepts. Integration of technology further enhances learning opportunities, while

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ongoing assessment and reflection support continuous improvement by engaging in practical activities such as experiments, projects, and real-world problem-solving tasks, students not only deepen their understanding of STEM subjects but also develop essential skills like collaboration and communication (Honey et al., 2014).

The objectives of STEM education are multifaceted, aiming to promote innovation, continuous curriculum renewal, and the enhancement of core skills for the twenty-first century. Additionally, STEM education seeks to prepare students for STEM careers, address global challenges, and promote equity and inclusion in education.

STEM teachers play a pivotal role in facilitating inquiry-based learning, integrating technology, promoting collaboration, fostering creativity, and addressing diversity and equity. Moreover, they collaborate with colleagues, industry partners, and community stakeholders to enhance STEM education initiatives and create diverse learning opportunities for all students (National Science Board, 2015). Through their dedication and innovative teaching methods, STEM teachers inspire the next generation of scientists, engineers, and innovators, driving forward progress and innovation in society (Bybee, 2013; Johnson et al., 2018).In Egyptian schools, STEM teachers face challenges such as limited resources and outdated curricula but remain committed to preparing students for the demands of a rapidly evolving world and driving technological advancement and economic development. Despite these challenges, dedicated STEM teachers in Egypt are working tirelessly to inspire and empower their students to pursue careers in STEM fields, driving the nation's progress towards a knowledge-based economy (El-Zeftawy & El Kordy, 2020).

In conclusion, STEM education and the dedicated efforts of STEM teachers are essential for equipping students with the skills and knowledge needed to thrive in an increasingly complex and interconnected world. Through innovative teaching methods and a commitment to excellence, STEM education empowers the next generation of leaders, innovators, and problem-solvers.

10. Findings and Discussions

The researchers utilized two instruments (the achievement test and the observation card test) to test the researchers' hypotheses. The following results were obtained and analyzed using SPSS statistical software version 21.

Findings Related to the First Question: To address the first research question, **"What are the most important Capstone teaching skills for STEM teachers?"**

The researcher answered this question in the third chapter by listing the Capstone teaching skills needed for STEM teachers to manage the applied

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projects (Capstone) that have been prepared in light of the STEM orientation by looking at literature, conference reports, and consultations of some specialists in curriculum and teaching methods, as well as experts in the STEM field. The list in its initial form consisted of two main areas: engineering design process (EDP) skills and management skills. It included eight main skills and 64 subskills for evaluating the work of applied projects in the framework of the KPI,, or Key Performance Indicators. The jury members validated the test and the needed skills, which were both used as the basis for designing the content of the e-training materials.

Findings Related to the Second Question: For the second research question, **"What is the proposed design of an e-training environment to develop capstone teaching skills for STEM teachers?"** The researcher answered this question in the third chapter by identifying the components of the e-training content required to enhance the Capstone teaching skills needed for STEM teachers to manage the applied projects. The researcher used diverse types of tools to help engage the participants and ensure their continual learning. The content has been designed in the form of eight main topics that represent the eight main skills, supported with different activities to ensure engagement of the trainees, followed by quizzes, feedback, and reflection questions as forms that impeded in the training environment. All of the training sessions started with objectives, the main open-ended question, and investigative activities, then ended with a main conclusion.

Also, the researcher developed the instructional design model for the e-training environment following the Elnaggar Model (2013). She designed the E-Training environment on Microsoft Teams as a platform that contained the E-Training content by using the tools that are provided by the Teams application to design many interactive activities, quizzes, and PowerPoint presentations, and integrated it into the Capstone team channel within the Microsoft Team platform. The validity of the E-Training content was confirmed through jury validation, which stated that the E-Training environment was valid and ready to be used by the trainees.

Findings Related to the Third Question: To answer the third research question, **"What is the effect of using an e-training environment to develop the cognitive aspects of capstone teaching skills in STEM teachers?"** The researcher verified the research hypotheses through the statistical analysis of the collected data that was applied using the Statistical Package for Social Sciences (SPSS) Version 21.. The researcher analyzed and calculated the data by applying the following statistical styles to verify the validity of the first hypothesis:

There is a statistically significant difference at the level of (a<=0.05) between the pre-test and post-achievement test of the

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experimental group on developing the capstone teaching achievement of STEM teachers in favor of the post-test.

To verify the validity of the first research hypothesis that states, "There is a statistically significant difference at the level of (a<=0.05) between the pre-test and post-achievement test of the experimental group on developing the capstone teaching achievement of STEM teachers in favor of the post-test," A paired sample t-test was used, as shown in the following table.

Table (1) Results of paired sample t-test to verify differences between mean scores of Capstone teaching skills achievement test in pre and post application

n = 27

Skill	Application	Mean	Std. Deviation	Earning		t	df	Sig.	η^2
				Mean	Std. Deviation				
Capstone teaching skills Achievement	Pre	34.67	3.174	23.407	3.029	40.157	26	0.000	0.984
	Post	58.07	2.319						

Notes from table (1) that mean scores of "Capstone teaching skills Achievement" achievement in pre application reached (34.67) with a standard deviation of (3.174), while the mean score was reached in post application (58.07) with a standard deviation of (2.319), the earned mean score in Capstone teaching skills Achievement was (23.407) with a standard deviation (3.029), the value of t-test between the two mean scores was (40.157), this value has a significance at the level of (0.05), as the calculated significance is equal to (0.000) which is less than (0.05), also the Impact factor has been extracted using Eta^2 via t value resulting from the mean difference in Capstone teaching skills Achievement test for STEM teachers in pre and post test, Where it turns out that Eta^2 value was (0.984) which indicated that the impact of E-training environment moderately achieved to develop Capstone teaching skills Achievement for STEM teachers, which means accepting the first research hypothesis.

The following figure shows differences between mean scores of the pre and post applications of Capstone teaching skills Achievement test for STEM teachers.

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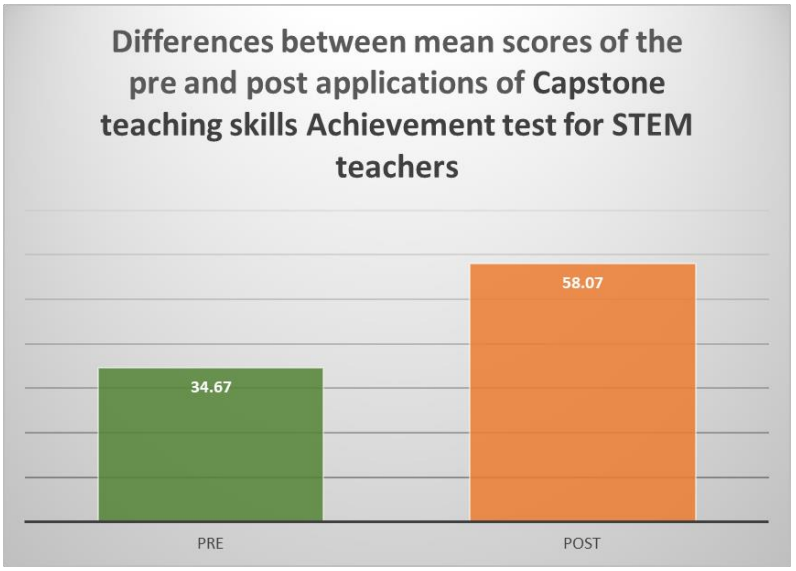

Figure (1) Differences between mean scores of the pre and post applications of Capstone teaching skills Achievement test for STEM teachers

The researcher explains the results of this research by citing the superiority of post-training scores over pre-training scores in the achievement test and the positive impact of the electronic training environment on the development of the cognitive aspects of Capstone teaching skills. This can be explained by the fact that the electronic training environment provided to STEM teachers through the Teams platform, which they are accustomed to using with their students, includes interactive activities, quizzes, PowerPoint presentations, and various interactions conducted directly among themselves and with the trainer. This familiarity led them to strive for mastery of the training content, as the electronic training environment facilitated a range of research activities and the submission of electronic work papers. It also provided training on decision-making skills by exposing them to various virtual scenarios presented through the environment, encouraging them to make decisions individually or collectively. Furthermore, the training included developing designing skills for research projects, practicing analyzing skills when dealing with scientific projects related to Capstone, mastering communication skills and performing their tasks, and training on time management skills and risk management. Additionally, the training covered budget-related skills such as budgeting, and through the various interactive activities offered by the electronic training environment, teachers were able to activate their roles when teaching their students and producing projects using Capstone skills, all of which were made possible through the Microsoft Teams platform. These results align with studies conducted by Katz (2005), Thurasamy et al. (2012), Hatwah (2013), Khatwah (2014), and Kalkan (2020),

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Wilson & Carter (2021), Johnson & Anderson (2021), Mitchell & Davis (2022), Smith & Williams (2022), Martinez (2022), Turner & Peterson (2023), Brown & Clark (2023).

The electronic training environment has been used to develop Capstone teaching skills and achievement, utilizing educational theories to build cognitive aspects. The training process should be cumulative, ensuring trainees have a cognitive and skillful reservoir for diverse educational situations. Interactivity in the environment increases information, knowledge, and skills acquired by teachers, aligning with behaviorist theory. The electronic training environment facilitates teacher interaction with educational activities, allowing for active participation and retention of learning outcomes. It also aligns with constructivist theory, building a skillful inventory based on previously acquired skills in dealing with STEM students. The study also aligns with communication theory, focusing on learning in electronic training environments and exploring how interactions within the environment influence learning through interactive media and tools. This approach views learning through networks within an effective social framework, reflecting contemporary technological advancements.

These results align with studies conducted by Smith & Brown (2021), Johnson & Wilson (2022), Martinez (2022), Brown & Anderson (2023), Wilson & Davis (2022), and Turner & Carter (2023).

There is a statistically significant difference at the level of p<=0.05 between the pre-test and post-observation card of the experimental group on developing the capstone teaching skills of STEM teachers in favor of the post-test.

Findings Related to the Fourth Question: To answer the fourth research question: **"What is the effect of using an e-training environment to develop the performance aspects of** the Capstone **teaching skills of STEM teachers?"** The researcher analyzed and calculated the data by applying the following statistical styles to verify the validity of the second hypothesis:

There is a statistically significant difference at the level of (a<=0.05) between the pre-test and post-observation card of the experimental group on developing the capstone teaching skills of STEM teachers in favor of the post-test.

To verify the validity of the second research hypothesis that states, "There is a statistically significant difference at the level of (a<=0.05) between the pre-test and post-observation card of the experimental group on developing the capstone teaching skills of STEM teachers in favor of the post-test," A paired sample t-test was used, as shown in the following table.

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Table (2) Results of paired sample t-test to verify of differences between mean scores of Capstone teaching skills observation card in pre and post application

Skill	Application	Mean	Std. Deviation	Earning		t	df	Sig.	η^2
				Mean	Std. Deviation				
The research skills	Pre	15.93	1.859	13.963	2.609	27.810	26	.000	0.967
	post	29.89	1.805						
The decision-making skill	Pre	13.44	3.250	11.259	3.265	17.918	26	.000	0.925
	post	24.70	1.031						
The designing skills	Pre	10.44	1.219	7.630	2.420	16.381	26	.000	0.912
	post	18.07	1.752						
The Analyzing skills	Pre	15.81	2.001	12.852	3.613	18.483	26	.000	0.929
	post	28.67	2.646						
Communication skills	Pre	13.93	1.730	15.370	2.976	26.835	26	.000	0.965
	post	29.30	2.091						
Time management skill	Pre	3.96	.706	3.926	1.141	17.878	26	.000	0.925
	post	7.89	.847						
Risk management	Pre	7.11	.801	6.778	1.368	25.742	26	.000	0.962
	post	13.89	1.050						
Budgeting	Pre	6.48	1.282	3.963	1.581	13.027	26	.000	0.867
	post	10.44	.892						
All Capstone teaching skills	Pre	87.65	5.010	75.296	6.330	61.814	26	.000	0.993
	post	162.85	3.581						

The mean scores of "All Capstone teaching skills" observation card in pre application reached 87.65 with a standard deviation of 5.010, while the mean score was reached in post application 162.85 with a standard deviation of 3.581, the earned mean score in The All Capstone teaching skills was 75.296 with a standard deviation 6.330, the value of t-test between the two mean scores was 61.814, this value has a significance at the level of 0.05, as the calculated significance is equal to 0.000 which is less than 0.05, also the Impact factor has been extracted using Eta2 via t value resulting from the mean difference in The All Capstone teaching skills observation card for STEM teachers in pre and post test, Where it turns out that Eta2 value was 0.993 which indicated that the impact of E-training environment moderately achieved to develop Capstone teaching skills for STEM teachers, which means accepting the second research hypothesis

The following figure shows differences between mean scores of Capstone teaching skills observation card in pre and post application.

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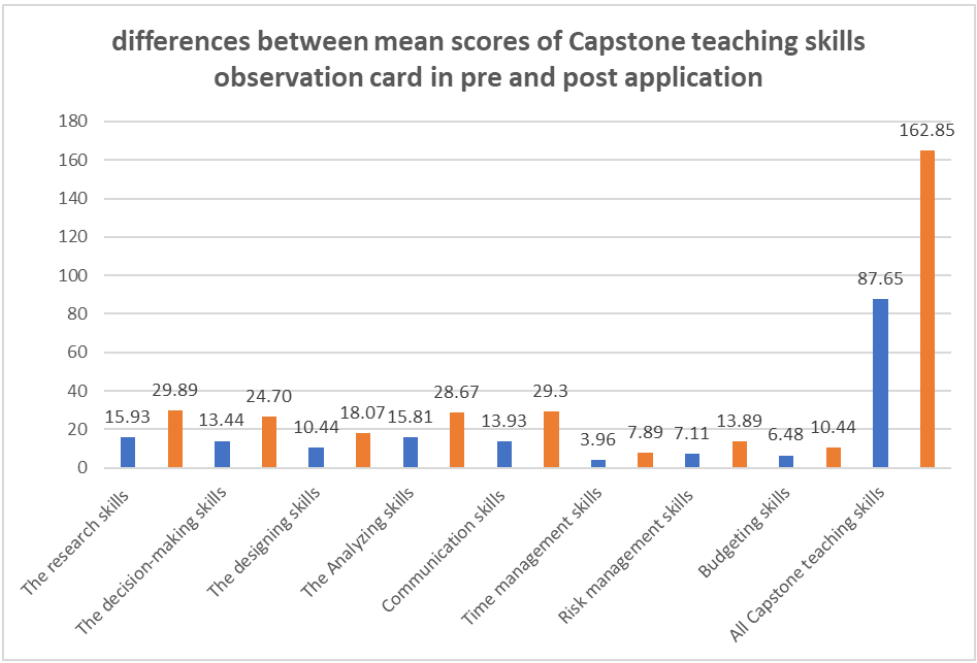

Figure (2) differences between mean scores of Capstone teaching skills observation card in pre and post application

Discussion

The research focuses on the effectiveness of using an E-training environment in developing Capstone teaching skills for STEM teachers. The results show that the proposed environment has proven effective, providing flexibility, cost-efficiency, scalability, interactive learning, resource sharing, scheduling flexibility, assessment and feedback tools, professional development tracking, customization, reduced environmental impact, integration with other tools, safety and health during public health crises like the COVID-19 pandemic, and global collaboration.

The study found that E-training environments like Microsoft Teams are highly effective in developing Capstone teaching skills for STEM teachers. They offer flexibility, accessibility, cost-efficiency, and a range of interactive and collaborative features, making them suitable for training programs involving numerous teachers or educators from different locations.

E-training platforms also allow for real-time collaboration with peers and experts, fostering global collaboration and the exchange of innovative teaching practices. This aligns with the modern approach to education and professional development, ensuring that teachers have access to the resources and support they need to excel in their roles.

In conclusion, using an E-training environment like Microsoft Teams can significantly enhance teacher training by offering flexibility, accessibility,

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cost-efficiency, and a range of interactive and collaborative features. It aligns with the modern approach to education and professional development, ensuring that teachers have access to the resources and support they need to excel in their roles.

The current research results are consistent with the previous studies providing clear evidence for the effectiveness of using E-training environment in developing the Capstone teaching skills. However, the current research added more depth than previous studies in the points outlined below:

E-training environments facilitate global collaboration and the connection with peers and experts from around the world in several ways:

The research demonstrates the effectiveness of using E-training environments in developing Capstone teaching skills. It highlights the benefits of global collaboration and connections with peers and experts from diverse locations. E-training platforms host online communities and forums, allowing participants to interact with peers and share experiences. Virtual conferences and webinars allow educators to attend presentations, workshops, and panel discussions without physical travel. Collaborative projects enable educators from different countries to collaborate on research, curriculum development, or other educational initiatives. E-training platforms also facilitate guest lectures and expert sessions, exposing participants to diverse perspectives and expertise. Peer review and feedback processes are supported by e-training platforms, allowing teachers from different countries to provide valuable insights and suggestions. Cross-cultural learning is also possible through e-training programs, enriching understanding and pedagogical approaches. Online networking features allow educators to build professional relationships with educators from around the world. Language translation features help overcome language barriers, enabling effective communication and collaboration. Overall, e-training environments break down geographical barriers, allowing educators to connect and collaborate with peers and experts from diverse locations, fostering knowledge exchange and innovative ideas in education.

Pedagogical Implications:

Using Microsoft Teams as an e-training environment for improving the Capstone teaching skills of STEM (Science, Technology, Engineering, and Mathematics) teachers has several pedagogical implications as follows:

- **i.** Blended Learning: Microsoft Teams allows for a blend of synchronous and asynchronous learning, accommodating different learning styles and schedules.
- **ii.** Group Projects: Teachers can collaborate on Capstone project development, sharing ideas, best practices, and feedback within the Teams environment.

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iii. One-on-One Coaching: Teachers can schedule one-on-one coaching sessions with trainers or experts through Teams, allowing for personalized support.
iv. Assignment Submission: Teachers can submit capstone project drafts for feedback through Teams. This process supports formative assessment and iterative improvement.
v. Peer Review: Teams can facilitate peer review of Capstone projects, fostering a culture of constructive feedback and improvement.
vi. Resource Repository: Teams can serve as a repository for educational materials, research papers, and relevant content, making it easy for teachers to access and share resources.
vii. Professional Development: Certifications and Badges: Teachers can pursue Microsoft certifications and earn badges through training modules within Teams, enhancing their professional qualifications.
viii. Progress Tracking: Teachers and administrators can monitor progress through analytics and reporting features in Teams, identifying areas where additional support is needed.
ix. Technical Support: Teams offers technical support resources to troubleshoot any platform-related issues, ensuring a smooth learning experience.
x. Data-Driven Decision-Making through Data Analytics: Teams provides data analytics tools to assess teacher engagement and performance, enabling data-driven decisions to improve the training program continually.
xi. Professional Learning Communities: Teachers can join Teams-based professional learning communities focused on specific STEM disciplines or capstone project themes, fostering collaboration and knowledge sharing.
xii. Feedback Loops: Continuous Improvement: Regular feedback mechanisms within Teams allow for ongoing refinement of training content and delivery methods based on teacher input.

Incorporating Microsoft Teams as an e-training environment for capstone teaching skills enhances pedagogical practices by promoting flexibility, collaboration, access to experts, effective assessment, and continuous improvement. These pedagogical implications contribute to the professional growth and effectiveness of STEM teachers involved in capstone education.

Recommendations

The results of the research highlighted several recommendations, including:

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The research suggests that an e-training environment can be used to develop the Capstone teaching skills of STEM teachers. This involves creating customized training programs, implementing a blended learning approach, creating interactive and engaging content, promoting collaborative learning opportunities, providing access to experts and resources, incorporating formative assessment methods, offering structured professional development pathways, establishing mentorship and coaching programs, ensuring inclusivity and accessibility, collecting feedback from participating teachers, using data analytics tools, providing technical support, fostering professional learning communities, aligning with educational objectives, continuously evaluating the effectiveness of the e-training environment, considering scalability and accessibility, keeping training content and resources up-to-date with the latest developments in STEM education, and empowering teachers to take ownership of their professional development.

These recommendations can contribute to the successful development of Capstone teaching skills for STEM teachers, supporting their professional growth and ultimately enhancing the quality of Capstone education in STEM disciplines. The e-training environment should be accessible to all teachers, ensuring that the content and objectives align with broader educational goals and the specific needs of STEM teachers.

Suggestions for Further Studies and Research

The research suggests several studies to improve the Capstone teaching skills of STEM teachers using E-Training environments. These studies should investigate the effectiveness of E-Training environments in improving teachers' trainings, assessing teachers from different types of education, training science teachers, and assessing administrative tasks in STEM schools. Additionally, the research should explore the impact of E-Training environments on academic achievement, attitudes, problem-solving skills, and creativity for teachers and students in STEM schools. The pedagogical benefits of different E-Training environments implementations should also be investigated. The implementation of chatbots in E-training systems and virtual environments with text-to-speech technology should also be explored.

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Declaration for Human Participants: This study has been approved by: Obour STEM School of outstanding students in science, technology, engineering and mathematics, and the principles of the Helsinki Declaration were followed.

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