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Empowering Young Minds: The Impact of An Innovative Enrichment Program on Gifted Students' STEAM Skills Development

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ABSTRACT

The purpose of this study was to examine the effect of a Science, Technology, Engineering, Arts, and Mathematics (STEAM) enrichment program on grade 10 high-achieving students' creativity in science and problem-solving skills. The participants comprised a total of 87 students in grade 10 from three schools in Al Ain city, Abu Dhabi. The study used a quasi-experimental mixed-methods design. The Creative Scientific Ability Test (C-SAT) was used as a pre-post assessment to measure students' creative skills in dealing with scientific problems. The experimental group students were involved in a STEAM enrichment unit based on the COVID-19 pandemic. The results of the study showed that students in the experimental group outperformed students in the control group in both fluency and flexibility. Female students had higher scores than males in C-SAT originality scores. The qualitative analysis yielded several themes. For students, the themes generated were enjoyment about the program, gained benefits, effective promotion of the 21st-century skills, supporting school STEAM subjects, students' selection of future professions, and challenges. For teachers, the generated themes were challenges faced by students, students' benefits, students' enjoyment, students' selection of future professions, and general judgment about the enrichment program.

Keywords: STEAM, high-achieving, enrichment, COVID-19, high school, Abu Dhabi

INTRODUCTION

As Gardner (2004) stated, *"countries that do not prepare all children for a new world may lose their economic and cultural status"* (p. 2). This statement is derived from the identified need to prepare *all* students for the expanding global economy of the 21st century. Even though various enrichment programs have been implemented to meet the differentiated needs of gifted learners, there is still a scarcity of research studies that have evaluated the gains and outcomes of these programs on gifted/talented (g/t) students, especially in countries such as the United Arab Emirates (UAE). For instance, there was just one study that examined the effect of STEM project-based learning on the academic performance of high school students (Fouad, 2018). Patterson et al. (2021) and Steeves et al. (2025) analyzed the challenges women in the UAE face when they pursue STEM careers, emphasizing improved educational opportunities but limited job prospects. There is a clear need for more research to better understand the impact of STEM programs on high school students' creative thinking skills and attitudes toward STEM.

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According to Davis et al., (2011), contrary to the widespread belief that gifted individuals can simply "make it on their own", g/t students need concerted support and encouragement from parents, the school system, and the community to achieve full development. Failure to recognize their real potential as well as their educational and developmental needs, and/or lack of appropriate accommodation, gifted and talented children and youth might be at risk of failing to fully develop and flourish academically. Therefore, gifted learners should be provided with curriculum experiences that allow them to reach their full potential, and, on many occasions, it should be individualized to meet the needs and characteristics of each gifted student (Van-Tassel Baska, 1995; Richardson, 2024; Van-Tassel Baska & Wood, 2009; Sabrina et al., 2022).

Gifted Education in the UAE

Gifted education has gained much popularity lately, as it has become a prominent issue in the Arabian Gulf. In response to the international calls for inclusive education as a form of equity in education, and following Merry's (2008) suggestion, that gifted students worldwide should have justice in education, the UAE educational system acknowledged that gifted children have a right to be recognized and catered for within school. Hence, the 'School for All' initiative, in line with the MoE's Strategy 2010-2020, focused on encompassing all special needs services for both gifted students and students with disabilities. As a result, gifted education has been gaining momentum, interest, and support and governmental funds have been increasing to address their needs.

Additionally, in 2008, the MoE created the '*development of gifted and talented students' skills*' initiative. Hundreds of gifted students benefited from this initiative, whilst many teachers received training on identification and intervention programs for the g/t students. In 2014, the MoE introduced a new initiative called the '*integrated system to identify and care for talents*' (AlGhawi, 2017). Since then, several other organizations implemented various programs for g/t students in the Arabic Emirates (e.g., the Hamdan Bin Rashid Al Maktoum Foundation for distinguished Performance, 2015; the Emirates Association for the Gifted, etc.), while various agencies were created to support gifted education in the Gulf (e.g., the Abu Dhabi Education Council, ADEK (2016), and the Knowledge and Human Development Authority in Dubai, KHDA, (2011).

Moreover, since 2008, the United Arab Emirates has participated in several international standardized tests to examine and benchmark the performance levels of its education system. These tests include the 'Program for International Student Assessment, (OECD, PISA, 2019; 2021; Auld et al., 2019), Trends in International Mathematics and Science Study (TIMSS), and the 'Progress in International Reading Literacy Study' (Martin, Mullis, & Kennedy, PIRLS 2007). However, the study of Al Obaidly (2006) had shown that programming for g/t students in Abu Dhabi government schools had been limited mostly to small-scale special projects and site-based initiatives. In addition, the UAE received top ranks in the Arab world, but unfortunately, results from the PISA, released in 2016, showed that UAE students continue to fall below the 'Organization for Economic Co-operation and Development' (OECD) average in science, reading, and mathematics (OECD, 2019; 2021). This undesired result was in great conflict with the UAE's National Agenda calls, according to which, the UAE was supposed to rank among the top 20s in PISA by 2021.

In its continuous and keen efforts to gauge academic performance in the country, the Ministry of Education (MoE) in the UAE has launched an ambitious, strategic four-year (2017-2021), developmental plan, that is characterized by innovation and creativity. This aspirated education system aimed to instill a sought-after knowledge base that would produce competitiveness among society members to create a distinguished realm at all venues. In recent years, the UAE has developed various methods for identifying and providing programs for g/t students. These include the National Plan for the Gifted and the work of the Hamdan Awards for Academic Excellence. In addition, ADEK has worked on several initiatives that focus on the education of gifted learners. The purpose of the ADEK pilot program was to implement "international best practices in g/t education aligned to the local context and create a roadmap for future programs throughout the Emirates.

REVIEW OF LITERATURE

Many enrichment programs have been widely implemented all over the world to facilitate and reinforce gifted students' academic, social, and abilities. STEM education has been gaining momentum, interest, and support from ministries of education and researchers in many countries around the world (Robinson et al., 2014). Countries that have shown significant developments in the areas of science, industry, and technology have started to incorporate STEM education in the educational practices offered to the g/t school population (Lacey & Wright, 2009).

STEM education includes an integrated curriculum with different disciplines (Bybee, 2010), upon which several countries have focused, as a means of providing appropriate learning environments for their g/t students. In addition, the educational systems of these countries have started to train educators and other professionals in STEM fields (Sayler, 2006). For instance, the study by Hughes (2009) revealed that China, India, and the USA have

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trained thousands of engineers in STEM education, thus illustrating the significant contribution of STEM education, especially in the field of engineering. Among the main goals of STEM education is digital literacy within the scope of the technology discipline (Şen, 2018). More precisely, the engineering dimension of STEM focuses on providing students with critical, creative, and problem-solving skills, whereas the mathematics discipline aims to develop students' abilities in terms of producing logical arguments and providing higher-level reasoning between differing conditions (Bryan et al., 2015).

More recently, across the world, scientists, policymakers, and the public have recommended reforms in STEM education, by adding the dimension of Art and Design, which resulted in the STEAM (STEAM-Art) approach (Benek & Akcay, 2018). These reforms are designed to create a workforce who are literate in scientific, numeric, and technological fields and who have developed the expertise to become STEAM innovators, having the potential to become leading STEAM professionals and creators of significant breakthroughs and advances. Several researchers have highlighted the benefits of STEAM for students. According to Cook et al. (2017), STEAM education allows students to view themselves as scientists, engineers, or designers, while Land (2013) argued that STEAM allows the right and left lobes of the brain to work simultaneously. Furthermore, it has been argued that it improves scientific thinking by increasing imagination (Sparkes, 2017) and often leads to a multi-faceted achievement in scientific and artistic studies (Rabalais, 2014). Also, Zhang and Jia (2024) examined the incorporation of visual arts into STEAM education, focusing on its educational advantages and offering practical teaching examples and underscored how visual arts can improve students' memory retention, causal reasoning, and critical thinking abilities. As a result, STEAM education is anticipated to fulfil the needs of gifted and talented students by employing educational methods grounded in research, problem-solving, inquiry, and creative thinking. Hughes et al. (2022) examined the impact of integrating arts with STEM, showing that a STEAM-first approach significantly enhances science learning gains, particularly for emerging bilingual students. These methods are implemented within project-based, differentiated, and enriched educational programs (Sagat & Katakus, 2020; Ülger & Çepni, 2018; Ribeirinha et al., 2024).

The leadership in the UAE is very committed to STEAM and innovation, as demonstrated by the UAE National Agenda, which stands on six pillars including world-class health care, a competitive knowledge economy, a strong, fair, and just public judiciary system, a cohesive society and preserved identity, sustainable environment and infrastructure, and first-rate globally competitive education system. To achieve the National Agenda goals, the MoE has taken major steps to introduce "high-concentration" science, math, and technology content disciplines in K-12 and higher education curricula by introducing STEM, STEAM and STREAM in several schools across the UAE to empower society with engineers and scientists who will meet the UAE's 2021 and 2071 visions. In the UAE, STREAM education represents Science, Technology, Reading, Engineering, Arts, and Mathematics. This method combines these fields to offer a well-rounded and interdisciplinary learning experience. The goal of STREAM education is to foster critical thinking, creativity, and problem-solving abilities in students through interactive, project-based learning activities. Although the UAE is committed to improving pathways to STEAM, no study has been found in the UAE that focuses on identifying and cultivating exceptional talents in STEAM. Although previous research has demonstrated the importance of modifications in the curriculum for gifted learners (Van Tassel-Baska & Wood, 2009; Okunlola & Naicker, 2025), gifted learners in most UAE public schools have not been provided with curriculum experiences that allow them to reach their full potential. To date, Fouad (2018) investigated the impact of STEM project-based learning (PBL) on high school students' achievement in the UAE. The study found that STEM PBL significantly enhances students' cognitive and scientific skills. No further studies were found in relation to the use of systematic enrichment programs in UAE public schools. Researchers have examined and documented the effectiveness of STEAM professional development training conducted for classroom teachers (Robinson et al., 2014; Trna & Trnova, 2015). However, the studies examining the positive effects of STEAM education on the perceptions and attitudes of g/t students are very limited (e.g., Cheng et al., 2024, Ihrig et al., 2018), while researchers have not examined STEAM programming in relation to innovation for gifted students. For example, Ihrig et al. (2018) assessed the STEM program aimed at high-achieving students from economically disadvantaged rural areas. Key findings included increased levels of creative and critical thinking as reported by teachers and students. Students also shared positive feedback and satisfaction with the program. Cheng et al. (2024) examined how a STEM curriculum impacted students' engineering design skills and their perceptions of STEM disciplines. The curriculum also had a positive effect on students' attitudes toward STEM fields, with students expressing greater interest and confidence in these subjects.

Other studies, which have focused on STEM education in the gifted population, have revealed some positive effects on the students' perceptions of science, engineering, and mathematics fields, as well as about STEM careers (e.g., Dieker et al., 2012; Kaenzing, 2009; Koyunlu Ünlü & Dökme, 2016; Ming & Mansor, 2024; Sagat & Katakus, 2020). More specifically, no research has been identified, in which STEAM programming and innovation programs have been provided for gifted students in the UAE in general. Even though there are some studies about the positive effects of STEAM on students' attitudes and motivation towards science, however, these studies involved

typical students, rather than g/t learners (e.g., Jeong & Kim, 2015; Kim et al., 2012a; 2012b; Kong & Ji, 2014; Kong & Huo, 2014;).The Rationale for the Study

Previous research substantiates the need for modifications in the curriculum for gifted learners and several researchers documented the effectiveness of enrichment programs for gifted and talented learners (e.g., Renzulli, 2012; VanTassel-Baska 2009). Only limited research has been conducted to evaluate the effectiveness of enrichment programs for g/t students in the UAE (e.g., Elhoweris et al., 2022), which provided a direction for the current study. Hence, in this study, gifted students in STEAM will be provided with an enrichment and innovation program to enhance their 21st Century skills.

Unlocking the potential of high school students through a STEAM program is not just an educational imperative but a societal necessity. As we strive to bridge the gender gap in STEM careers, this research underscores the urgent need to foster creative thinking and positive attitudes toward STEM among young women, ensuring a diverse and innovative future workforce. Another added value of this study is to increase female students' participation and interest in STEAM-related programs (see Patterson et al. 2021). This study is important for several reasons. First, research related to exploring the effect of enrichment programs for gifted students in the UAE is scarce. Second, the current study addressed gifted students' needs during the COVID-19 pandemic where school lockdowns did not allow for opportunities for enrichment and extension activities. The results of this study can inform the future practices in relation to offering remote enrichment activities/programs for gifted students to overcome busy school-day schedules and commitments. The 21st-century skills create a fertile ground for creative thinking by promoting problem-solving, teamwork, and flexibility. These abilities help individuals think innovatively and tackle challenges with fresh perspectives. By integrating technology, effective communication, and critical thinking, creativity becomes essential for thriving in an ever-evolving world.

The following questions guided the quantitative study:

1. What is the effect of a STEAM enrichment program on the scientific creativity abilities of grade 10 students in some high schools in Al Ain, Abu Dhabi?
2. Are there any statistically significant differences between males and females in the scientific creativity scores?

The following question guided the qualitative study.

What are the perceptions of the participating school staff and students in relation to the effectiveness, gains, and challenges of the enrichment program?

METHOD

This study employed a mixed-method design to examine the impact of the STEAM enrichment program on students' creativity in science and scientific content knowledge. According to Pardede (2018), this approach refers to a study employing both qualitative and quantitative approaches to produce a complete explanation of the research problem. In this study, the researchers utilized mixed methods to address both the "what" (quantitative) questions and the "how" or "why" (qualitative) questions (Pardede, 2018, p. 231). The mixed-method design is advantageous in answering research questions and enhancing the design of the study (Schoonenboom & Johnson, 2017). An explanatory sequential mixed-method design consists of two separate stages: the first involves collecting and analyzing quantitative data, and the second focuses on gathering and analyzing qualitative data. This approach is ideal for expanding on or clarifying quantitative findings with qualitative insights. The first stage involves obtaining quantitative data to detect patterns, test hypotheses, or assess variables, offering a general overview of the research issue. Afterward, qualitative data is collected to further explore the results, helping to clarify any unexpected outcomes, or important trends discovered in the quantitative phase. Justifications for using this method includes depth of understanding as starting with quantitative data helps identify overall trends and relationships. The following qualitative phase enables a deeper exploration of these findings, offering a more detailed and nuanced understanding (Creswell & Clark, 2017). To gain more understanding of the research, the mixed-method design was adopted, starting with the quantitative phase followed by the qualitative interviews with teachers and students.

Participants

The sample of this study consisted of a total of 87 high-achieving male and female students in grade 10 from three high schools in Al Ain, Abu Dhabi. The students were randomly selected from the three schools. Each school randomly selected two groups (experimental and control).

Students in the schools studied in advanced STREAM classes. Students in advanced STREAM classes are selected based on the last year results of national achievement tests prepared by the MoE and a national assessment that targets students' cognitive skills in different school disciplines. They study more advanced content in

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mathematics, chemistry, physics, and biology. Also, the researchers in this study asked parents and teachers to nominate students who have strengths/interests in science fields.

The students were consented to participate in this study via a virtual workshop in which the research team briefed them about the objectives, duration, content, and outcomes of the enrichment program. One school included female students, and two schools included male students. The rationale for selecting participants from both male and female schools was to ensure diversity. Students' characteristics are shown in **Table 1.**

Table 1. Participating Students' Characteristics across the Three Schools

	Experimental	Control	Total
School 1 (male)	10	6	16
School 2 (male)	21	8	29
School 3 (female)	23	19	42

Instrument

The Creative Scientific Ability Test (C-SAT). The C-SAT is a paper-and-pencil test that can be administered in groups or individually (Atakaya et al., 2022; Ayas & Sak, 2014; Sak & Ayas, 2013). It was developed on the premise of integrating research on creativity and Dual Search Model (Scientific Discovery; Klahr, 2000). The theoretical model of the test comprised three dimensions: performance domains of science, general creativity processes, and scientific reasoning processes. The performance domains of science include five areas including ecology, chemistry, physics, biology, and interdisciplinary science. The general creativity processes include flexibility, fluency, and total creativity score. Scientific reasoning processes are composed of evidence evaluation, hypothesis generation, and experiment design. The purpose of the first subtest, fly experiment, is to assess flexibility, fluency, and creativity in hypothesis generation in biology. A figure is presented representing an experiment that is designed by a researcher. Students are required to generate as many hypotheses as they can think of that the researcher might develop. The purpose of the second subtest, the change graph, is to assess students' fluency, flexibility, and creativity in hypothesis generation in interdisciplinary science. The subtest consists of a graph of changes in the amounts of two variables and the effect that starts these changes. Students are required to think about three variables that fit the graph. The purpose of the third subtest, the sugar experiment, assesses flexibility, fluency, and creativity in experiment design in chemistry. In the problem, a figure of an experiment designed by a researcher and a graph showing the researcher's hypothesis. The purpose of the fourth subtest, the string experiment, is to assess flexibility, fluency, and creativity in experiment design in physics. From the presented figure in this problem, students are asked to think about changes that should be implemented in the experiment to accomplish the goal. The fifth subtest, the food chain, assesses students' creativity in ecology. A figure of the food chain and a graph of the change are presented, and students should think about the reasons for the change. The construct validity of the test yielded one general and three second-level factors (Ayas & Sak, 2014). In the current study, concurrent validity analysis showed a significant correlation between school chemistry and math scores and students' scores on the C-SAT. For example, students' school chemistry scores in chemistry correlated significantly with their scores on the C-SAT as following: fluency ($r = .26$, $p < .05$), flexibility ($r = .31$, $p < .01$), and originality ($r = .33$, $p < .01$). Also, students' school mathematics scores correlated significantly with their scores on the C-SAT as follows: fluency ($r = .28$, $p < .01$), flexibility ($r = .34$, $p < .01$), and originality ($r = .34$, $p < .01$). The internal consistency reliability using Cronbach's alpha was .93. The C-SAT can be scored using three types of scores: fluency, flexibility, and originality. Two independent science teachers from the same schools rated students' fluency, flexibility, and originality criteria instructed by the original test authors (see Atakaya et al., 2022; Ayas & Sak, 2014). These criteria were explained thoroughly by the research team to ensure that the independent raters understand the scoring system. The inter-rater reliability of scores in the three areas were as follows: fluency ($r = .65$, $p < .05$), flexibility ($r = .711$, $p < .01$), and originality ($r = .54$, $p < .01$), which shows acceptable indices of inter-rater reliability. Although the validity of the test was established in the literature, the content validity of the test was maintained by showing the test subscales to a consortium of 8 STEM professionals including university professors and science teachers, who confirmed that the test content can assess students' creative scientific ability.

STEAM Unit Content Assessment. To assess students' content knowledge before starting the STEAM unit, seven questions were provided to them as a pre-post assessment. The questions asked students about some facts in relation to the COVID-19 pandemic such as the R naught, the pathogenesis of the lung injury, the role of immune system in fighting the pandemic, how the COVID-19 vaccine works, how the vaccines affect outbreaks, and herd community. A rubric was developed to evaluate students' answers. The rubric criteria included correctness, details, and original or unique ideas presented by the students. Three levels (the answers meet expectations, the answers are within the expectations, and the answers don't meet expectations) were used to rate students' answers with scores 1, 2, and 3 representing the three levels respectively. The highest score the student can get is 21 and the lowest is 7. For the purpose of content validity, the rubric was shown to a group of science

teachers who applied minor changes to wording and questions. The content validity of the unit content assessment was established by showing the test questions to a group of 8 science professionals including university professors and science teachers who endorsed the appropriateness of the test questions that cover the content of the STEAM unit. Also, two independent science teachers from the schools scored students' answers on the assessment and there was a high agreement between the two raters on their scores ($r = .78$, $p < .01$).

Procedure

This study was approved by the Social Sciences Ethics Committee at the United Arab Emirates University with ethics approval reference ERSC_2023_3951. Informed consent was obtained from all participants and their parents for this study. The students and parents consented to participate in the study. The students whose written consent was received were included in the study. Six teachers from the three participating schools, in addition to the two research assistants, received training in relation to how to implement the enrichment program. The research team developed pre-recorded videos that contained instructions for presenting the different lessons included in the STEAM unit. In December 2021, an orientation session was held with the students, teachers, and school staff to brief them about the enrichment program. The meeting included briefing the participants about the objectives of the STEAM program, the targeted students, the expected roles of students, and the duration of the program. Also, an orientation meeting was held with the team of supervising teachers and lab technicians who oversaw the implementation of the unit with the students. In this meeting, the supervising team was briefed about the implementation of the pre- and post- assessment, and they had an overview of the scope and duration of the program. They also had an overview of the content of the STEAM unit, the different activities, and how to deal with any issues in relation to the implementation of the enrichment program. The research team informed the supervising team at the three schools to develop a weekly plan to implement the STEAM unit activities. The research team also prepared pre-recorded videos that included detailed explanation of the STEAM unit structure, the content of each lesson, the different activities that students should work on, and the pre- and post- assessments.

The STEAM unit was developed based on the overarching topic, the COVID-19 pandemic. The purpose of developing the unit was to get the students involved in different issues in relation to the pandemic and how to address them in a scientific way. The unit booklet included a glossary that included all possible terminology in the unit and beyond, 8 lessons with activities and assessments, and content pre- and post- assessment. The content of the units included the concept of R naught and its role in the pandemic, how the immune system fights the infections, how the vaccines can fight the pandemic outbreaks, how to involve herd community, modeling the chances of getting an autoimmune disease, and programming simulation activities using a software (Scratch). "R naught" is a term in epidemiology that refers to the basic reproduction number of an infectious disease. It indicates the average number of secondary infections caused by one infected person in a population that is entirely susceptible.

Each lesson included an introduction, some YouTube videos in relation to the topic, student worksheets that included questions/activities that need to be answered by the students with the assistance of the supervising teachers, and hands-on activities (e.g., simulations using software programs, and using materials and resources to simulate actual experiments in relation to the lesson content). The last part of each lesson included career connections which highlight the different types of careers related to STEAM in the real world. Some of the lessons included experiments that can be conducted at home with easy materials such as scissors, digital scales, measuring cup, paper, pencil, and rulers. The unit also included some artistic design activities related to the topic. Also, the unit included a language arts component in which the students wrote persuasive essays about how to persuade others that social distancing works using teaching models such as the Literature Web, the Hamburger Model for Persuasive Writing, and the Vocabulary Web. Students started working on the STEAM unit from January 2022 to June 2022. Because of the lockdown due to the pandemic, most of the enrichment program sessions were online while few of them were physical and were introduced in the school face to face. The research team prepared four training videos for the schools' teams as a resource they can consult in the implementation of the enrichment unit. Also, another video explained how the teachers and students can use the STEAM enrichment program online platform. To integrate fine arts into the unit lessons, students were asked to develop posters or infographics that illustrate the spread of infectious diseases, the importance of immunization, or the impact of public health measures. This helped them visualize data and communicate complex information effectively either to their classmates or teachers. The integration of persuasive essay writing is another example of integrating language arts in the enrichment program.

An online platform was developed by the research team to provide both teachers and students with resources that could help implement the program. The platform also served as a tool to follow up students' progress in the implementation of the enrichment unit activities by both the research team and school staff. An example of the STEAM online platform is shown in **Figure 1**. There were two links, STEAM boys and STEAM girls. Each link

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included several resources such as announcements, forums, pages and collections, students' journals, shared files, and files uploaded by the students. The unit content was made available on the platform.

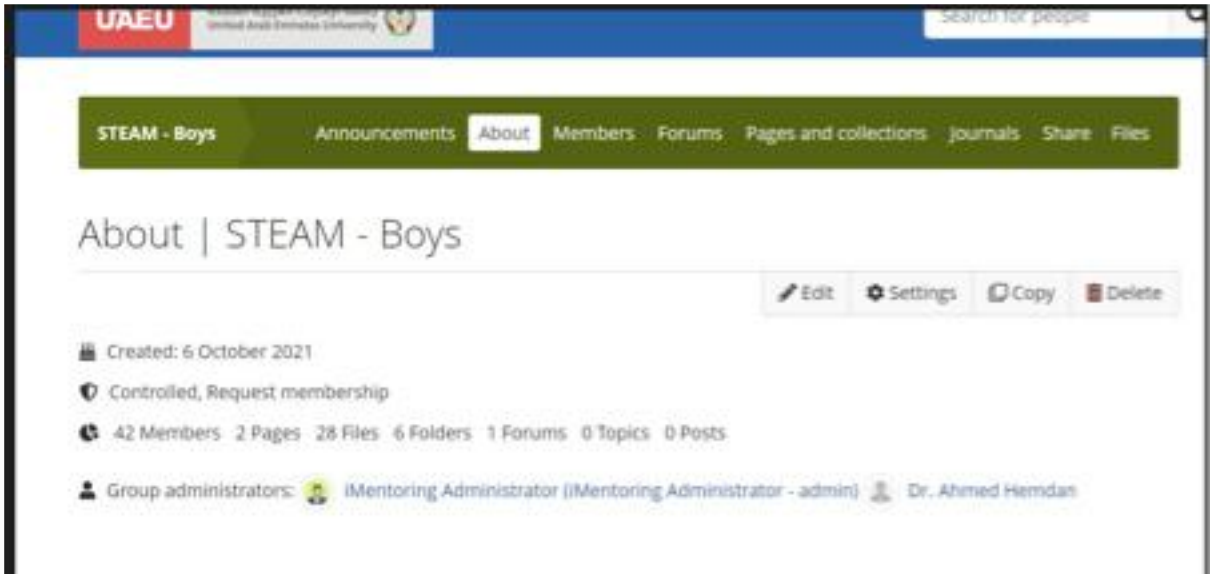

Figure 1. *STEAM Online Platform Used in the Implementation of the Enrichment Program*

The platform served as an effective tool for students and teachers to exchange ideas, resources, and experiences in relation to the different activities of the enrichment unit. For the two groups (students and teachers), several questions guided the focus group discussions as follows:

1. What have you enjoyed about the STEAM enrichment program?
2. In what ways was the program effective in preparing you for the 21st century skills (e.g., critical thinking, communication skills, creativity, problem-solving, technological skills, etc.)?
3. What do you think about the activities conducted throughout the program? Were they helpful? Were they engaging?
4. Did these activities help you understand science/biology better? Were these activities related to what you learn in school?
5. Do you have any issues/concerns related to the enrichment program?
6. In what ways did the enrichment program help you think about possible future STEAM jobs? Which kinds of jobs have you become interested in?

What are the challenges you've encountered in this enrichment program? If you were to involve in these programs again next year, what would you want us to do differently? Why?

RESULTS

The data analysis plan for the study questions included the assumptions check, data analysis plan, and control for potential confounding variables. The assumptions check included independence of observations through random sampling of the experimental and control groups. The Shapiro-Wilk test was conducted to ensure the data are normally distributed. Results indicated that data for the experimental ($W = 0.98$, $p = 0.45$) and control groups ($W = 0.97$, $p = 0.32$) were normally distributed. The control for potential confounding variables was achieved by ensuring that students are mostly from similar age groups, socio-economic status in addition to controlling other variables that might influence the dependent variables such as prior knowledge and participation in extra-curricular enrichment activities related to the unit content.

To answer the first question, What is the effect of the STEAM enrichment program on the scientific creativity abilities of grade 10 students?', an independent-samples *t* was conducted to explore the differences in the three C-SAT scores (fluency, flexibility, and originality) between the experimental and control groups.

The results showed that there are no statistically significant differences between the two groups on the three scores in the pre-test. The results are shown in **Table 2.**

Table 2. *Means, Standard Deviations, and Independent-Samples t Test in the Pre-Test and Post-Test*

Pre-Test

		N	*M*	*SD*	*df*	*t*	*Sig.*
Fluency	Experimental	54	7.53	4.50	85	.784	.43
	Control	33	6.81	3.47			
Originality	Experimental	54	1.94	2.19	85	.884	.52
	Control	33	1.84	1.22			
Flexibility	Experimental	54	7.12	4.52	85	1.50	.14
	Control	33	5.84	3.37			

Post-Test

		N	*M*	*SD*	*df*	*t*	*Sig.*
Fluency	Experimental	54	10.63	2.17	85	2.27	.01
	Control	33	8.36	3.05			
Originality	Experimental	54	2.63	2.35	85	1.9	.08
	Control	33	1.85	2.75			
Flexibility	Experimental	54	9.94	1.86	85	2.22	.01
	Control	33	7.73	2.99			

The independent-samples *t* test showed that there was a statistically significant difference between the experimental and control groups in the post-test in favor of the experimental group in both fluency, t (85), 2.27, p = .01, Cohen's d = .83 and flexibility t (85), 2.22, p = .01, Cohen's d = .94. The Cohen's d for the two scores is larger than .80 showing that the effect size was large (Cohen, 1992). Also, the paired samples t test showed a statistically significant difference between the STEAM unit content assessment pre- and post- assessment in favor of the post-assessment for the experimental group, t (53), 3.12, p = .05, Cohen's d = .63. The effect size using Cohen's d was medium.

To answer the second question, **"**Are there any statistically significant differences between males and females in the scientific creativity scores?" an independent samples t test was conducted to explore the difference between male and female students on the scientific creativity test scores in the post-test. The results showed females were better than males in originality, t (85), 3.69, p = .001, Cohen's d = .79. The effect size using Cohen's d was medium. No statistically significant differences were found in relation to the fluency and flexibility scores.

Qualitative Results

The purpose of the qualitative section was to understand the different viewpoints of students and teachers in relation to the impact of the STEAM enrichment unit. To preserve the participants' privacy, all identifying information was removed when discussing the quotes and themes. The participants were later approached by the research team to check the results and themes. Two research assistants conducted semi-structured interviews with students from the three schools who participated in the STEAM enrichment program. A total of 19 students participated in the interviews. Also, a total of 5 school staff [math teacher (8 years of experience), biology teacher (24 years of experience), lab technician (12 years of experience), lab technician (16 years of experience), and vice-principal (18 years of experience) from the three participating schools participated in the interviews. The students and teachers were asked to participate in the interviews and those who gave their consent were interviewed.

To maintain a rigorous qualitative data collection, the semi-structured interview was adopted (Kvale & Brinkmann, 2015). The interview questions were presented to participants but were open to further elaborations that the participants shared. The thematic analysis was used to analyze the qualitative data from the interviews and followed the six steps proposed by Braun and Clarke (2006) for the inductive thematic analysis. The steps included familiarity with the data, generating initial codes, looking for themes, reviewing the themes, defining and naming the themes, and producing the report (Braun & Clarke, 2006). The first step included familiarization with the data through immersing in the data by reading and re-reading it, noting down initial ideas. The second step included generating initial codes by identifying and coding interesting features of the data systematically across the entire dataset. The third step included searching for themes by collating codes into potential themes, gathering all data relevant to each theme. The fourth step included reviewing themes to check if the themes work in relation to the coded extracts and the entire dataset, generating a thematic map. The fifth step included defining and naming themes by refining each theme and creating clear definitions and names for each. The sixth step included producing

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the report by weaving together the narrative of the data with the themes to produce a final report. To ensure the inter-rater reliability in this analysis, some key steps were followed. These steps involved that the coders were trained in the coding process and framework. Second, a detailed codebook (excel sheet) was developed with clear definitions and examples for each code to guide coders. Third, pilot coding was conducted where two independent coders provided their codes of the data, and the results were compared to refine the codes and ensure consistency. Some meetings were held to discuss coding decisions and resolve any discrepancies. The inter-rater reliability using Cohen's Kappa was moderate (k = .60). Finally, the codes were revised to improve consistency.

Students who participated in the STEAM program from the three schools were also asked about their perspectives on the program. **Table 3** displays the students' perspectives on six themes, their frequency, and representative examples.

As shown in **Table 3**, five of the extracted themes reflected the students' positive perspectives which revolved around the program's positive impact namely "students' enjoyment", "gained benefits", "the effective promotion of 21st-century skills", "supporting school STEAM subjects', and "students' selection of future profession".

Only one theme reflected students' concern which was the "challenges" theme. Students and teachers who participated in the STEAM program from the three schools were asked about their perspectives on the program. They were positive about their experience and expressed many strengths of the program.

However, they also mentioned a few challenges and offered some suggestions. Four of the extracted themes reflected the positive perspectives which were revolving around the program's strengths namely "student enjoyment", "the effective promotion of 21st-century skills", "supporting school STEAM subjects', "students' selection of future profession", and finally "challenges".

Table 3. *Themes, Frequencies, and Examples of Students' Perspectives about the STEAM Enrichment Program*

Theme	Frequency	Examples
1 Students' enjoyment	14	
		"What I enjoyed was the fact that it gave us a break from the routine of classes like it was something new and we all just one straight into it expecting nothing. So, it's really surprising to see us here." "It was really fun for me personally because I had to do a lot of reading." "Yes, did I learn more about immune system and about COVID-19 and other diseases in the world. I learned to think in another way, different way. and I communicated more with my classmates at the class to solve the same problems." "At the most it was about biology and some mathematics and physics, but we learn too much about biology, and it gave us the knowledge we know about why the vaccine is important to take it and how the immune system can fight the virus and what is the step to fight with the virus." "I enjoyed when we do the salt and the magnet how the virus secret with the magnet is so fast." "It was fun actually to go and do experiments with my classmates and find out that results together and discover something we never knew before." "I enjoyed the biology here, the biology project where we had to search for information about COVID-19, and I learned some new stuff about genetics and how COVID19 spread and its impact on our world today." "So, as my colleagues have said that the project of the STEAM was so helpful. That we learned a lot of stuff about genetic and a lot of stuff about COVID-19 and how it spreads around people and how to Immunity." "I would say that the project was so like amazing. It made a combination of biology and math. And it made us think in a real another world." "As my colleague said, it's so helpful. Uh and uh. Useful for us because it's like review our information and a grade before and therefore this information will help us in the other grades when we come bigger in grade 11 and like this." "Uh, the activity. I like it. I was on the food web. And it was really basic. And I really enjoy it. That's it." "I enjoyed and we all enjoyed while doing the STEAM project, because it was not only about one like one information it was under various sub subtitles that meet a lot of like our expectations." "I have really enjoyed about doing analysis and just analyzing how to. how covered works and how to get the results and how to you know see them into the future I really enjoyed that, and it gave me a lot of information about what we can do in the future too."

Continued

2- Gained benefits	15	"I have enjoyed the uh.. like about the causes, the causes of disease and how some variables can affect the disease like how much of people like some people have taken (vaccinate) when a lot of people vaccinate it will like cause a protection for the community. When a lot of people have herd immunity it will like to be more benefit for the community to be safe. " "What I like about the STREAM is that it lists your brain work hard like to work to analyze and how the virus spread and everything and like what my classmates said about the calculations for everything that's in the future and everything they said." "The main thing the main thing that I enjoyed about the stream, the main thing that I enjoyed about the stream is especially a part where we would we go to analyze the charts and get to know the vaccinated people and just the ratios of it, so it was really helpful to know about the state of the world from the chart in many several ways." "It teaches us how to analyze because it gave us like and some diagrams that we have to fill with the numbers like from the graph. Uhm we also know how to think out of the box like it needs, like everyone wants his answer to be like a unique answer. So, it's like it's growing some of our futuristic thinking and skills and we also use the problem-solving skills because as it was mentioned in the last of more than three steps um one problem was one problem was there, and we have to solve it. So, I think that was one of the best ways to apply the futuristic thinking and the 21st century skills." "I would like to say that it affected my analyzing when they ask for how this thing happened like for the reasons it affect like when you think out of the box like my friend mentioned, improve your analyzing skills you will think and you will try to find the best answer you will try to think about every smallest step about every small thing that in this problem. so I think it affect our analyze and improve it." "It did indeed help us grow our critical thinking skills focusing on many other or several targets; uh one of them is to is to teamwork with our classmates into solving uh to solving a specific question uh and in fact and they've served to grow and improve our critical thinking." "It helped us and other ways by giving us analysis and give us about information about herd immunity." "The questions in the project really helps a lot because it can improve your communication skills and it can improve your critical thinking and it can like let you think of the books like each question is like meant to be for each of these skills to collaborate and think of the books and the communication and it's really the questions are really impressive because it can make you like work hard for it and get a unique answer and it's also help us in our searching skill when you search to get a unique answer and yeah that's it."
3- Effective promotion of the 21st century skills	17	"As I mentioned before it made us think more critically and in more details about the front things as Aisha said our immune system, omicron, COVID-19 virus, how it affected people and how it affected us personally as well and how could we avoid it." "Also really helped us with communication skills, we were working as classmates, it made us improve our relationships, our communication skills. we were more comfortable and like sharing our ideas talking about these new ideas and so on." "It was helpful because it's made a connection between all the information which is familiar to us by previous grades and previous years, and it helped us to review them and so we can use them later and keep them in mind so we can keep using them over and over again in different math subjects. And in biology, it helped us review our last year's information about genetics and how they divide, which is the same way for cover 19. It spreads through genetics and divide, which make it harmful for our body and immune system." "So, it's about giving students the skills they need to succeed in the new world and helping them grow their confidence to practice those skills with so much information like available to them in the 21st century. Skills focusing on like sense skills which make sense to the student and

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Continued

3- Effective promotion of the 21st century skills	17	information sharing and using it in a smart way. So, the student can like to observe it. So, I found all Like these things in your project." "I can talk about how we used the Internet and website to get the analysis and how we use our minds with math using some math to get some results. We just did some questions and stuff to have the results we didn't just take copy and paste. No, we did some work on them, and it was really fun doing that. So, we used a lot of stuff like analysis, calculations, brainstorming, thinking out of the box all of that just to give the answer. So, in the end it gave us the feeling of being you know doing something." "I think it helped with the point of critical thinking and problem solving, because these are one of the more important criteria of the being a leader in the future." "I learned to think in another way, different way. and I communicated more with my classmates at the class to solve the same problems."
4- Supporting school STEAM subjects	17	"We calculated how much the ages like when we calculate when someone had the Covid." "One of the experiments we did was calculating probabilities of how many classmates would have the immune system syndrome control and how wouldn't. we used m&m. chocolate and cups and different papers to calculate it so that included mathematics and about the biology part that make us learn more than what we already did because we don't study biology for grade 10 besides we learned about our system and how it could be affected from virus like COVID-19." "The activity about the information for COVID-19 and I have a lot of information that I take its new but this information and help me in our real life with knowing that the COVID-19 what will do if I go out without the Mask or something like that. Uh, and uh, there was a for drawing a graph and then he combined between the biology and mathematics that helped me that a new information that tell us that the not one science type can be with himself." "Uh, yes. it help us to know a new information and there if you another information that we take before and help us to prepare for the 2nd grade for the 11th grade and to know about things like food web that start with the plant and the plant elements ate and the animals eat another animals like this one and help us to review the things or formation information that we take it before." "As I was saying as I was reading through the project, I realized something that I didn't know before. Something called R Capital R and Biology and by this. The Doctors and scientists called this R level by levels one level one level 2 and et cetera depending on the level you have a percentage of getting disease by a certain virus and this impact was fully important in COVID-19 because you had to have a certain R level to be dangerously targeted by this disease. So, you don't have immunity to stand up for it. And this was something I never knew before that existed in biology because biology is all about genetics. In the middle information like the R, the R information which is levels. This level makes you immune to COVID-19. This level means that if you are in danger of getting that disease, it was new, and I never know something like that existed in biology. "This program didn't only help me in biology and about Omicron, Covid-19 and some disease but it also has another subject such as mathematics when we use the probabilities for example to know who is immune or not. also improved our reading skills, searching skills because we needed to read a lot to understand, so yes, I do agree with her. "the STEAM project if it was applied in our books using the same techniques and the project like the relate and the contrast and like find the difference collaborate communicate a lot of like different 21st century skills it will be like a very beautiful addition to our critical and I think it is a very like it's a very good idea to add it to our curriculum and that's it."

Continued

5-Students' selection of future profession	20	"Well, there was an engineer part and the chemical and bio engineer. I thought it was really interesting so it got my mind but overall, it like if it would be related to COVID I think a scientist would fit these criteria." "I like the bio engineer and when I finish my school, hopefully." "I think I'm interested to be a bioengineer because I love to study about body system." "I love biology so I will study bioengineering, neurological science." "I would like to be a doctor and bio engineer so I can help the people and learn more about diseases under the vaccine that we should get." "If I had to choose between them, I would like to go with the chemical parts or the engineering because I like chemistry and I also like biology, I'd like to learn more about immune systems and our bodies and how does it work." "The job that I was thinking about before is the doctor. But when I did the project, I said that the doctor will be so and so not easy and will take a lot of time to work. But I said when I do the project, I think that the engineer is better for me and it's so helpful and like, it's kind like the math that I love math. It's kind like it." "Well, I before I do the program, I was interested only in engineering, technology engineering to be exact. But after I made the project and had to see the differences between biology and math either it's from the test we took or the last project which was the Covid 19 and stuff. I realized how much of a wide world of biology, how it's so condensed and contain a lot of the of information in between and how you have to take more knowledge in it so you can crack the surface and know more from the inside about information that you can only know by taking special courses in genetics and the medical experiments in in general" "And one of the jobs in biology that I really liked was an academic researcher and biotechnologist and Biotechnologist is one of my favorite jobs that studies the chemical, genetic, and physical attributes of the cells." "I am interested to become biologist Because I think I want to know more about the more same information about life." "Engineering" "I'm interested in being a coder like making games and programs." "I thought about an IT job because I got interested in computers and programming or coding or computers in general." " Um whenever anybody asked me what I want to be in the future my answer was a medical specialist and after I entered the STEAM project I recognized that there is a new type of information like it mentioned about the immunity I was really interested in the immunity system and I think like the STEAM project effected on me like and what branch was like a medical specialist I want to be something which is related to the immunity system " "Yes, first of all I want when I when I grow up I want it to be a pediatrician and which is in the medic and this project really helped me a lot to know the structure of the virus you know the spread time and everything which also will be used in medic to know the patient's disease and the symptoms and really helped me a lot." "So STREAM helped me like it gives me another vision for the future like I think or I thought about my future like I I would like to be a scientist that discover how things work the problems how to solve problems I like that kind of work like they give me a problem and how to solve it and this thing was what was on our STREAM like our STREAM questions, they ask for us problems and how for problems and how this solve it how like i think out of the box, many solution and I think that helped me like decide my future and I like it I like it that questions so much because it was talking about biology and science." "Yes, the STEAM activity helped me so much to and change my career. I want to be engineer but now I want to be a chemical engineer to make a new medicine to protect from a new disease."

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		"I like to add that sometimes we have some issues when we were doing the program." "At the end of it when we try to review what we had done the website or the link provided in the sheet the website had underwent I think maintenance and so we were held back a few lessons because it couldn't open, so that added to the pressure of having to complete it in due time." "As we mentioned earlier, we do not study biology in grade10, so it was a bit hard to comprehend and take the full information since we had short amount of time. So, we had to read a lot and understand a lot in fast time but other things were like as Alyazia said that the website sometimes held us back and how to take extra lessons where the program and miss our main lessons. so that's mainly the main challenges." "We had short time because we had an exam at the same time. so… but it was fun like we need more information about it and more things that we didn't know." "We had no time, and we were at the doors of final, so it was so hard to us to finish school duties and to this program." "Yeah, well, the difficulties are because the so much old things were there at the time, and since we had to remember them in some ways it was difficult to review it because as you know, as time passes you start to forget information and it will. In that way it was hard enough, but also since we had our studies to focus on, it was kind of an intense time to balance between the two by filling our projects in the steam and doing our normal life school homework and projects asked for months. It was kind of a. Yeah, a big load to take. It was kind of a big load to take in at one time, but it was organized in. It was organized like this week. We have to do this and the other week we have to do this. So it wasn't that much of a bad timing, but it was the best thing." "Some of the questions are extremely based or related to the to the Internet into Internet surfing and there could be many several problems including that since it has to be reliable as a source of for the source of information that could help the student. and improving many different skills it is important but like making it harder though be a wouldn't be a solution for the student, may be decreasing the uh difficulty of the of the question might be a solution." "I think it's a good idea to make the question a little bit like easier for the student." "Yes, in order to complete each step, each step was harder than the before one and most of the steps has no relation to each other and as long as I was moving to a different step the resources were more the facts were less." "I did enjoy the program like generally, but the problem was that she said we were under pressure because of the short time we had, and it was online so we were like crazy to be productive but when we go to school program it was amazing, we could search and do experiments." "I would just like to have more time to read and research and understand more and not have everything rushed because even our school was behind our backs, so it wasn't only the program it was also the school. So, it was a bit pressuring since we were like in a final phase that time and as I said we only did online by then by that time, so it was also just challenging."
6- Challenges	23	"I like to add that sometimes we have some issues when we were doing the program." "At the end of it when we try to review what we had done the website or the link provided in the sheet the website had underwent I think maintenance and so we were held back a few lessons because it couldn't open, so that added to the pressure of having to complete it in due time." "As we mentioned earlier, we do not study biology in grade10, so it was a bit hard to comprehend and take the full information since we had short amount of time. So, we had to read a lot and understand a lot in fast time but other things were like as Alyazia said that the website sometimes held us back and how to take extra lessons where the program and miss our main lessons. so that's mainly the main challenges."

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	"We had short time because we had an exam at the same time. so… but it was fun like we need more information about it and more things that we didn't know." "We had no time, and we were at the doors of final, so it was so hard to us to finish school duties and to this program." "Yeah, well, the difficulties are because the so much old things were there at the time, and since we had to remember them in some ways it was difficult to review it because as you know, as time passes you start to forget information and it will. In that way it was hard enough, but also since we had our studies to focus on, it was kind of an intense time to balance between the two by filling our projects in the steam and doing our normal life school homework and projects asked for months. It was kind of a. Yeah, a big load to take. It was kind of a big load to take in at one time, but it was organized in. It was organized like this week. We have to do this and the other week we have to do this. So it wasn't that much of a bad timing, but it was the best thing." "Some of the questions are extremely based or related to the to the Internet into Internet surfing and there could be many several problems including that since it has to be reliable as a source of for the source of information that could help the student. and improving many different skills it is important but like making it harder though be a wouldn't be a solution for the student, may be decreasing the uh difficulty of the of the question might be a solution." "I think it's a good idea to make the question a little bit like easier for the student." "Yes, in order to complete each step, each step was harder than the before one and most of the steps has no relation to each other and as long as I was moving to a different step the resources were more the facts were less." "I did enjoy the program like generally, but the problem was that she said we were under pressure because of the short time we had, and it was online so we were like crazy to be productive but when we go to school program it was amazing, we could search and do experiments." "I would just like to have more time to read and research and understand more and not have everything rushed because even our school was behind our backs, so it wasn't only the program it was also the school. So, it was a bit pressuring since we were like in a final phase that time and as I said we only did online by then by that time, so it was also just challenging."

Theme 1: Students' Enjoyment

The first theme was the "students' enjoyment" which reflected how really the students enjoyed their participation in this enrichment program. The students brought many situations and experiences to feel this way. For example, Student 2 explained why he enjoyed it "*What I enjoyed was the fact that it gave us a break from the routine of classes, it was something new and we all just one straight into it expecting nothing. So, it's really surprising to see us here*". Student 1 extended by saying "*It made us think as if we were in another world*". Student 5 confirmed her enjoyment to participate in "*a new type of experience, it was different from what we are taking in school*". Student 1 extended by saying "*It made us think as if we were in another world*". Additionally, many students described their enjoyment of practicing new skills like doing analysis as mentioned by student 4 "*I have really enjoyed doing analysis and just analyzing how to get the results and how to, you know, see them [he means He means how the virus will reproduce] into the future. I really enjoyed that, and it gave me a lot of information about what we can do in the future too*". Student 2 confirmed "*I enjoyed the biology here, where we had to search for information about COVID-19, and I learned some new stuff about genetics and how Covid 19 spread and its impact on our world today."* Also, student 9 brought up another example for his enjoyment "*I enjoyed when we did the experiment of the salt and the magnet and how the virus reacted with the magnet is so fast.*" Another student expressed that "*It was really fun to conduct experiments with my classmates and see the results together and discover something we didn't know before*". Moreover, the integration between academic subjects brought another dimension to enjoying the enrichment program. Student 10 said "*I would say the project was absolutely amazing. It combined biology and mathematics. It made us think about another world.*"

The teachers who participated in delivering the enrichment program supported the students' view of the program's power to excite and break the school routine. Teacher 4 said "*This program was something new for students to learn, and it was more beneficial than the traditional method of education.*" The teachers also stressed the students' enjoyment of participating in some activities. Teacher 1 said "*There are many experiences that the students benefited from, including the*

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experience of antibodies. I noticed that the students were very enjoying it.". Teacher 1 explained "I will mention to you an example that was in the second week of the program, which is the Anti Bodies activity that the students enjoyed very much, as it represented its role in immunity against disease, and it was benefited from very much, the students enjoyed it very much". Teacher 3 extended "*The students were also excited and benefited from a lot of valuable information such as how to deal with the pandemic and information about the disease*".

Theme 2: Effective Promotion of the 21st Century Skills

This theme reflected that the STEAM enrichment program improved students' 21st century skills and raised their awareness of its importance in their future as student 10 said, *"So, it's about giving students the skills they need to succeed in the new world and helping them grow their confidence to practice those skills with so much information like available to them in the 21st century. Skills focus on sharing of knowledge and using it in a smart way".* Student 2 explained, *"Participating in this program helped us with problem solving because we have to think in a unique way. So, like thinking outside the box, there are the answers you can't expect by convergent or traditional thinking".* Student 1 confirmed *"it also helps us improve our knowledge and many perspectives, helped us think out of the box and create new ideas and thinking differently".* Additionally, student 5 described the improvement of the students' skills that prepare them for future, he said, "*First, we used the communication skills because the first thing in the program to give us the general idea and we discuss it with our teacher, and the second thing is it teaches us how to analyze because it gave us some diagrams that we have to fill with the numbers from the graph. We also need to think out of the box to find unique answers. So, it's like it's growing some of our futuristic thinking*". Student 3 confirmed, *"So it's about giving students the skills they need to succeed in the new world and helping them grow their confidence to practice those skills with so much information like available to them in the 21st century".*

The teachers also focused on 21st century skills while talking about the program's strengths. Teacher 6 listed many skills that the students developed while working on this program such as "*Team working, problem solving, critical thinking, knowing the conditions of the problem, practical application of the program and providing students with information about disease and immunity increase, data analysis, developing a way of thinking, meeting students with each other, programming skill, in addition to awareness of disease and the necessary vaccinations*". Teacher 4 clarified that,*" These skills were missed during the past two years, because it was difficult to communicate with the students during the pandemic. The program contributed to activating these skills".* Teacher 2 added, "*In addition to what mentioned by my colleague, one of the beautiful things about this program is the skill of prediction and conclusion, such as deduction in some questions, what is the reason for the spread of cases? How does the incidence of infection increase? in addition to the practical application of the information they study with the reality in which they live".* Teacher 5 extended, *"Even the pre-test had a lot of critical thinking questions, and it was varied and enriching for talented students".* Teacher 3 talked about using knowledge and the nature of the program in the students' life, "*The participation of the students in teamwork and critical thinking, the interaction of the students with experience, discovery through practical application, and knowledge of some important matters that they deal with in life."*

Theme 3: Supporting School STEAM Subjects

Students mentioned many benefits of this program such as reviewing students' previous topics and linking them to their current and future study topics. For example, student 1 said about the program, "*It is very useful for us because it is like reviewing our information in this class 10 and past year classes, so this information will help us in other grades and subjects when we grow up in class 11 and so on".* Student 6 clarified, "*I learned a lot of things because while searching for information to get answers in either mathematics or biology, in this project, we had to review all the information and add some new information in advance so that we could arrive at the perfect possible answer.* Furthermore, student 8 added, *"I agree with my colleague, this program didn't only help me in biology and about Omicron, Covid-19 and some diseases but it also includes subject such as mathematics when we use the probabilities for example to know the number of immunizations in the community. Also, the program improved our reading and research skills because we needed to read a lot to understand*," "Student 5 indicate more gains where the STEAM program helped them to be prepared for later grades, "*Actually, we haven't studied biology before, so the program helped us how to get an idea about biology and how to study the bio in later grades.*" The students also obtained information that broadened their horizons about the current issue of the pandemic. For example, Student 3 said, "*In the STEAM project, we learnt new information about health and how we can improve the chance of getting immunity. We also learned about* R *naught. We learned that if the ratio is more than one, it is possible to get a disease like Covid-19 ".* Student 5 added that they learn to use computer applications, *"I used the scratch app to see how the virus is spread and how it infects other cells".* Student 10 connected using technology in this program with the UAE's vision by saying, *"It's related to the UAE vision of the future because it helped us depend on and get more understanding of our technology because it will not stay the same. It will develop even more in the future. So, we have to start with the basics, know how to use our technology so we can use its newer versions".*

The teachers highlighted the students' gains from this program. Teacher 4 said, "*The implementation of this program has contributed to improving the students' skills that they lost during the pandemic*". Teacher 5 confirmed, *"The implementation of this program has helped the students in two ways; it helped improving the students' skills that were somewhat forgotten because they*

didn't practice them during the distance learning period, especially the skill of reading and preparing tables and data, and at the same time this program helped enrich some other skills. This improved their math and other subjects".

Theme 4: Students' Selection of Future Professions

The fourth theme was about students' selection of future professions where the students' comments showed the positive impact of the STEAM project on broadening their mind into STEAM new future professions. For example, Student 4 mentioned, "*Actually, I'm into cyber security computer science and those stuff related to technology so when I entered the STEAM project, it opened a path for me which is the data analysis and data collection. It opened me two paths; one as a biologist, and the other is as a data analyst*". Some students even changed their future profession after participating in the STEAM project. For example, student 7 said, "*STEAM helped me like it gives me another vision for the future like I thought about my future like I would like to be a scientist that discovers how things work the problems how to solve problems. I like that kind of work like they give me a problem and how to solve it and this thing was what was on our STEAM like our STEAM questions, they ask for our problems and how for problems and how this solves them. I like I think out of the box, many solutions and I think that helped me decide my future*". Student 6 also explained how he changed his mind about new future job opportunities, *"The job that I was thinking about before is a medical doctor. But when I participated in the project, I thought that the doctor profession would not be easy and will take a lot of time to get ready to work. So, I thought that I love math and the engineer is better for me because I could be so helpful".* A similar response was given by student 1, "*I was only interested in engineering, engineering technology to be precise. But after participating in the STEAM program, I saw the differences between biology and math either from the test we had or the last project which was the pandemic. I realized how vast the world of biology is, how it is very intense and contains a lot of information and how you have to take more knowledge into it, so that you can scratch the surface and know more from the inside than the information that you can get and known only by taking special courses in genetics and medical experiments in general."*

The teachers found that the program has a significant impact on students' future job selection as it offered new options to consider. Teacher 4 said, "*The students were very interested in different fields, including the field of data analysis, biology and its connections with the local environment, and the field of diseases and the program prepared them very well for these fields and their application in the future".* Teacher 2 supported the same view, *"In our school, the students were interested in more than one field, including genetic engineering and medical laboratory work, thinking in this field and the steps that should be taken in this field, in addition to the fields of medicine, pharmacy, and diseases treatment. "*

Theme 5: Challenges

The fifth theme was about "Challenges". The students agreed with their teachers that they have some concerns regarding the time, and the program content level. However, what was interesting about this theme was that some students saw these challenges as opportunities. For example, student 9 mentioned, *"I did enjoy the program generally, but the problem was that we were under pressure because of the short time".* Student 10 also highlighted the time constraint issue, she said: *"We didn't have time, and we were approaching the final exams, so it was difficult for us to finish the schoolwork and this program".* While student 6 didn't agree with his colleague's claim by saying, *"Actually time wasn't that much of a problem because not all the activities we had were about solving problems, some of the activities were that we had to review. But I think that the time they gave us to solve was reasonably enough.* Another challenge reported by students related to the high level of program content, for example, student 14 showed his concern about the content level said, *"I think it's a good idea to make the question a little bit easier for the students. and I know it can improve the students' knowledge and critical thinking and everything but not every student is working hard.*". While student 11 didn't agree and said, *"I don't face any difficulties because it may be this information I know before and I if I don't know it, or I have any difficult or unanswered question, I could even search or ask about it".* Content level concern was raised as students haven't studied biology in grade 10. They are expected to study biology in grade 11. Student 1 added, *"We do not study biology in grade10, so it was a bit hard to understand and take the full information since we had short amount of time. So, we had to read a lot and understand a lot in a fast time."* However, Student 1 looked at the previous challenges as opportunities saying, *"Time does not matter, because what matters is how we think and how we will be thinking in the future and if it was hard also the questions were long or small. Uh, people have different levels".* Moreover, student 7 was directing his colleagues to think differently as he said, *"The challenges that we have to meet, they teach us how to be more creative and how to solve our problems. As my friend mentioned, the challenge of time teaches us how to be organized and to help us do all our things and to be more creative".* From the students' previous views, the students' critical thinking and communication skills were clear as a good impact of the program on the students.

Table 4 displays themes of teachers' perspectives on five themes. The themes reflected challenges, students' gained benefits, students' enjoyment, students' selection of future profession, and general judgment about the program. Teachers also hold the same concerns. teacher 2 reported, *"Despite of assigning weekly classes to implement the program, it wasn't enough".* Teacher 5 supported this claim by saying, *"Also, the duration of the program was very short, as the implementation was carried out in the second semester only and lasted for four or five weeks".* Teacher 2 clarified that, *"The*

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second semester [the time of program implementation] the infections with Covid-19 were increasing and we switched into distance learning again. Thus, there were a lot of students' absences, which affected the program and its implementation". Another challenge was about the level of the program content where teacher 3 mentioned that *"The level of the program was very high. It required explanation more than once for the student to understand, and to master what is required from the student"*. But teacher 1 didn't agree by saying, "*There is no need to lower the level of questions in the program, it is an enrichment program"*.

Table 4. *Themes, Frequencies, and Examples of Teachers' Perspectives about the Impact of the STEAM Enrichment Program*

Theme	Frequency	Examples
1-Challenges	9	"There is a comment on the students not studying biology in the tenth grade; this was a severe obstacle for me, especially since the program was conducted by only one teacher (the speaker)." "Also, the duration of the application was very short, as the application was carried out in the second semester only and lasted for four or five weeks only." "For me, the level of the program was very high, that is, it is higher than the level of the tenth grade, and the amount of information provided is very large." "I agree with Participant 1 about the challenge in the process of motivating and encouraging students, because the process of motivation has a great role in influencing them. As a biology teacher, I taught my female students last year, and I know them well, but this year they do not study biology officially. Thus, when I implemented the program with them, the response was very little - because they know that the program is not linked to any subject grades."
2- Students' gained benefits	6	"Team Working, Problem Solving, Critical Thinking, Knowing the Conditions of the Problem, Practical Application of the Program and Providing Students with Information about Disease and Immunity Increase, Data Analysis, Developing a Way of Thinking, Meeting Students with Each Other, Programming Skill, in addition to Awareness of Disease and the Necessary Vaccinations." "The implementation of this program has contributed to improving the students' skills that they lost during the COVID-19 pandemic." "Students did not have any background on the subject or the nature of the questions, or regarding the method of infection spreading, through this project, the information provided to the students was benefited from, and the given information was transferred to others." "The participation of the students in teamwork and critical thinking, the interaction of the students with experience, discovery through practical application, and knowledge of some important matters that they deal with in life."
3- Students' enjoyment	3	"There are many experiences that the students benefited from, including the experience of antibodies. I noticed that the students were very enjoying it and benefited from a lot of valuable information such as how to deal with the pandemic and information about the disease." "I will mention to you an example that was in the second week of the program, which is the Anti Bodies activity that the students enjoyed very much, as it represented its role in immunity against disease." "For our school, the experiences that had the most positive impact on the students were the Anti Bodies and the probability experiment using M & Ms." "Yes, there are many experiences that the students benefited from, including the experience of antibodies. I noticed that the students were very enjoying it."
4-Students' selection of future profession	2	"Yes, for me, the students were very interested in different fields, including the field of data analysis, biological work and its link with the local environment, and the field of diseases and the program prepared them very well for these fields and their application in the future."

Continued

		"In our school, the students were interested in more than one field, including genetic engineering and medical laboratory work, thinking in this field and what are the steps taken in this field. in addition to the field of medicine, pharmacy and disease treatment." "For me, the students were very interested in different fields, including the field of data analysis, biological work and its link with the local environment, and the field of diseases and the program prepared them very well for these fields and their application in the future." "The students were interested in more than one field, including Genetic Engineering and medical laboratory work, thinking in this field and what are the steps taken in this field. in addition to the field of medicine, pharmacy, and disease treatment. "
5- General judgment about the program	5	"This program is like something new for students to learn, and it was more beneficial than the traditional method of education." "The content was understandable, but the lack of time to implement the program is the problem. We started the implementation in the second semester, that is, at the beginning of February to the end of April, but perhaps the class time was short to implement the program, and it needs more than one class." "Do not forget, doctor, that the second semester the infections with Covid-19 was increased and we turned into distance learning. Thus, there was a lot of absence, which affected the program and its implementation." "The implementation of this program has helped the students in two ways, it helped improving the students' skills that were somewhat forgotten because they didn't practice them during the distance learning period, especially the skill of reading and preparing tables and data, and at the same time this program helped to enrich some other skills."

Regardless of the challenges, teachers and students showed an agreement with the program's positive impact. For example, teachers 1 said, *"The implementation of this program has contributed to improving the students skills that they lost during the pandemic"* and teacher 2 reported, *"The implementation of this program has helped the students in two ways, it helped improve the students' skills that were somewhat forgotten because they haven't practiced them during the distance learning period, especially the skill of reading and preparing tables and data, and at the same time this program helped enrich some other skills"*. Additionally, the students' perspectives about STEAM project not only reflected that it helped the students in their school subjects but went beyond by wishing to include similar projects and questions format to their schoolbooks. For example, student 3 mentioned that "*If the STEAM project is implemented in our books and curriculum using the same techniques and the targeted skills including contrasting, finding the difference, collaborating, and communicate, that would be a plus. A lot of different 21st century skills will be a very beautiful addition and a very good idea to add it to our curricula and subjects"*.

DISCUSSION

The purpose of this study was to examine the effect of a STEAM enrichment program on gifted students' creativity in science. A related purpose was to explore the difference between male and female students' scientific creativity. The results showed that students in the experimental group outperformed those in the control group in both fluency and flexibility of the C-SAT test. The qualitative analysis yielded several themes. For students, the themes generated were enjoyment about the program, gained benefits, effective promotion of the 21st-century skills, supporting school STEAM subjects, students' selection of future professions, and challenges related to the program implementation. For teachers, the generated themes were challenges faced by students, students' gains, students' enjoyment, students' selection of future professions, and overall perceptions about the enrichment program.

One of the themes generated from the qualitative data from teachers was about the challenges faced by students when they started dealing with the STEAM content. The teachers mentioned that students' minimal or weak responses at the beginning of the program were related to not studying biology as a school subject in grade 10. In response to this theme, several teachers need to be knowledgeable about STEAM technology and knowledge. Hence it is important to provide professional school support and enable teachers to use the regular curriculum effectively (Ho, 2010). The teachers also reported that the STEAM program helped students gain several skills that have not been taken care of during the pandemic. Through the different hands-on activities involving drawing charts and analyzing several kinds of data, students gained some helpful skills. This is in line

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with the literature that supports teachers' use of 21st-century skills and the way they convey these skills to students (Spillane & Miele, 2007).

The results showed that the STEAM enrichment program had an impact on students' creativity skills. Students also reported that they made use of the hands-on activities. These hands-on activities helped them connect their learning to real-world problems to enhance their understanding and make their learning experiences meaningful (Pease et al., 2020). As such, STEM enables students to nurture their creativity effectively (Clements & Sarama, 2016).

Students who participated in this program showed their enjoyment. Many of them reported that the STEAM enrichment unit was new to them, and it provided a chance to try out new experiences and concepts away from the routine classes. Students reported that the hands-on activities in addition to the problem-solving skills they acquired made them enjoy biology with a special focus on the topic of the pandemic. Students' active engagement in learning and problem-solving experiences enhances their intrinsic motivation, confidence, and academic achievement (Lumpkin et al., 2015). The structure of the STEAM unit allowed the students to study and handle several topics and deal with different problems with an increasing level of difficulty.

The enrichment program helped students gain more insights about STEAM-based professions. Students went through a variety of STEM-related jobs. For example, some of the students who initially chose some possible future jobs decided to change their preferences to a STEM-related career because they have seen several professions throughout the STEAM unit content. What was surprising from the results of this study is that females had higher scores on originality in C-SAT. This consolidates that STEM role models for females can boast their interest in STEM in high school (Valla & Ceci, 2014). Moreover, the different hands-on experiments and simulation activities helped students develop several skills such as problem-solving, critical thinking, creative thinking, and collaborative work. Research has shown that students' involvement in scientific laboratory experiences enhances their engagement and problem-solving skills (Porter, 2017).

The results of the quantitative section of the study are in line with similar research studies that examined the impact of using STEM in improving creative thinking skills (Chasanah et al., 2017; Lestari et al., 2018; Ugras, 2018). The unique features of integrating STEM disciplines together can foster students' creativity through handling interdisciplinary and complex problems that are connected to daily life problems (Awang & Ramly, 2008).

CONCLUSION

In summary, this research emphasizes the notable influence of the online STEAM enrichment program on high school students' creative thinking skills, content knowledge, and attitudes toward STEM topics. The program effectively promoted critical thinking, problem-solving, and interdisciplinary collaboration, showing its success in improving students' engagement and learning gains as seen from the qualitative results. Although rooted in the pandemic context, the flexible structure of the STEAM unit guarantees its ongoing relevance by incorporating emerging global challenges and advancements in science and technology. This adaptability ensures the program's continued effectiveness while equipping students with the skills and confidence to tackle future societal issues.

LIMITATIONS

Limitations of this study include data collection during the pandemic. Although several students expressed their eagerness to such programs, others reported that the activities would have been more meaningful if they were implemented face-to-face with the collaboration of their classmates. Another limitation is that the study samples across the three schools were small. Future research might benefit from conducting similar studies on larger samples of students to yield results that can be generalized to larger populations.

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