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ENHANCING 21ST CENTURY SKILLS THROUGH INTEGRATED STEM EDUCATION USING PROJECT-ORIENTED PROBLEM-BASED LEARNING

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Abstract: In the pursuit of comprehensive education, the symbiotic relationship between 21st-century skills and STEM is crucial. These two domains work hand in hand to equip students with the knowledge and abilities required to thrive as productive and technically literate citizens in the future. This study assessed the impact of an integrated STEM education program on students' 21st-century skills using Project-Oriented Problem-Based Learning (PoPBL) as the core pedagogical approach. A one-group quasi-experimental design and survey methodology were employed to evaluate students' skills before and after participating in the program. The findings showed a significant increase in students' overall 21st-century skills, with high productivity skills notably improving from moderate to high proficiency. These results provide compelling evidence that PoPBL in STEM education effectively enhances students' skills by immersing them in authentic, real-life problem-solving experiences through project work. The study emphasizes the value of integrating PoPBL into STEM education to enhance critical skills such as problem-solving, creative thinking, collaboration, and effective communication. By engaging in practical, project-based activities, students not only apply their knowledge but also develop competencies to address complex challenges in their future endeavors.

Keywords: STEM education, Project-Oriented Problem-Based Learning, 21st-century skills, Literacy in the digital age, High productivity

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INTRODUCTION

STEM education is a contemporary educational approach that encompasses the integration and synthesis of knowledge and skills in the fields of science, technology, engineering, and mathematics. This trend has gained increasing interest due to its aim of simplifying these disciplines, connecting their ideas, and staying abreast of advancements and changes in science, engineering, technology, and mathematics. STEM education also considers the demands of the global job market in the twenty-first century, catering to the workforce needs in these fields. The emphasis on teaching science, technology, engineering, and mathematics represents a significant aspect of educational reform in the present era. This focus is commonly known as the STEM initiative, which was initially introduced in the 1990s by the National Science Foundation (NSF) through the development of curricula and topics in these four areas. Over time, the structure of the STEM initiative has evolved to align with the market demands and interests in STEM fields. Additionally, the initiative has expanded to include other fields such as computer science, information, sociology, economics, politics, and psychology (Breiner et al., 2012). The STEM orientation represents a highly influential and promising trend in science and technology education. It serves as a mission to restructure and enhance the education of science, engineering design, and mathematics. This restructuring aims to align with the demands of the global economy, the requirements of the labor market, and the needs of students in addressing the challenges and issues they encounter in their daily lives (Barcelona, 2014).

STEM Project-Based Learning (STEM PBL) is an instructional approach within STEM education that places emphasis on students' interests and abilities. By tailoring the learning experience to accommodate individual learning styles, STEM PBL facilitates the development of students' communication skills and critical thinking processes. Moreover, it provides students with the necessary motivation to engage with real-world challenges, allowing them the time to construct their own understanding within the learning context. This approach enables students to work at their appropriate levels, fostering positive attitudes towards future learning in STEM education classrooms (Eslami and Garver, 2013).

The Kingdom of Saudi Arabia's dedication to the Kingdom Vision 2030 demonstrates the kingdom's expanding commitment to developing STEM education. This national vision recognizes the value of investing in human capital by offering improved training and supplying individuals with the know-how and abilities needed for potential career opportunities. More than 80% of occupations worldwide are directly related to STEM subjects, according to research studies (AlAli et al., 2023; Ministry of Education, 2017). The Saudi Arabian Ministry of Education founded the National Center for the Development of Science, Technology, Engineering, and Mathematics (STEM) in 2017 in keeping with this pace. Putting the center's plans into action at three different levels is its main goal. The STEM scientific Mawhiba Advanced Program for Science and Math was established first. This program's main goal is to give talented students access to enriched learning experiences that go beyond what is taught in the classroom. The program's objectives are to awaken

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their potential, encourage their investigation of complex science and math ideas, and pique their curiosity. In order to do this, the program meets outside of regular school hours, providing these talented students with an extra period of time to participate in a deeper and more comprehensive learning experience.

The pursuit of a high-income developed nation status involves recognizing the critical importance of a high-quality human resource that possesses the necessary skills to navigate the challenges of the 21st century. To foster the development of a world-class nation, it is essential to cultivate a competitive, knowledgeable, creative, and ethically responsible human resource. This recognition has led to the creation of the enGauge 21st Century Skills model by the North Central Regional Educational Laboratory (NCREL) and Metiri Group (Osman and Marimuthu, 2010). The enGauge model emphasizes four main criteria that are crucial for producing a generation capable of addressing the challenges of the 21st century. These criteria are: Digital Age Literacy: In today's digital era, individuals need to be proficient in using technology, accessing and evaluating information, and utilizing digital tools for communication, collaboration, and problem-solving. Inventive Thinking: Encouraging innovative and creative thinking is essential for individuals to develop new ideas, solve complex problems, think critically, and adapt to evolving circumstances. Effective Communication: The ability to communicate effectively, both orally and in writing, is a vital skill in the 21st century. Individuals need to be able to express their ideas clearly, collaborate with others, and engage in constructive dialogue. High Productivity: The modern world demands individuals who can manage their time effectively, set goals, prioritize tasks, and demonstrate a strong work ethic to achieve desired outcomes. In addition to these four criteria, the enGauge model recognizes the importance of incorporating spiritual norms and values within the Saudi context. This acknowledges the significance of cultural and religious values in shaping individuals' behavior, decision-making, and ethical conduct (Wan Husin et al., 2016; Burkhardt et al., 2003).

Digital age literacy encompasses a range of competencies such as communication, data analysis, model understanding, task management, problem-solving, and ensuring well-being and safety (Wan Husin et al., 2016). It is crucial to develop digital age literacy in students to enable them to effectively utilize technology in modern learning environments. Inventive thinking is another vital skill that involves applying creative and critical thinking to problem-solving through innovative activities. Key elements of inventive thought include managing complexities, self-regulation, curiosity, risk-taking, and high-level thinking (Bravo et al., 2021; Brown, 2018). Effective communication is a skill that needs to be cultivated in individuals in the 21st century, encompassing information delivery, teamwork, interpersonal skills, social responsibility, interactive communication, and communication in various environmental contexts. The integration of information and communication technology (ICT) in communication activities enhances the learning process, facilitating faster information acquisition and supporting overall learning experiences. High productivity is the fourth skill, characterized by a student's ability to generate relevant, high-quality, intellectual, current, and original outputs. This skill also involves task delegation, prioritization, planning, and the production of high-quality work. Finally, spiritual values emphasize the practice of religious knowledge and beliefs, as well as the cultivation of positive attitudes and values (Burkhardt et al., 2003).

The increasing demand for workers with marketable skills, such as problem-solving, critical and innovative thinking, and teamwork proficiency, in the 21st-century workforce has prompted a need for evaluating students beyond their academic achievements. Mastery of 21st-century skills has become essential. Among the student-centered teaching and learning approaches available, Project-Oriented Problem-Based Learning (PoPBL) stands out as a project-centered method. Developed by Aalborg University in Denmark, the PoPBL approach utilizes experiential steps that engage students and establish connections between science education and real-life situations. PoPBL is derived from the Problem-Based Learning (PBL) model and is guided by core principles, including student-centeredness to motivate and engage learners, a focus on the learning process of finding solutions, project-based activities with actionable goals, exemplarity, and the promotion of group work, teamwork, social skills, and communication abilities. By involving students in project-based activities, PoPBL aims to foster critical thinking, active learning, and problem-solving skills while also developing communication skills through group discussions. Implementing PoPBL in STEM programs provides students with valuable opportunities for self-directed learning and enhances their soft skills (Alanazi and Benlaria, 2023; Ibrahim and Halim, 2013; Yasin and Rahman, 2011). Classroom observations highlighted the positive impact of implementing PBL (Problem-Based Learning). PBL activities elevated students' collaboration and problem-solving skills, fostering advancements in their collaborative abilities such as endorsing each other's perspectives, vocalizing thoughts, attentive listening, and engaging in meaningful discussions. Throughout the PBL project, students demonstrated active involvement and efficient collaboration, which significantly contributed to its success (Rehman et al., 2022). In summary, while the findings suggest promising benefits of PoPBL and PBL in promoting student engagement and skill development, further research is needed to validate these claims and address potential limitations in implementation and generalizability.

Certainly! Project-Oriented Problem-Based Learning (PoPBL) is an instructional approach that focuses on student-centered, project-based activities to enhance learning outcomes. Here are some additional details about PoPBL: Student-Centered Approach: PoPBL places students at the center of the learning process. It aims to actively engage students in their own learning by encouraging them to take ownership of their projects and collaborate with their peers. Problem-Based Learning (PBL) Roots: PoPBL is derived from the Problem-Based Learning model, which is a student-centered instructional approach that emphasizes problem-solving and critical thinking skills. In PoPBL, students work on project-based activities that involve identifying and addressing real-world problems or challenges. Experiential Learning: PoPBL incorporates experiential learning, where students engage in hands-on experiences that connect their learning to real-life contexts. By applying knowledge and skills in practical situations, students develop a deeper understanding of the subject matter. Connection to Everyday Life: PoPBL aims to bridge the gap between classroom learning and everyday life. The approach facilitates the connection of scientific concepts and theories to practical applications, making learning more meaningful and relevant to students. Emphasis on Collaboration and Communication: PoPBL promotes collaboration and teamwork among students. Group discussions, problem-solving activities, and project work provide opportunities for students to develop their interpersonal and communication skills while working towards shared goals. Skills Development: PoPBL focuses on the development of 21st-century skills, such as critical thinking, problem-solving, creativity, communication, and collaboration. By engaging in project-based activities, students have the opportunity to hone these skills and become better prepared for the demands of the modern workforce. Self-Directed Learning: PoPBL encourages self-directed learning, where students take responsibility for their learning process. They identify learning goals, plan their work, and seek resources and guidance as needed, fostering independence and autonomy. Implementing PoPBL in STEM programs has shown promise in enhancing students' soft skills, such as communication, teamwork, and critical thinking, while also promoting a deeper understanding of STEM subjects. Overall, PoPBL offers a student-centered and experiential learning approach that integrates problem-solving, collaboration, and real-world application to foster the development of essential skills for the 21st century (Desai et al., 2022; Alwi and Hussin, 2018).

In alignment with STEM education's objective of fostering interdisciplinary thinking, the Project-Oriented Problem-Based Learning (PoPBL) approach is considered a suitable method for STEM education. PoPBL is recognized as an approach that holds the potential to facilitate meaningful learning experiences by connecting teaching to real-life situations, allowing students to directly engage with these situations. It serves as an alternative teaching method that prioritizes project-based learning rather than relying solely on traditional lecture-based instruction. One concerning issue is the students' inability to apply the concepts and skills they have learned in STEM subjects to solve problems both within the field and in everyday life. This lack of application stems from difficulties in comprehending abstract concepts, which consequently hinders their ability to effectively utilize theoretical knowledge in solving STEM-based problems (Maegala et al., 2021; Wan Husin et al., 2016; Rasul et al., 2016). In summary, while PoPBL shows promise as an approach for promoting interdisciplinary thinking and application-oriented learning in STEM education, further research is needed to address implementation challenges, validate its effectiveness, and tailor instructional strategies to meet the diverse needs of students and educators. PoPBL has emerged as a highly favored pedagogical model for structuring teaching methods, offering benefits beyond academic learning by placing significant emphasis on the development of students' personal skills and fostering creativity. As a result, PoPBL holds immense potential in aligning STEM-based education with the demands of the 21st-century generation. This is achieved through PoPBL's systematic approach, which involves the analysis of research problems and the subsequent design and execution of projects aimed at solving these problems. This process is vital as it establishes a strong STEM foundation for students, equipping them to navigate career challenges and thrive in the 21st century (Eliyawati et al., 2020; Schmidt et al., 2011).

Recent research has demonstrated that the PoPBL approach has the potential to enhance students' interest in science. By making science subjects more accessible and facilitating easier learning, PoPBL fosters students' sense of the importance of science, ultimately increasing their interest in the field (Eliyawati et al., 2020). Furthermore, the PoPBL approach has been found to be effective in generating new knowledge and addressing real-world issues, such as the low percentage of recycling practices on campus, by integrating these topics into the curriculum (Alwi and Hussin, 2018). Empirical evidence also supports the notion that the PoPBL approach contributes to students' academic achievements. Studies have shown that students who engage in PoPBL activities exhibit high levels of achievement and motivation in their learning processes. Moreover, through teamwork, PoPBL enhances students' interpersonal skills, including effective communication and collaborative planning. An investigation conducted among students in the Faculty of Electrical and Electronics explored the application of the PoPBL approach. The findings indicated that implementing PoPBL in the teaching and learning processes improved students' ability to analyze and create analog circuits using various types of transistors and diodes (Diana and Sukma, 2021; Fadzilah et al., 2016). In summary, while the findings suggest that PoPBL holds promise for enhancing students' interest, academic achievement, and interpersonal skills, further research is needed to address limitations, validate findings across diverse contexts, and explore the long-term effects of PoPBL on student learning and development.

In their 2024 study, Rizki and Suprapto explored the implementation and effectiveness of the POPBL model in the SR-STEM project for enhancing critical thinking skills in renewable energy materials. Their findings indicated high feasibility of the model, effective improvement in critical thinking skills, and a positive correlation with student achievement, perceived control, and affective perception. The research underscores the importance of innovative learning approaches to promote critical thinking in renewable energy education and emphasizes the need to consider factors influencing lesson implementation for sustainable development. In their 2022 study, Smith et al. aim to establish principles for supporting a PBL model of STEM education in schools, drawing from literature insights and expert focus groups of PBL professionals. The research identifies four key principles: flexible knowledge, skills, and capabilities; active and strategic metacognitive reasoning; collaboration driven by intrinsic motivation; and real and rich contextualized problems. The findings offer evidence-informed guidance for educators contemplating the adoption of PBL in school-based STEM education. The research by Stehle and Peters-Burton (2022) investigates the effectiveness of inclusive STEM high schools in developing 21st-century skills in students. Analyzing data from seven exemplary schools, the study examines student work samples and teacher lesson plans. Out of 67 collected lesson plans, 50 included instruction on 21st-century skills, mostly at introductory levels. Few plans addressed multiple skills or higher skill levels. Notably, plans for grades 11 and 12 tended to emphasize higher skill levels. Longer-duration plans were associated with increased skill levels. The findings highlight the potential of inclusive STEM high schools in nurturing 21st-century skills but emphasize the need for enhanced teacher training to improve skill instruction. In summary, while these studies provide valuable contributions to the literature on STEM education and skill development, they also highlight the need for continued research and improvement in educational practices.

Addressing limitations such as instructional gaps, enhancing teacher training, and adopting rigorous research methodologies can further enhance the effectiveness of educational models in promoting critical thinking and 21st-century skills among students. With the aim of promoting interest and engagement in STEM-related careers, extracurricular programs encompassing the domains of Science, Technology, Engineering, and Mathematics (STEM) have emerged as a favorable approach. These programs, conducted outside regular school hours, provide an alternative avenue for advancing STEM education. Additionally, the integration of STEM subjects within the educational framework stimulates students' cognitive abilities, fostering creative, critical, and innovative thinking, and contributing to technological advancements. STEM education involves exploring the teaching and learning processes that connect two or more STEM components or bridge STEM with other fields of knowledge. It essentially entails integrating technology and engineering design concepts into the teaching and learning of science and mathematics (Altoum, 2021; Han et al., 2016).

The aim of the STEM program investigated in this study is to boost students' engagement in Science, Technology, Engineering, and Mathematics (STEM) fields and equip them with the essential skills for success in the 21st century. The program adopts a multidisciplinary approach and places emphasis on active learning through inquiry, the application of 21st-century skills, and exposure to careers in contemporary science and technology domains. The study is grounded in the Constructivism learning theories, which encompass five phases: orientation, idea generation, idea restructuring, idea application, and reviewing. During the idea application phase, the study incorporates the theory of Constructionism, particularly in practical activities involving problem-solving in the Metaverse world. According to Constructionism, the effective generation of new ideas occurs when participants engage in the design processes of artifacts. The theory highlights participants' involvement in artifact designing activities throughout the learning journey. In the artifact designing process, participants employ the TMI model of the engineering design process (Think, Make, and Improve).

The application of this process unfolds through three core stages: ideation (T), making (M), and improvement (I). In the ideation phase, participants are presented with authentic situations or problems that require resolution. They engage in group discussions, collaboratively working to define the problem, generate suggestions, and formulate plans. Facilitators provide continuous support to ensure the successful completion of this phase. Moving onto the making phase, participants actively construct, create, experiment, and address both the initial problem and any additional challenges encountered during the artifact design process. Once the technical aspects are finalized, testing is conducted to identify and address potential issues. Lastly, the final improvement phase involves participants enhancing the artifact they have constructed. They engage in testing, rebuilding, and implementing improvements to address emerging issues or develop a superior artifact in line with established guidelines (Fajrina et al., 2020; Rasul et al., 2016).

The objectives of science education in Saudi Arabia encompass the development of globally competitive human resources and the advancement of science and technology civilization. This entails equipping students with scientific knowledge and technological skills that enable them to contribute to society and excel on an international scale. However, a significant challenge lies in the declining interest of Saudi students towards science, which hampers the realization of these objectives.

The aim of this study was to evaluate the impact of implementing Problem-Oriented Project-Based Learning (PO-PBL) within a Science, Technology, Engineering, and Mathematics (STEM) education program, particularly focusing on the development of 21st-century skills among students. To address this objective, a one-group quasi-experimental pre- and post-test design was utilized to investigate the research questions posed in this study:

1. Did the PO-PBL learning program result in statistically significant changes in the skills of 21st-century students?
2. Can the implementation of PO-PBL enhance students' 21st-century skills?

METHOD

Experiential learning, also known as "learning by doing," is an effective approach for helping students comprehend abstract content more effectively. One method that promotes this approach is Problem-Oriented Project-Based Learning (PoPBL). Through project work that emphasizes artifact creation, students engage in solving real-world problems based on authentic and practical experiences. The success of the project work relies on collaborative teamwork among students and facilitation by the teacher. The integration of PoPBL with STEM disciplines is a novel approach in the learning environment. The implemented program combines PoPBL and STEM education, offering project-based and multidisciplinary activities that foster enjoyable and student-centered learning. The program's primary objectives include the development of 21st-century skills, higher-order thinking, and research abilities. To facilitate participation, the program introduced four distinct module units to the students: Energy, Urban Infrastructure, Transportation, and Wireless Communication as shown in Figure 1.

1. Population and Sampling

The study population consisted of intellectually gifted students who were enrolled in Mawhiba, a program in Saudi Arabia. A total of 115 high school students from public and private schools participated in this research. These students demonstrated exceptional performance on the Mawhiba test in both science and mathematics subjects and had also attended summer programs that provided STEM support. Further, Mawhiba Advanced Program for Science and Math.

2. Study tools

This study utilized two assessment tools: students' interest in science, technology, engineering, and mathematics (STEM), and 21st-century skills. Both tools employed a Likert scale with five levels of agreement (1=strongly disagree, 5=strongly agree).

The first tool, focusing on students' interest in STEM, utilized a questionnaire adapted from the work of Tyler-Wood, Knezek, and Christensen (2010) and modified to suit the Saudi context. This questionnaire encompassed three dimensions:

the perception of a supportive environment for pursuing a career in STEM (4 items), interest in pursuing educational opportunities leading to a STEM career (5 items), and the perceived significance of a career in STEM (3 items). The final version of the questionnaire comprised 12 items. The second tool centered on assessing 21st-century skills. The questionnaire was developed by synthesizing insights from relevant prior studies, taking into account various components of 21st-century skills (Van Laar et al., 2020; Chu et al., 2017; Rasul et al., 2016; Arsad et al., 2011). These skills encompassed five dimensions: literacy in the digital age (7 items), innovative thinking (12 items), effective communication (8 items), high productivity (8 items), and spiritual values (5 items). The final version of the questionnaire comprised 40 items.

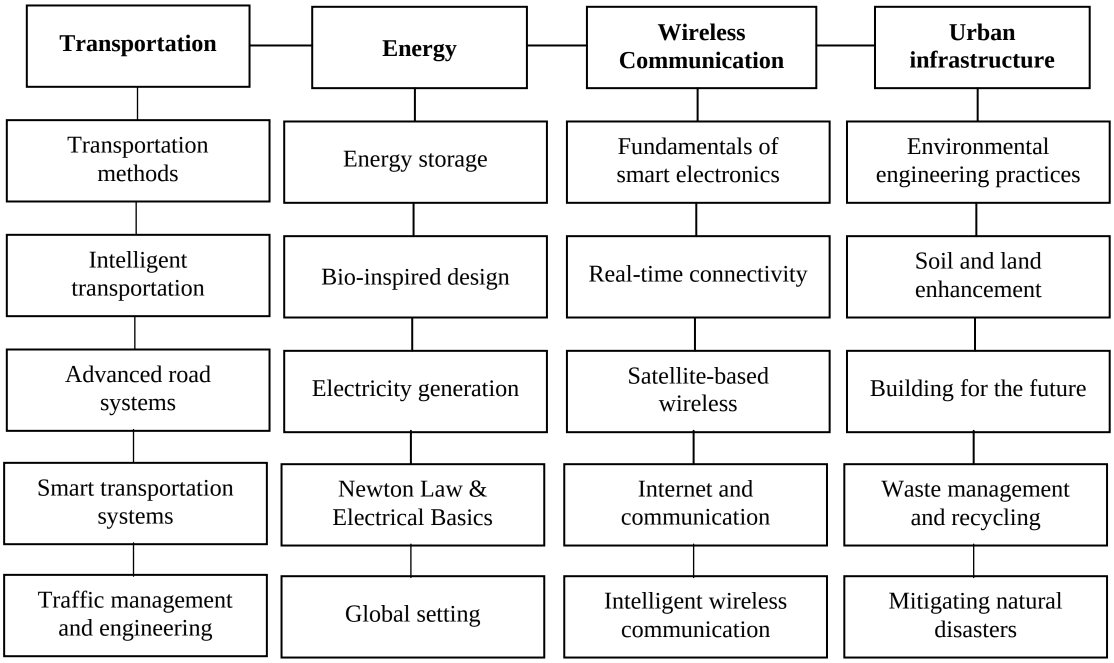

Figure 1. The units of intervention and modules

2.1. The validation of the reliability and validity of the scales.

The assessment tools underwent an initial evaluation conducted by a committee of expert judges consisting of esteemed faculty members at various Saudi universities. These faculty members held the rank of professor and possessed specialized knowledge in areas such as mathematics education, measurement and evaluation, and educational technology. The researchers received valuable feedback, comments, and suggestions from the committee, which were given careful consideration. Following this, the wording of the questions underwent a comprehensive review, and alternative options were thoughtfully assessed. Essential modifications were implemented to the scales to guarantee their accuracy and suitability.

After that, a pilot study was conducted to assess the validity and reliability of the assessment instruments using a sample of twenty students. To prove the measurement tool's construct validity, a number of metrics were looked at, including Composite Reliability and Macdonald's Omega. The study also evaluated discriminant and convergent validity. Macdonald's Omega and Composite Reliability (CR) values vary from 0.84 to 0.94 and 0.88 to 0.95, respectively, according to the results, which are shown in Table 1. These numbers are higher than the suggested cutoff point (>0.7), suggesting that the scales have a high degree of internal consistency. Additionally, the average variance extracted (AVE) values are above than the 50% minimum requirement, ranging from 0.682 to 0.801. Moreover, the square root of the AVE, or discriminant validity coefficients, need to be greater than the intercorrelations among the latent variables or factors.

Table 1. Indicators and coefficients used to assess construct validity

Scale	Constructs	Items	Macdonalds Omega	CR	AVE	$\sqrt{AVE}$
Students' interest in STEM	Perception of a supportive environment for pursuing a career in STEM.	4	0.87	0.88	0.68	0.82
	Interest in pursuing educational opportunities leading to a STEM career.	5	0.88	0.87	0.77	0.88
	Perceived significance of a career in STEM.	3	0.87	0.88	0.80	0.89
	Literacy in the digital age.	7	0.84	0.85	0.73	0.85
21st-century skills	Innovative thinking	12	0.91	0.92	0.74	0.86
	Effective communication	8	0.89	0.90	0.79	0.89
	High productivity	8	0.95	0.95	0.73	0.85
	Spiritual values	5	0.85	0.86	0.77	0.88

It is clear from a comparison with the previous column that this criterion is satisfied because the loading factor values are higher than the required minimum. These results validate the scales' validity and reliability (AlAli, 2020).

Confirmatory factor analysis (CFA) was performed using statistical programs like Amos and SPSS in order to demonstrate factor validity. CFA, a component of structural equation modeling (SEM), examines the connections between latent components in order to find underlying patterns in the data. In several phases, such as the creation of measuring instruments, assessment of construct validity, and examination of methodological impacts, this statistical methodology is essential. Confirmation factor analysis (CFA) is a crucial step in the instrument development process because it confirms the primary dimensions and factor loadings incorporated in the measuring tool as well as its latent structure. In light of this, CFA is a crucial analytical method that greatly enhances other facets of psychometric evaluation (AlAli and Saleh, 2022; AlAli and Al-Barakat, 2022). The study sample was given the final version of the questionnaire to guarantee factorial construct validity. The alignment of the scale items with their corresponding dimensions was evaluated using confirmatory factor analysis (CFA). Examining the loading values of the scale items on their respective dimensions was imperative, as illustrated in Figure 2. It was determined that products with loading factors less than 0.40 ought not to be approved (AlAli and Abunasser, 2022). The results demonstrate that all items exhibit loading factors greater than 0.40, satisfying the established criterion.

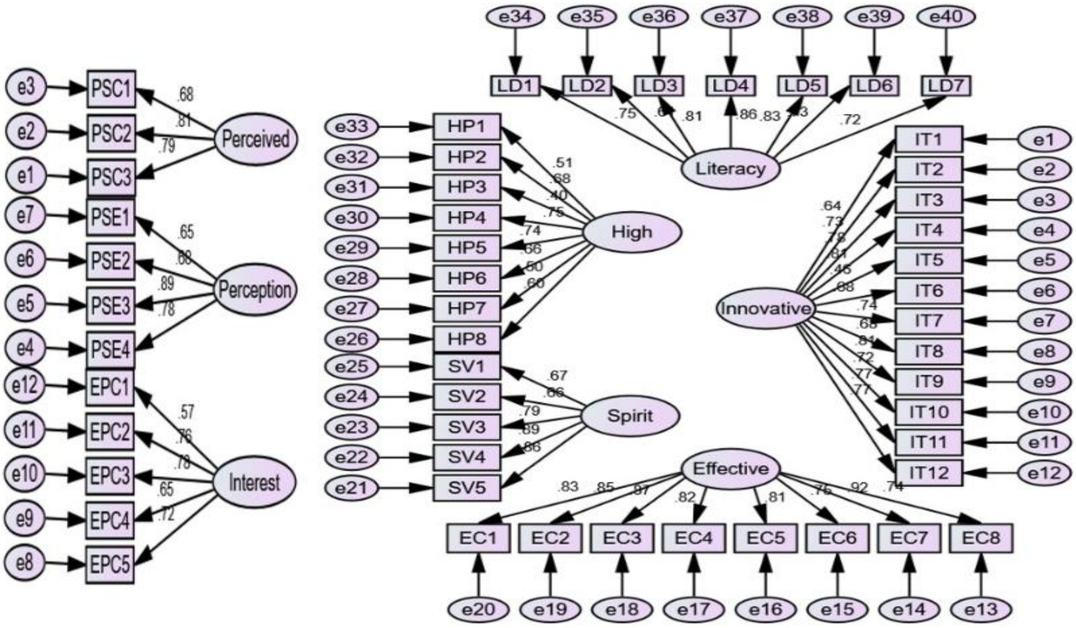

Figure 2. The findings from the confirmatory factor analysis to determine the association between the items in the questionnaire and their respective dimensions, as well as the extent of their loading

RESULTS

In the study, the researchers aimed to examine the effects of the Problem-based Project-Based Learning (PoPBL) approach in science, technology, engineering, and mathematics (STEM) programs on students' 21st-century skills. To measure these skills, pretests and posttests were conducted. The pretests were administered before the implementation of the PoPBL approach, while the posttests were administered after the completion of the intervention. The paired sample t-test was used to compare the average scores of the pretests with the average scores of the posttests.

This statistical test allowed the researchers to determine if there were significant differences in the students' skills before and after the intervention. The assessment of 21st-century skills focused on five dimensions: literacy in the digital age, innovative thinking, effective communication, high productivity, and spiritual values. These dimensions encompassed various aspects of skills that are crucial in the 21st-century learning environment.

Table 2. The results of the comparison between the average pre- and post-test scores for all dimensions tested to measure students' skills in the twenty-first century

variable	Test	N	Mean	Std. Deviation	T-Value	Sig.	Statistical significance
Literacy in the digital age.	Pre-test	115	3.66	0.52	3.35	0.02	Statistically significant
	Post-test	115	3.80	0.59			
Innovative thinking	Pre-test	115	3.90	0.52	1.67	0.11	Not Statistically significant
	Post-test	115	3.94	0.71			
Effective communication	Pre-test	115	3.98	0.53	1.98	0.06	Not Statistically significant
	Post-test	115	4.06	0.69			
High productivity	Pre-test	115	3.74	0.51	3.54	0.02	Statistically significant
	Post-test	115	4.01	0.59			
Spiritual values	Pre-test	115	4.43	0.52	1.16	0.21	Not Statistically significant
	Post-test	115	4.41	0.62			
Overall Degree	Pre-test	115	3.93	0.45	3.07	0.03	Statistically significant
	Post-test	115	4.04	0.56			

Table 2 provided a comprehensive overview of the comparison between the average pretest and posttest scores for each aspect measured within the 21st-century skills framework. The table also included the average values of the scores and the standard deviation (SD) for both the pretests and posttests. This information offered insights into the central tendency and variability of the scores within each dimension of 21st-century skills.

The data presented in Table 2 indicates a noteworthy improvement in the average scores across all dimensions of twenty-first century skills, except for spiritual values, which experienced a minor decline of 0.039. However, this decrease was not statistically significant (t (115) = 1.16). On the whole, the findings demonstrate that students exhibited higher average scores in 21st century skills after their participation in the Mawhiba Advanced Program for Science and Math, as indicated by a significant increase (t(115) = 3.07). Further analysis revealed significant differences in specific dimensions of 21st century skills. Notably, there was a significant improvement in literacy in the digital age (t (115) = 3.35) and high productivity (t (115) = 3.54). However, no significant differences were observed in the dimensions of innovative thinking (t (115) = 1.67) and effective communication (t (115) = 1.98). A significant proportion of students exhibited a strong proficiency in 21st-century skills, indicating the program's effectiveness.

Subsequently, there was an observed increase of 4.7% in the number of students demonstrating a high level of competency in 21st-century skills following their participation. Table 3 presents a detailed analysis of the distribution of students' proficiency in 21st century skills, categorized into three distinct stages: low, medium, and high. The table provides comprehensive insights into the percentages of students falling into each proficiency stage, thereby offering a comprehensive understanding of their overall skill levels in relation to the 21st century skills framework.

Table 3. Distribution of Gifted Students' Proficiency Percentage Based on 21st Century Skills

		Lowest	Moderate	High
Gifted Students' Proficiency Percentage Based on 21st Century Skills	Pre-test	0	15.5	84.5
	Post-test	0	7.4	92.6

DISCUSSION

Enhancing 21st Century Skills through the Mawhiba Advanced Program for Science and Math: Analysis and Teaching Approach, where the acquisition of essential 21st century skills is paramount for students' development. This study conducted an analysis to evaluate the impact of the Mawhiba Advanced Program for Science and Math on students' proficiency in these skills, with the exception of Spiritual Values. The findings indicate an overall increase in the levels of 21st century skills following students' participation in the program.

Among the identified skills, High Productivity demonstrated the highest improvement, with a notable mean score difference of 0.27 between pre- and post-tests. This was closely followed by Digital Age Literacy (0.14), 21st Century Skills (0.11), Effective Communication (0.08), and Innovative Thinking (0.04). The Mawhiba Advanced Program for Science and Math employed a teaching and learning approach centered around Problem - and Project-Based Learning (PoPBL). This approach fostered hands-on, minds-on activities that encouraged students to identify and solve real-world problems. The research findings underscore the positive impact of this approach on nurturing inventive thinking among students. Collaborative group activities prompted students to collectively devise solutions by drawing upon their individual experiences, fostering exploration and connections between problem contexts and their own experiences. Additionally, students were tasked with designing novel artifacts, which further stimulated their inventiveness and consequently had a positive effect on High Productivity.

These findings align with previous research (Hilal, 2021; Rasul et al., 2016; Wan Husin et al., 2016; Ibrahim and Halim, 2013) that highlights the efficacy of PoPBL in yielding significant academic achievements among students. The Advanced Programs for Science and Math's emphasis on this approach has proven instrumental in enhancing students' 21st century skills and fostering a culture of inventive thought (Hacioglu, 2021; Fajrina et al., 2020).

Elevating Digital Era Literacy and Exploring Spiritual Values in the Mawhiba Advanced Program for Science and Math, where the research findings reveal a significant improvement in students' Digital Era Literacy Skill following their participation in the Mawhiba Advanced Program for Science and Math. The program incorporated the use of the internet as a valuable resource during teaching and learning activities, enabling students to access additional information to enhance their projects and designs. This application of Problem- and Project-Based Learning (PoPBL) resulted in a high and commendable level of Digital Era Literacy Skill among students who attended the program (Muhammad et al., 2020; Wan Husin et al., 2016).

However, the results of the study show that after students participated in the Mawhiba Advanced Program for Science and Math, the value of Spiritual Values decreased (-0.039). This decline emphasizes the need for more research to create programs in the future that strengthen and reaffirm spiritual beliefs. To guarantee that students demonstrate not only creativity, effective communication, digital literacy, and high productivity, but also the essential spiritual values needed for the betterment of humanity, it is imperative to improve the integration of spiritual values into the teaching and learning processes.

Furthermore, neither before nor after the program, any student was at the lowest competence level, according to a review of student percentages based on 21st century competencies. Notably, pupils who took part in the Mawhiba Advanced Program for Science and Math saw a noteworthy overall gain in their level of 21st century skills, with the highest scale seeing an astounding increase of 4.9%. These results confirm that the PoPBL teaching and learning approach used in the program is appropriate and effective in piqueing students' attention and ultimately improving their knowledge of STEM-based education. Overall, the study's conclusions demonstrate how well PoPBL works to improve students' 21st century skills, especially when used in STEM programs (Wan Husin et al., 2016; Rasul et al., 2016). With its emphasis on digital era literacy and the necessity for additional study of spiritual values, the Mawhiba Advanced Program for Science and Math is a testament to the program's dedication to developing well-rounded students who excel in vital competencies for success in the contemporary day.

CONCLUSION

Empowering 21st Century Skills through PoPBL in the Mawhiba Advanced Program for Science and Math, where based on the extensive research findings, it can be confidently concluded that the application of the Problem- and Project-Based Learning (PoPBL) approach in teaching and learning processes, as exemplified in the Mawhiba Advanced Program for Science and Math, effectively enhances the levels of five crucial 21st century skill elements. These elements include Digital Age Literacy, Inventive Thinking, Effective Communication, High Productivity, and Spiritual Values.

Moreover, the collaborative nature of PoPBL as a teaching strategy proves to be particularly effective in improving communication skills. By engaging students in group activities, the program fosters the development of positive attitudes and essential interpersonal skills. These include effective interaction during project presentations, teamwork, perseverance, and creative thinking. Such a teaching model and principle are of utmost importance in today's educational landscape, where students are expected to be active and creative, poised to confront the challenges of the 21st century.

Hence, it is imperative to ensure that teaching and learning processes remain relevant and coherent with the demands of the modern era. The Mawhiba Advanced Program for Science and Math, with its integration of STEM education, embodies a forward-thinking, flexible, and dynamic approach. This program effectively nurtures a human resource pool that is not only creative and innovative but also adept at mastering the essential 21st century skills. Furthermore, it equips individuals with the ability to strategically plan for the future and make informed choices in the face of globalization and the rapid influx of information. In summary, the Mawhiba Advanced Program for Science and Math, with its PoPBL pedagogy, plays a pivotal role in empowering students with the necessary skills and competencies to thrive in the 21st century. By embracing this program, educational institutions can cultivate ingenious and forward-thinking individuals capable of navigating the complexities of our rapidly evolving world.

Limitations

Limitations of this study include the exclusive focus on intellectually gifted students enrolled in the Mawhiba program in Saudi Arabia, potentially limiting the generalizability of the findings. Additionally, the self-selecting nature of the sample, comprising students with exceptional performance on the Mawhiba test and participation in STEM summer programs, may introduce bias. The reliance on Likert scale questionnaires for data collection could be susceptible to social desirability bias, affecting the accuracy of responses. Furthermore, the adaptation of the questionnaires from prior studies may not fully capture the nuances of the Saudi context, potentially compromising the validity and reliability of the instruments. Lastly, the limited scope of the questionnaire on 21st-century skills, focusing on specific dimensions, may overlook other critical competencies essential for students' success in the modern workforce.

Recommendations and future directions

Based on the findings of this study, several recommendations and future directions can be suggested to further enhance the integration of Project-Oriented Problem-Based Learning (PoPBL) in STEM education and promote the development of 21st century skills among students: Provide comprehensive professional development opportunities for teachers to familiarize them with the principles and methodologies of PoPBL. This will help them effectively implement the approach in their classrooms and facilitate student engagement in authentic, project-based learning experiences. Curriculum Design: Integrate PoPBL into the curriculum design process, ensuring that it aligns with the learning objectives and standards of STEM education. This can involve mapping out specific projects and problem-solving tasks that allow students to apply their knowledge and skills in meaningful ways. Collaboration and Partnerships: Encourage collaboration and partnerships between educational institutions, industry professionals, and community organizations. This can provide students with opportunities to work on real-world projects, gaining exposure to authentic challenges and fostering connections between classroom learning and practical application.

Technology Integration: Explore the integration of technology tools and resources to enhance the implementation of PoPBL. This can include utilizing online platforms, virtual simulations, and digital resources that support collaborative project work and facilitate the acquisition of digital literacy skills. Assessment Strategies: Develop comprehensive assessment strategies that align with the objectives of PoPBL and the development of 21st century skills. Consider incorporating authentic assessment methods, such as portfolios, presentations, and real-world application of knowledge, to evaluate students' abilities to apply their skills in practical contexts. Research and Evaluation: Conduct further research and evaluation to gather additional evidence on the effectiveness of PoPBL in enhancing students' 21st century skills. This can involve longitudinal studies, comparative analyses, and exploring the impact of PoPBL on various student populations. Scaling and Sustainability: Explore strategies for scaling up the implementation of PoPBL in STEM education at a broader level. This can involve establishing frameworks, guidelines, and support systems to ensure the sustainability and widespread adoption of PoPBL in educational institutions.

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