Long and Short-Term Impact of Problem-Based and Example-Based STEM Learning on the Improvement of Cognitive Load among Egyptian and Omani Learners

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Abstract

The study's main objective was to investigate the long and short-term effects of problem-based and example-based stem learning on enhancing cognitive load among Egyptian and Omani students. The sample population comprised of 350 teachers and educational stakeholders aged (25-60 years) - an equal number of respondents was drawn from each country. Mixed methods were employed in this research to test the validity of the hypotheses and draw relationships between STEM learning and cognitive load. The tools for data collection were teacher reports, student performance, and engagement reports, questionnaire. The data were analyzed using the Pearson correlation, linear regression, and the Chi-square test. The study results showed that example and problem-based learning methods were superior, particularly peer modeling, erroneous working examples, and standard working examples. The effective peer modeling pedagogical interventions were observing animation, psychomotor skills, self-efficacy, earning/retention, and highly structured problems. The integration of the pedagogical interventions in STEM learning could unlock critical thinking and creative skills among learners, leading to better extraneous, germane, and intrinsic cognitive loads; this would translate to higher success rates in STEM education national development. On the downside, there are critical constraints to unlocking students' potential such as an unclear vision and mission for STEM graduates with university level and new systems.

Keywords: Problem-Based, Example-Based, STEM Learning, cognitive load, Short-Term Impact.

1.0 Introduction

The study investigates the long and short-term effects of problem-based and example-based stem learning on enhancing cognitive load among Omani and Egyptian students. The outcomes are benchmarked against the U.S., the global leader in STEM learning and innovation (Hartman, 2019; McNutt, 2019). Egypt implements a STEM policy in the

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2011/2012 financial year. Since then, the government has established 12 STEM schools across the nation. In contrast, Oman's STEM policy is relatively new; it is first piloted in the 2017/2018 financial year, and since then, the government has opened 30 schools across the country. The state of STEM education is reviewed below.

1.1 Background Information

1.1.2 State of STEM education in Egypt and Oman

STEM education is critical to national development and the future of Middle Eastern countries, which have been lagging in innovation, as illustrated by the global innovation index (Cornell INSEAD WIPO, 2018; WIPO-Cornell University- INSEAD, 2018). The highest-ranking countries are in the E.U. and North America. The highest innovative country in the Middle East is Israel, followed by Cyprus, and the UAE - Egypt and Oman- do not feature in the top regional rankings (WIPO, 2019). The national governments in the two countries are aware of the unique benefits afforded by STEM-led innovation. They have instituted reforms such as the Egypt STEM Schools Project by the Ministry of Education in collaboration with USAID (World Learning, 2020) and 2061 in Oman (Elayyan & Al-Shizawi, 2019). Moreover, the countries have initiated an international collaboration with other Middle Eastern states.

The present research focuses on Egypt and Oman because of the following reasons. One, Egypt’s educational system is the largest in the Middle East (PwC, 2019) and is in the process of establishing an advanced STEM education system (World Learning, 2020). Second, there is scant information about STEM education in Oman. However, empirical research shows that Omani teachers are responsive to STEM education. Moreover, the teachers have a high perception concerning integrating STEM curriculum to equip students with the labor market's prerequisite skills (Elayyan & Al-Shizawi, 2019). Considering that both Egypt and Oman have less developed STEM educational systems, the reforms should be benchmarked on US STEM educational policy.

The U.S. *Federal Implementation of The STEM Education Strategic Plan* advocates for better funding to ensure that more students were enrolled in STEM subjects and federal financing for reinforcing existing STEM investment priorities. However, the national strategic plans' attainment is contingent on active learning strategies considering that fewer students are motivated to take up STEM subjects. In particular, it was reported that the U.S. was faced with a STEM crisis (Xue & Larson, 2015). Besides, there is a considerably low number of STEM women (The Institution of Engineering and Technology, 2016) - less than 25% of the STEM jobs are allocated to women (Beede et al., 2011). The observations made by Xue and Larson are aligned with Israel (2017), who reported a 6% decline in the STEM workforce in the U.S. between 1984 and 2009 - a phenomenon that may compromise innovation and U.S. leadership in global technology.

A contrary school of thought suggests no real shortage of STEM professionals based on high unemployment levels in the sector. The school of thought is also augmented by recent statistics drawn from the NSB science and engineering indicators for 2018. The NSB data indicates that there is a consistent increase in STEM enrolment across all fields. Between

2012 and 2017, count of students enrolled in STEM subjects increased from 278,180 to 406,240 (National Science Board, 2018). The population of students enrolled in S.E. in 2-year and 4-year institutions. Besides, the STEM sector is less impacted by field switching compared to other subjects. In brief, the current discourse is informed by the different schools of thought concerning the STEM crisis.

The proposed correlation between STEM learning and the adoption of new strategies is aligned with Business-Higher Education and (BHEF) Forum (2011) research, which affirmed that enhancing the number of students enrolled in STEM subjects would be dependent on the adoption of a responsive higher education strategy, draws learners attention to STEM starting from preschool through high school to university. Additionally, it was proposed that the STEM reforms' success would be augmented by enhancing student persistence and success in STEM education at the undergraduate level and recruiting a critical mass of STEM-capable teachers. Similarly, Israel (2017) proposed that the STEM challenge may be partly offset by STEM-specific secondary schools, innovative pedagogy, better teacher training, and after school programs. From the researcher's perspective, example-based learning and problem-based learning were an innovative pedagogical approach for enhancing students' cognitive load.

The complexity of STEM education augments the need for innovation in pedagogy - a survey conducted at UC Berkeley reported a substantially higher risk of depression (>50%) among STEM students (Bernstein, 2019) relative to their counterparts enrolled in other programs. The stress linked to STEM education could be attributed to the lack of consensus on STEM skills' inculcation. Atkinson and Mayo (2010) claim that the educational system has traditionally focused on teaching STEM facts.

1.2 Problem Statement

STEM education is a crucial pillar of national innovation and economic growth (Atkinson & Mayo, 2010). However, there has been a significant under-investment in STEM education as demonstrated by the barriers to enrolment in 2-year and 4-year STEM programs (National Academies of Sciences Engineering and Medicine, 2016), an inadequate number of STEM graduates (BHEF, 2011) and the projected STEM crisis (Xue & Larson, 2015). Even though there are myriad challenges, there has been limited emphasis on novel pedagogical interventions. This research's primary goal is to resolve the gaps in existing research relating to the utility of example and problem-based learning methods in enhancing students' understanding of STEM subjects.

1.3 Justification

The focus on STEM education is based on the absence of consensus - there is conflicting evidence concerning the severity of the STEM crisis (Xue & Larson, 2015). Besides, there is an urgent need to increase STEM graduates' ratio (BHEF, 2011). The adoption of reforms in education would be dependent on the approval of new policies. On the downside, there is limited evidence relating to the integration of example-based learning and problem-based learning in STEM, even though the pedagogical methods have been proven effective in other domains (Dyer et al., 2015). Other concerns include limited federal government involvement in funding and state-specific educational policies (Corsi-Bunker, 2010). In brief, there are valid grounds for investigating interventions that may enhance cognitive load among STEM students.

1.4 Significance of the Research

1. The study contributed new knowledge and understanding of the forces that shape STEM learners' cognitive load
2. The review of the pedagogical challenges in STEM learning would enable teachers to adopt better evidence-based teaching practices
3. The study findings would help inform future STEM policies in the education sector

1.5 Research Aim

1. To investigate the long and short-term effects of problem-based and example-based stem learning on enhancing cognitive load among Omani and Egyptian students.

1.6 Research Objectives

1. To review the pedagogical challenges faced by teachers and long-term implications of the example-based method in STEM education in Egypt and Oman
2. To explore the short-term implications of the example-based method in STEM education in Egypt and Oman
3. To review the relationship between cognitive load, example-based, and problem-based learning methods.
4. To evaluate the progress made in the education sector and the future of STEM learning because of the policy constraints

1.7 Research Questions

1. What are the long-term implications of the example-based method in STEM education?
2. What are the short-term implications of the example-based method in STEM education?
3. What are the long-term effects of problem-based learning in STEM education?
4. What are the short-term effects of problem-based learning in STEM education?
5. What are the effects of integrating example-based and problem-based learning methods on cognitive load among STEM students?
6. Are there viable alternatives beyond example-based and problem-based learning methods?

1.8 Hypotheses

1. There are significant short-term implications of the example-based method in STEM education among Egyptian and Omani students.

2. There are significant long-term implications of problem-based learning in STEM education among Egyptian and Omani students.
3. There are significant short-term effects of problem-based learning methods in STEM education among Egyptian and Omani students.
4. There are significant long-term effects of problem-based learning method in STEM education among Egyptian and Omani students.
5. The integration of example-based and problem-based learning significantly impacts students' cognitive load in the two countries.
6. There are no viable alternatives beyond example-based and problem-based learning methods?

2.0 Literature Review

The literature appraisal critiques pedagogical literature specific to STEM education in Egypt and Oman, industry and government data, and scholarly theories concerning educational reforms and innovation to align curriculum with industry needs. The first subsection highlights the general state of education in the U.S. and the future of STEM.

2.1 Example-Based Learning and Cognitive Load

2.1.1 Example-Based Learning

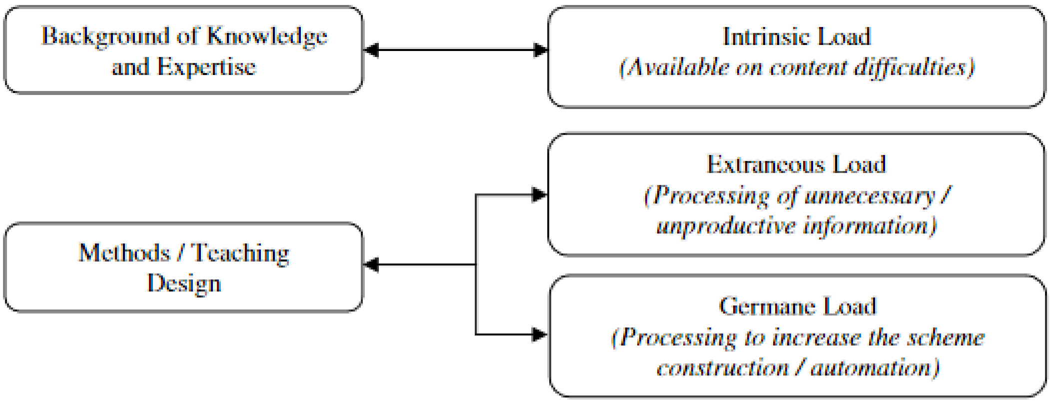
Example-based learning assumes two forms, namely cognitive and social-cognitive dimensions. The former is characterized by a "written worked-out didactical solution to a problem" in an area of study (Van Gog and Rummel, 2010, p. 155). The socio-cognitive dimension encompasses modeling examples, which allow learners to learn from peer models or adults performing the task. The learning process can be virtual (screen recording, video, or animation) or in-person (face-to-face). The peer model often adopts diverse forms, including natural or didactical methods.

2.1.2 Cognitive Load

According to Jalani and Sern (2015), the total cognitive load comprises three elements: intrinsic, extraneous, and germane loads, as shown in Figure 1. The different elements are drawn from processing unnecessary information (via teaching designs and methods), scheme construction processing, and focusing on content difficulties (drawn from personal expertise and background knowledge).

Figure 1.

Total cognitive load (Jalani & Sern, 2015)



2.2 Education in Egypt and Oman and the Future of STEM

Similar to other emerging and established economies, STEM learning is constrained by gender stereotypes (Makarova et al.,2019; Nagdi & Roehrig, 2019). For example, there is a low transition of STEM students to the marketplace (UNESCO, 2020). Beyond gender, the pedagogical interventions in Egypt and Oman are distinct. On the one hand, Egypt had aggressively enrolled students across all fields, leading to a steady demand for education due to population growth (PwC, 2019). Additionally, stable institutional settings and vocational training have helped bridge the skills gaps (Elayyan & Al-Shizawi, 2019). However, there are significant education disparities and a lower STEM education preference (DAI, 2020a). Such disparities are not unique to the region - skewed educational opportunities have been noted in the U.S. (Blazer, 2018; The National Council on Teacher Quality (NCTQ), 2012). The disparities have persisted despite the initiation of race-specific stimulus programs for learning (U.S. Department of Education, 2020). In brief, not all schools could experiment with example-based and problem-based learning methods due to resource constraints.

2.3 The utility of Example-Based Learning and Problem-Based Learning in Enhancing Cognitive Load

Experimental data shows that example-based learning is a suitable technique because it catalyzes critical thinking and clinical reasoning in physiotherapy (Dyer et al., 2015); comparable outcomes were reported in statistical learning tasks in a group of 116 undergraduate students enrolled at the Midwest University, U.S. (Huang, 2017). Even though Dyer *et al.* (2015) and Huang (2017) concur on the role of example-based learning on the cognitive load and a student’s ability to retain knowledge, near and far transfer, Huang (2017) observed that the relationship is dependent on the types of example-based learning namely, peer modeling, expert modeling, erroneous working examples, and standard working examples. Additionally, the researcher observed that far and near transfer, knowledge retention was advanced using expert modeling examples. In contrast, the study established that peer modeling is the ideal mechanism for fostering self-efficacy in each of the four types of examples.

The outcomes reported by Huang (2017) and Dyer *et al.* (2015) in support of example and problem-based learning validate the cognitive load theory (CLT) (Jalani & Sern, 2015). The CLT postulates that learning, including STEM-based education, occurs in an environment aligned with a learner's cognitive design, as demonstrated by the example problem-based learning model in Appendix 2, which integrates problem-solving techniques and works examples (Jalani & Sern, 2015). On the downside, the model's validity is based on the assumption that the germane, extraneous, and intrinsic loads do not exceed the mental resources of a learner and cognitive load in the working memory. The hypothetical outcomes based on situations 1-3 students' cognitive load and learning and assumptions that define the model are presented in Appendix 3.

Based on the fundamental assumptions that define the Example-Problem-Based Learning model and the empirical outcomes reported by Huang (2017), Dyer *et al.* (2015), and Van Gog & Rummel (2010), the utility of example and problem-based learning in augmenting knowledge acquisition in STEM education in Egypt and Oman would be dependent on a wide array of factors, including the types of teaching methods adopted in schools and universities in Egypt and Oman. Therefore, customized interventions were necessary to match examples and problem-based learning with the students' unique cognitive design. Additionally, it would be imperative to acknowledge the influence of intelligence quotient (I.Q.) in STEM learning - learners across the world have different I.Q.s.

2.4 The relevance of Example and Problem Based Learning in Egypt and Oman

Following the appraisal of Huang (2017), Dyer *et al.* (2015), and Jalani and Sern, (2015) research, the main question is whether the observations applied to STEM education in Egypt and Oman. The unique learning environments inform the concern in the U.S. vis-a-vis the Middle East. Additionally, the insights were drawn from physiotherapy and statistical learning experiments that may not represent STEM in Egypt and Oman. Another concern is the scarcity of relevant concerning the adoption of problem-based learning and example-based learning in Egypt and Oman. The relevance of example-based learning and problem-based learning was inferred from western literature - the primary assumption was that the West's progress was relevant to Egypt and Oman and the broader MENA region.

Research by Microsoft Tech Company noted that computer-aided STEM education could be augmented by example-based learning, especially in the delivery of massive open online courses (Gulwani, 2013). The observations made in the study are informed by the integral role of example-based learning on feedback, solution, and problem generation in mathematics (algebra and geometry) and computer program (Gulwani, 2013). Other variants of example and problem-based learning have been integrated into other countries. For example, design-based STEM learning has been embedded into STEM education to augment the identification of a problem in real-life situations, analyze viable and best alternatives, the decision applications, and the decision and application phases (Altan et al., 2018). The findings reported by Altan et al. (2018) and Gulwami (2013) were collaborated by the U.S. National Academies of Science Engineering and Mathematics, which observed that evidence-based STEM educational practices were instrumental to the student's mastery of science, technology, and engineering concepts and skills (National Academy of Sciences Engineering and Medicine, 2018). However, in the latter case, the researcher noted that evidence-based education alone could not suffice; it has to be integrated with equity, diversity, and inclusion.

Based on the U.S. National Academies' findings, it can be deduced that focusing on example-based and problem-based STEM learning was integral. However, stakeholders should focus on inclusive and equitable learning. The proposals made by the National Academy of Sciences Engineering and Medicine (2018) have been assimilated into the ‘new learning agenda for Egypt,' which takes into account the diversity in the learner's capabilities to build interest in STEM and formal learning. The new agenda also places greater emphasis on STEM starting from secondary school - a recent report proposed establishing STEM programs for talented students as part of the Central Administration of secondary education (OECD, 2016).

Even though the proposal would augment STEM learning, equity in education is crucial under the *thanawiya amma* system (OECD, 2016). Egypt's educational system seems to reward and favor those who can afford private tuition (shadow education), familiar with secondary school. According to the OECD, private tuition is correlated with better educational outcomes in school. However, the researcher is mindful of the fact that not all students can afford private tuition. The lack of equity could be a significant impediment to adopting example-based and problem-based learning in Egypt. However, it is imperative to acknowledge that educational reforms in Egypt will improve STEM learning, including selecting STEM courses at the university level.

In contrast to Egypt, Oman had not initiated significant educational reforms. Al-Ani (2017) notes that the country was still dependent on traditional learning methods, incompatible with the industry's needs. The entrenchment of traditional learning methods is paradoxical considering that other countries in the region, such as Saudi Arabia, had initiated substantial reforms in the educational sector, which in turn, led to a greater emphasis on STEM education in the transition to a knowledge economy (Khorsheed, 2015; Islam, 2017; Aldahmash, Alamri, and Aljallal, 2019). Moreover, failure to reform the educational sector had deprived the industry of essential skills and expertise, which are instrumental to national growth.

The findings reported by Al-Ani (2017) contradict Nasser (2019), who notes that the ministry of education in Oman had adopted sector-wide changes, which involved the complete modification of the curriculum, the integration of practice-based learning and pedagogical approaches, which are aligned with workplace needs and international benchmarks.

Nasser notes that the reforms had enabled Omani students to draw upon the 21st-century skills and competencies to gain leverage at the workplace. Nasser's observations are consistent with UNCTAD's report regarding the science, technology, and innovation policy review of Oman. The review acknowledges that STEM learning is integral to the realization of the national Vision 2040. Additionally, the Research Council (TRC) was in charge of the

STEM-based R&D strategy (UNCTAD, 2014). The progress is not limited to the public sector - private conglomerates complemented government initiatives as part of the corporate social responsibility (DAI, 2020b). The interventions include the construction of the STEM center in Muscat that specializes in transferring programming skills to school going children within the capital city and the 'Traveling STEM Festival' for rural and other areas outside Muscat (DAI, 2020b). The contrasting evidence reported by Al-Ani (2017) and Nasser (2019) makes it challenging to investigate the short and long-term effects of example-based learning and problem-based learning on enhancing cognitive load among STEM students in Oman. From the researcher's point of view, policymakers' inconsistencies should be addressed in the educational sectors because the arguments made by Al-Ani (2017) and Nasser (2019) are based on observations drawn from the educational sector in Oman.

2.5 Gaps in Literature

The appraisal of the literature demonstrated the following. The impact of the problem and example-based learning and cognitive load of students is dissociated from STEM education. The two variables are considered independently. One could not ascertain the impact of short- and long-term effects of both example-based learning and problem-based learning on enhancing cognitive load among STEM students. The effects were inferred from studies conducted in other fields. Two, there is no data concerning the strategies adopted in STEM education learning in Egypt and Oman.

2.6 Conclusion

The review of literature advanced the current understanding of STEM education in Egypt and Oman. The two countries had initiated substantial reforms such as ‘new learning agenda for Egypt' that propelled technical subjects to the periphery of national development. However, there is no clear evidence regarding adopting evidence and problem-based learning in schools and universities. Besides, the observations that were inferred from the U.S. and non-STEM case studies might not be relevant to STEM education in Egypt and Oman. Despite the absence of causal findings, published evidence supports the adoption of evidence-based and problem-based learning, especially modeling and worked examples. The methods adopted in data collection are discussed in the next section.

3.0 Research Methods

This section reviews the outcomes adopted in data collection, including the criteria for selecting respondents and the theoretical justification. The research methods form the basis for the questionnaire items in the appendix.

3.1 Research Design

A mixed methods research approach (different methodological approaches) for questions and hypothesis is adopted. First, a quantitative method is employed to validate or invalidate the hypotheses. Second, the research questions are addressed using qualitative methods. The theoretical justification is presented below.

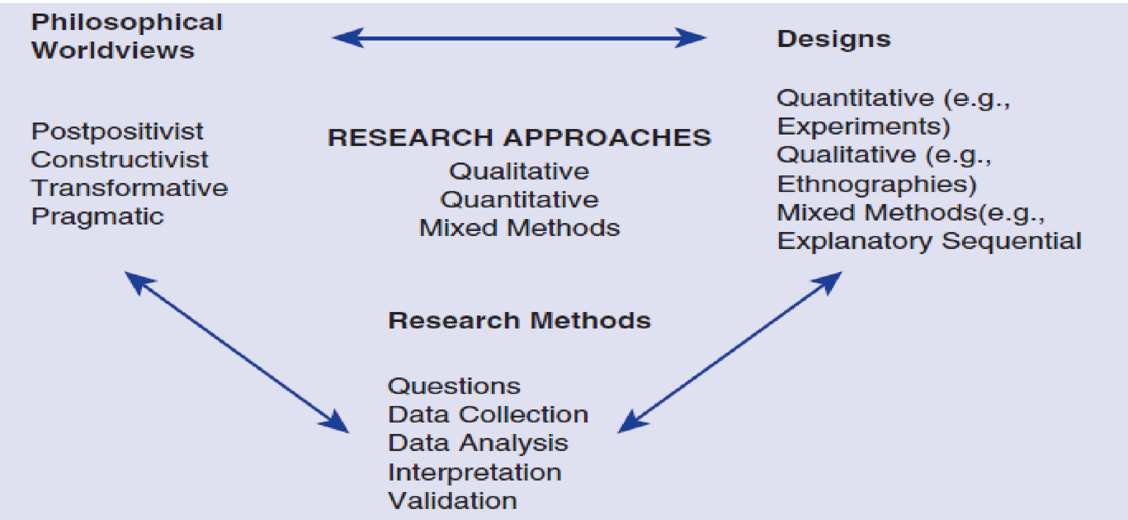
The quantitative research design is grounded on Cresswell (2013) work concerning research methodology. The quantitative research design is based on questionnaires, scales, teacher reports, student performance, and engagement reports. The utilization of questionnaires in quantitative research is validated by (Cresswell, 2013) who notes that "survey research provides a quantitative or numeric description of trends, attitudes, or opinions of a population by studying a sample of that population. It includes cross-sectional and longitudinal studies using questionnaires or structured interviews for data collection" In brief, there are valid grounds for selecting questionnaires.

The research design selection should be aligned with the philosophical worldview and research methods (including the research questions), as shown in Figure 2. The core research questions could not be addressed without experimental data owing to the scarcity of research relating to STEM learning and cognitive load in the two countries. Published evidence cannot predict the short- and long-term effects of both example-based learning and problem-based learning on enhancing and improving cognitive load among STEM students. Additionally, their published data is not specific to STEM education; relevant data published by Dyer et al. (2015) and Huang (2017) was based on statistical learning tasks and physiotherapy learning in other countries in place of STEM in Egypt and Oman.

Apart from empirical data collected from the stakeholders (STEM teachers), additional insights were drawn from the teacher reports. Established precedents and best practices legitimize teachers' emphasis in place of other stakeholders in the educational system. For example, studies on the public school approach in Miami by Thompson (2016) and The National Council on Teacher Quality (NCTQ) (2012) focused on teachers.

Figure 2

Selection of the research methods (Cresswell, 2013)



Beyond the provision of information that would help address the gaps in knowledge, experimental research yielded novel insights and provided state of the art data concerning the STEM learning methods in the two countries. In brief, there were compelling grounds for quantitative research. The research questions were best addressed using published data because previous studies listed the viable alternatives beyond example-based and problem-based learning methods. Additionally, qualitative data complemented quantitative outcomes drawn from the questionnaires. The core aspects of the experimental research design are reviewed in the next section.

3.2 Research Approach

A deductive research approach was adopted to test existing theories (Soiferman, 2010), and by extension, the validity of the hypotheses concerning STEM learning in Egypt and Oman. The deductive approach was suitable, considering scholarly research has investigated the impact of different pedagogical interventions on students' cognitive load. The inductive approach was excluded because it is best suited for "research studies, in which there is no theory to test and conclusions drawn based on an inductive method can never be proven." (Streefkerk, 2020).

3.3 Tools

The primary tools for data collection were teacher reports, questionnaires, student performance, and engagement reports.

3.4 Participants

The research participants are teachers and other stakeholders in the education sector. The participants' selection depends on their understanding of pedagogical challenges in STEM learning at the secondary and college level in Egypt and Oman. The utility of example-based learning and problem-based learning methods was capable of augmenting the cognitive load. The primary criteria for inclusion were the educational qualifications (bachelor’s degree and teacher training) and practical experiences in the educational sector.

3.4.1 Participants - Egypt

The total number of participants is N=350; 175 respondents are drawn from Egypt (50%). The participants' age varied between 25 and 60 years; vulnerable populations such as minors and the elderly were excluded. The number of male respondents was 100, while the number of female respondents was 75 - the differences in gender representation were justified by the low population of women in STEM.

3.4.2 Participants - Oman

The number of Omani participants was n = 175. Like Egypt, the number of male and female participants was set at 100 and 75, respectively. All participants were required to possess a minimum of a bachelor's degree in education. Both the private sector and public sector teachers were included in the study.

3.5 Data Collection

3.5.1 Quantitative Data

The investigation of short and long-term effects of example and problem-based learning was based on questionnaires, teacher reports, and perspectives on student performance and students' engagement. The listed tools were preferred because of the following reasons. First, the preliminary reliability of questionnaire items has been established in pedagogical and non-pedagogical research (Cho, 2016). Second, teacher reports on students' performance provide invaluable historical data that demonstrates their competencies. The in-person data collection process was eliminated in favor of virtual platforms such as Zoom. Geographical constraints and global events validate the approach. First, it was unfeasible for the researcher to travel to Egypt and Oman to conduct face-to-face interviews or administer the questionnaires. The preference for remote data collection is supported by Szolnoki & Hoffmann (2013) and Lindhjem & Navrud (2011), who confirmed the internet's utility as a data collection platform.

Szolnoki & Hoffmann (2013) compared the utility of telephone, in-person, and online surveys. The researchers observed that the three methods yielded expected outcomes. However, there was a risk of response bias in online surveys. The risk of bias in the current case was mitigated in the selection process. The selection process was limited to professionals; it was hypothesized that the respondents were not motivated to provide misleading information. In contrast, Lindhjem & Navrud (2011) did not report any significant differences between face-to-face and internet-based data collection methods.

The data collection tool/questionnaire had three subsections, namely the demographics (age of the students/teachers/policymakers, educational level, age, gender), cognitive load (intrinsic, extraneous, and germane loads), for example, and practice passed learning (modeling and worked examples). However, three different questionnaire variants were developed for each target population (STEM students, teachers, and policymakers/ thought leaders in education). The sampling strategy and data collection methods are discussed below.

3.5.2 Qualitative Data

The qualitative data was drawn from scholarly articles through desk research. The inclusion/exclusion criteria were informed by the publication window (2010-2020), scope (STEM learning, pedagogical challenges, cognitive load, example, and problem-based learning), and context (Egypt and Oman and benchmarking with the U.S. educational sector). Additional qualitative data was derived from teacher reports, student performance reports and engagement, and interviews.

3.6 Sampling

As noted in the preceding sections, the population of interest comprises STEM students, policymakers, and teachers. The focus on three groups is validated by the scope and the context of the research. The respondents in each category were recruited through a random sampling method. The focus on random sampling in convenience sampling is guided by the need to generalize the findings, bias, and legitimacy. According to Etikan (2016), sampling should be informed by the respondents' availability, subjectivity, and randomization risk. The population's size was limited to 350 respondents, drawn from teachers, students, and stakeholders in the Egypt and Oman educational sectors. However, the size was varied depending on the response rate. The selection bias risk was mitigated by random selection - each subject and nearly equal chances for selection. On the downside, there was a risk of delayed responses, inadequate responses, and response bias because schools, colleges, and universities were non-operational due to the global health epidemic. According to *Reuters* and *Al Arabiya*, schools in Egypt and Oman had remained closed since mid-March 2020 (Reuters, 2020; Skaf, 2020). The data analysis methods are reviewed in the next section.

3.7 Data Analysis

Advanced SPSS statistical analyses were conducted. The primary inferential measures were the Chi-square test, Pearson correlation, and linear regression, which helped to evaluate the relationship between categorical variables, direction, and level of significance, model the relationship between explanatory variables and scalar responses, and significant differences between the two mean groups. The statistical analyses helped to determine the validity or the invalidity of the research hypotheses.

3.8 Reliability and Validity

The specific measures of validity and reliability are reviewed individually in the next section.

3.8.1 Reliability

The reliability of the dataset, in this case, denoted the stability and consistency aspects. According to Mohamad, Sulaiman, Sern, & Salleh (2015), the data's reliability is augmented by utilizing established scales such as the Students' Perception in Cognitive Dimension (SPCD), pilot studies, and the Cronbach's alpha values. Traditional scales such as SPCD were not deployed in data collection because the study was structured to address a fundamental problem and address context-specific issues. The only measure of reliability in this study was Cronbach's alpha value. The method has been extensively employed to assess data reliability, as noted by Tavakol & Dennick (2011). The SPSS output relating to the alpha values is presented in Table 1. The measures for validity are presented below.

Table 1

Reliability test

Cronbach's Alpha	N of Items
.62	5

The qualitative data's reliability was defined by researcher triangulation and inter-observer reliability, which established reliability and validity measures. Triangulation involved the inclusion of both qualitative and quantitative methods to study the same phenomenon as noted by (Hussein, 2009). The approach was preferred because it was a methodological framework aligned with the constructivist paradigm (Mertens & Hesse-Biber, 2012). In other cases, the method facilitates a deeper understanding of the phenomenon (Hussein, 2009) and improves accuracy. The inter-observer reliability was undertaken by taking into account the reports of different observers.

3.8.2 Validity

The validity of the study was calculated using face validity and concurrent validity. The approach involved comparing the level of agreement among the responses provided by the 350 teachers in Egypt and Oman. Following the comparison of the outcomes, it was deduced that at least ten teachers in each country provided similar responses; the similarity demonstrated the validity of the study outcomes concerning STEM learning and cognitive load among the students. Concurrent validity was determined using SPSS by calculating the appropriate correlation coefficient. Correlation coefficient values above 0.8 denoted a significant statistical relationship and evidence of good concurrent validity. The Pearson correlation measures in support of concurrent validity are presented in Table 3.

The data presented in Table 2 further demonstrates the validity of the outcomes because there was a significant link between the most effective modeling examples technique for STEM, education, and the education system's ability to satisfy global standards ($p < 0.00$). The outcomes are in line with Huang (2017), Dyer *et al.* (2015), and Van Gog & Rummel's (2010) research on teaching/learning methods. Beyond the correlation test, the outcomes' validity is affirmed by the linear regression data in Table 3. The findings show that the model was an appropriate fit for the data - the educational attainments could help establish whether the teachers were adequately trained and the best methods for STEM learning.

Table 2

Statistical table denoting the Pearson correlation test and significance

		What is your educational level?	Does the educational system in Egypt and Oman meet global standards	Which learning methods have enhanced the total cognitive load	Which is the most effective modeling examples technique for STEM
What is your educational level	Pearson Correlation	1	.203**	.061	.819**
	Sig. (2-tailed)		.000	.252	.000
	N	350	350	350	350
Does the educational system in Egypt and Oman meet global standards	Pearson Correlation	.203**	1	.081	-.191**
	Sig. (2-tailed)	.000		.131	.000
	N	350	350	350	350

		What is your educational level?	Does the educational system in Egypt and Oman meet global standards	Which learning methods have enhanced the total cognitive load	Which is the most effective modeling examples technique for STEM
Which learning methods have enhanced the total cognitive load	Pearson Correlation	.061	.081	1	.043
	Sig. (2-tailed)	.252	.131		.427
	N	350	350	350	350
Which is the most effective modeling examples technique for STEM	Pearson Correlation	.819**	-.191**	.043	1
	Sig. (2-tailed)	.000	.000	.427	
	N	350	350	350	350

**. Correlation is significant at the 0.01 level (2-tailed).

Table 3

Linear regression

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.822[a]	.675	.673	.565

a. Predictors: (Constant), Are teachers trained on the best pedagogical practices to augment learning? Which is the most effective modeling examples technique for STEM

b. Dependent Variable: What is your educational level

3.9 Ethical Criteria

The ethical criteria mitigated the risk of bias in the participants' recruitment, violation of research ethics concerning personal privacy, volition, informed consent, and confidentiality. The responses drawn from stakeholders in the Egypt and Oman educational sectors were anonymous, and participation was contingent on informed consent provision. The provision of informed consent is a mandatory requirement in behavioral, social, and educational research (Schofield, 2014; Tai, 2012). On the downside, adherence to the departmental research ethics did eliminate the impact of subjectivity and bias on interpreting the research outcomes.

3.9 Conclusion

The empirical data contributed new insights and perspectives relating to the short- and long-term effects of example-based and problem-based learning on enhancing cognitive load among STEM students. The sample size (n = 350) was representative and appropriate, given the population's general size and the unique circumstances under which the study was undertaken.

4.0 Results and Discussion

The results and discussion chapters present and discuss two types of findings: one, models of the Egypt and Oman STEM policy and progress made by learning institutions. Two data were collected from the 350 respondents.

4.1 Qualitative Data

The qualitative data was drawn from teacher's qualitative reports of students' engagement in STEM education and remote interaction with STEM-based teachers in the two countries.

4.1.1 STEM Curriculum in Oman

The following observations were drawn from the teachers and stakeholders in Oman's educational sector. First, the Omani STEM curriculum and strategy satisfied global standards because it was "designed by the British Rolls-Royce Company and adopted by the Omani Partnership for Development in the Sultanate in partnership with the British Rolls-Royce as part of its commitment to the Partnership for Development program and cooperation with the Ministry of Education represented by the Department of Innovation and the Scientific Olympiad." Similarly, Egypt's STEM curriculum was par with global standards because it was modeled on the American education system with minimal amendments.

The curriculum's suitability is further demonstrated by integrating STEM teaching materials, scientific experiences, and practical application of knowledge in the laboratory to link education with daily life experiences. The hands-on approach to teaching STEM subjects is integral to optimizing the students' critical thinking and creative skills, which are critical to societal growth and sustainable economic development. From a long-term perspective, the STEM strategy would enhance Oman's competitiveness in the global economy considering that STEM education has a domino impact on industrial research and development (R&D) and national innovation scores; countries with high innovation index scores had an advanced STEM-based curriculum (Atkinson & Mayo, 2010). Additionally, STEM learning augments decision-making skills (Altan et al., 2018).

The stakeholders also argued that the reforms initiated in the STEM sector had yielded tangible benefits because the reforms were aligned with the University of Cambridge curriculum, which is continuously updated in line with the global scientific and technical development. In brief, the reforms are not confined to teacher training, and the international linkages helped ensure that Omani students acquired the latest scientific knowledge and practical skills. Additionally, the stakeholders observed that standard working examples, observing an animation, (psycho) motor skills, self-efficacy, learning/retention, and highly structured problems were preferred example-based learning methods and practical modeling examples technique for STEM. Moreover, there was ample evidence of optimized modeling and worked examples employed to maximize their effectiveness among students. Examples include chemical reactions and small models of rockets. In general, it was deduced that learning by experiments, and projects, simulated labs, grouped learning, discovery learning, and trial and error learning strategy were effective methods of STEM teaching.

On the downside, there was no unique link between STEM education, secondary school level, and university admission requirements. Moreover, there was no clear evidence of the government's commitment to strengthening tertiary education research competencies in STEM subjects. The structural shortcomings in implementing a STEM-centric policy should be addressed to enhance the Omani educational sector's competitiveness. The proposal is critical considering that the extraneous, intrinsic cognitive loads were low. Additionally, there were multiple pedagogical challenges in STEM learning at the secondary and college levels, such as unclear vision and mission for STEM graduates with university level, multiple new systems like STEM and Cambridge series system, and funding gaps due to global economic shocks.

4.1.2 STEM Curriculum in Egypt

Second, teachers were highly equipped to teach STEM subjects; this is evident from the agenda program for training the teachers working in STEM Oman. Between 2017 and 2018, three-stage sessions of training had been completed. For example, in the second stage, 41 male and female teachers were trained on applying the curriculum and enabling them to use modern methods to teach students and re-apply them in a complementary way to the existing curricula in public schools. Egyptian teachers were also equipped through scientific training and missions in the USA. Additionally, the educational reforms enhanced STEM learning or demonstrated the national government commitment to the STEM agenda through the educational sector's overhaul starting from Kg1 to G12. The new reforms were implemented two years ago. However, it is imperative to note that the reforms were partial at the KG1 level.

The stakeholders in Egypt's education sector also observed a limited correlation between STEM subjects at the secondary school level and university admission requirements considering that the university admission coordination system relies on "the flexible ratio." The strategy involves dividing the number of successful high school students by the number of high school students in colleges undertaking the following courses; medicine, dentistry, pharmacy, veterinary medicine, engineering, computers, information, and science. On the other hand, international universities in Egypt offer ideal STEM graduates and external scholarships. The utility of tertiary STEM learning is further augmented by strengthening tertiary education research competencies in STEM subjects.

In contrast to Oman, the stakeholders in Egypt’s education sector considered erroneous working examples as better example-based learning methods to peer modeling and standard working examples. Similar differences were observed in the most effective modeling examples technique for STEM. The preferred examples included observing an animation, metacognitive skills, learning/retention, highly structured problems, and group-based or individual STEM projects. Despite the differences, learning/retention and highly structured problems were common in both countries. The optimization of modeling was realized by emphasizing critical thinking, problem-solving, guidance, and mentoring. From a futuristic perspective, the stakeholders hypothesized that example-based learning and problem-based solving problems would be the most effective techniques, especially in STEM projects, which constitute up to 60% of the course load in the first two years, and 20% at the final year of study.

The students' cognitive load was enhanced by the following pedagogical techniques; learning by projects, cooperative learning, and practical models as examples of learning. Egypt's approach is comparable to Oman's simulated labs, grouped learning, discovery learning, and learning by experiments. From an abstract perspective, the STEM-centric pedagogical interventions successfully considered the students’ extraneous and intrinsic cognitive load was rated as high. Nonetheless, the stakeholders should address the main pedagogical challenges in STEM learning at the secondary and college level in Egypt, such as the weak link between STEM schools and public schools at the level of the government; limited information about STEM at the level of general and formal level; a non-clear Egypt'sion and migration and weak academic adjustment when moving to college level.

4.2 Quantitative Data

The inclusion of quantitative observations was reinforced by qualitative observation limits, which successfully considered research hypotheses and established causal relationships.

4.2.1 Demographics and STEM Learning

The data depicted in Table 4 shows that most of the respondents were male. The gender distribution had significant implications for STEM education, given the underrepresentation of women in STEM education in the MENA region. The gender gap in STEM is not unique to MENA (Egypt and Oman included). UNESCO and other stakeholders have reported similar trends across other regions (Makarova et al., 2019; UNESCO, 2020). On the positive side, Nagdi & Roehrig (2019) notes that commendable progress had been made in Egypt. For example, the nation had established girls-only STEM schools to counter the marginalization of the female gender in mainstream STEM learning. Apart from the development of girls-only schools, Nagdi & Roehrig (2019) postulated that the situation might be further remedied by developing student-centric pedagogical interventions, positive school environments, diverse gender-friendly teaching approaches, dynamic formative assessment, and teacher support. The proposals made by the researchers are consistent with the observations made in the qualitative data section.

Table 4
Gender distribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	284	81.1	81.1	81.1
	Female	66	18.9	18.9	100.0
	Total	350	100.0	100.0	

The bachelor's degree was the highest educational qualification in 82% of the population, followed by master's and Ph.D. degrees at 9%, as shown in Table 5. The STEM teachers' educational qualifications illustrate that the teachers were best equipped to impart knowledge.

Table 5

Educational level

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Bachelor’s degrees	287	82.0	82.0	82.0
	Master's degree	31	8.9	8.9	90.9
	PhD	32	9.1	9.1	100.0
	Total	350	100.0	100.0	

The outcomes reported in Table 6 collaborated the qualitative outcomes - 91.1% of the respondents affirmed (strongly agree and agree) that the educational system in Oman meets global standards in STEM. The alignment of the educational system with global standards is vital for sustainable growth - national development is strongly correlated with investments in STEM learning and education, as illustrated in the U.S. and Saudi Arabia's transition into a knowledge economy (Gallarotti et al., 2013; Khorsheed, 2015).

4.2.2 STEM Learning

Table 6

Ability of the educational system in Egypt and Oman to meet global standards in STEM.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Agree	255	72.9	72.9	72.9
	Agree	64	18.3	18.3	91.1
	Strongly Disagree	31	8.9	8.9	100.0
	Total	350	100.0	100.0	

The respondents had a positive perception of STEM learning in Egypt and Oman, as shown in Table 7. Two-thirds of the respondents suggested that the educational system integrated STEM teaching materials. One-third of the population noted that the education sector was responsive to emerging needs, incredibly sustainable development.

Table 7

Perspective on STEM education in Egypt and Oman

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	It integrates STEM teaching materials	227	64.9	64.9	64.9
	Contributes to sustainable development in society and knowledge-based economy	61	17.4	17.4	82.3
	It is a promising educational system that copes with emerging changes in STEM	62	17.7	17.7	100.0
	Total	350	100.0	100.0	

As expected, teachers in Egypt were trained on the best pedagogical practices to augment STEM learning - nine in ten respondents concurred with the above statement; this is illustrated in Table 8. The opposing observations made by the rest of the respondents suggest that teacher training was not ubiquitous, and individual schools were excluded. Alternatively, the teachers were not content with the training methods.

Table 8

Teachers trained on the best pedagogical practices to augment STEM learning.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly agree	319	91.1	91.1	91.1
	Neither agree nor disagree	31	8.9	8.9	100.0
	Total	350	100.0	100.0	

The data depicted in Table 9 show that there was a link between STEM subjects at the secondary school level and university admission requirements in 65% of the cases. The link is vital, considering that STEM learning in secondary schools was an accurate predictor of a student's willingness to enroll in a STEM major at the university (Makarova et al., 2019). Additionally, STEM policy for schools in Egypt (Nagdi & Roehrig, 2019; World Learning, 2020) predicted STEM learning at the university. In brief, linking secondary STEM learning to university enrollment ensured continuity in the integration of student-centered pedagogical interventions such as example-based and problem-based learning methods in STEM education.

Table 9

Link between STEM subjects in secondary school level and university enrolment

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly agree	228	65.1	65.1	65.1
	Neither agree nor disagree	30	8.6	8.6	73.7
	Disagree	92	26.3	26.3	100.0
	Total	350	100.0	100.0	

The data in Table 10 shows that a combination of peer modeling and erroneous working examples were preferred by 83% of the teachers. In contrast, a combination of standard working examples and peer modeling or standard working examples were least preferred. The proposals may help augment STEM learning by eliminating the trial-and-error methods adopted to enhance Egypt's cognitive load.

Table 10

Example-based learning methods

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Standard working examples	31	8.9	8.9	8.9
	Combined peer modeling erroneous working examples	289	82.6	82.6	91.4
	Combined standard working examples peer modeling	30	8.6	8.6	100.0
	Total	350	100.0	100.0	

The effective modeling example techniques for STEM were psychomotor skills at 90%, followed by learning and retention at 9%, as illustrated in Appendix 1. The utility of these methods is affirmed by previous research. According to the findings presented in Appendix 2, discovery learning was the most effective method of enhancing students' cognitive load. The students' extraneous cognitive load was high in 82% of the cases, as shown in Appendix 3; this is a testament to the pedagogical interventions' effectiveness. On the downside, the cognitive load was not measured in 18% of the students. The core pedagogical challenges were low enrolment rates and inadequacy of teachers, as shown in Appendix 4. The outcomes drawn from the 350 respondents were reliable because Cronbach's alpha value was 0.6 (Appendix 5).

4.3 Strong and Lasting Impacts of the Study on the Broader Fields of Education and Psychology and Recommendations for Practice

The outcomes drawn from this study have broad, long-term implications for education and psychology because of the following reasons. First, the demographic data illustrated that gender stereotypes and underrepresentation of women was commonplace in both countries. The stereotypes and gender biases impeded unlocking the national potential in STEM and innovation (UNESCO, 2020; Makarova et al., 2019). The observation is reinforced by the fact that lower uptake of STEM subjects in primary and secondary schools predicted the student's probability of enrolling in a university's STEM degree.

Beyond the issue of demographics, the established utility of discovery learning, simulated labs, and trial and error learning strategies show that alternative methods of improving the cognitive load were less effective and should not define STEM learning. On the downside, there was no evidence of consistency in the pedagogical interventions; teachers adopted context-specific methods, including the *thanawiya amma* system (OECD, 2016) and girls-only schools (Nagdi & Roehrig, 2019). Even though customizing STEM learning was vital, stakeholders needed to harmonize the national level's educational curriculum. The harmonization process would ensure that all students have equal learning opportunities. Other recommendations concern the resolution of pedagogical challenges in STEM learning at the secondary and college level. The stakeholders outlined the following challenges; unclear vision and mission for STEM graduates with university level, multiple new systems like STEM and Cambridge series system, funding gaps, low enrolment rates, and teachers' shortage.

4.4 Validation of the Research Hypotheses Statements Using Quantitative Data

As a standard practice in research, quantitative methods were employed in the validation/invalidation of the hypotheses because qualitative data could not be employed to determine the relationships' strength. The specific statistical test employed was the Pearson correlation (p-values and R-values). Following the analysis of the data, the following hypotheses were validated;

there are significant short-term implications of the example-based method in STEM education among Egyptian and Omani students;

there are significant long-term implications of problem-based learning in STEM education among Egyptian and Omani students;

there are significant short-term effects of problem-based learning method in STEM education among Egyptian and Omani students; here are significant long-term effects of problem-based learning method in STEM education among Egyptian and Omani students; the integration of example-based and problem-based learning has a significant impact on the cognitive load of the students in the two countries. However, there was no adequate data to validate or invalidate the last hypothesis.

4.5 Conclusion

The research established that the main pedagogical challenges encompassed funding, policy constraints, and commitment to STEM education at the university. The pedagogical challenges predicted the educational challenges in STEM learning at the secondary and college level. For example, there was no defined modeling examples technique for STEM; teachers were free to explore different methods through trial and error, such as observing an animation, natural performance by peer/adult, metacognitive skills, psychomotor skills, self-efficacy, learning/retention, and highly structured problems. Even though there was no broad consensus on the best-example based learning method, the teachers concurred that peer modeling, erroneous working examples, and standard working examples were highly effective and were capable of augmenting the cognitive load among STEM students.

From the researcher’s point of view, the long-term implications of integrating example-based and problem-based learning methods in STEM education include optimization of the learner's critical thinking and creative skills; this would, in turn, have a domino effect on societal growth and national development. Based on the available literature, there were no practical alternatives beyond example-based and problem-based learning methods. The statistical findings led to the validation of the following hypotheses: One, the integration of short-term and long-term effects of example-based learning has a significant impact on Oman students' STEM learning. Second, example-based and problem-based learning significantly impact students' intrinsic cognitive load in the two countries.

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Appendices

Appendix 1

Effective modeling example techniques for STEM

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	(Psycho) motor skills	318	90.9	90.9	90.9
	Learning/retention	32	9.1	9.1	100.0
	Total	350	100.0	100.0	

Appendix 2

Learning methods that have enhanced the total cognitive load of the students

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Simulated labs	31	8.9	8.9	8.9
	Discovery learning	288	82.3	82.3	91.1
	Trial and error learning strategy	31	8.9	8.9	100.0
	Total	350	100.0	100.0	

Appendix 3

Assessment of the cognitive load of STEM students

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Extraneous cognitive load is high	286	81.7	81.7	81.7
	Cognitive load cannot be measured	64	18.3	18.3	100.0
	Total	350	100.0	100.0	

Appendix 4

Pedagogical challenges in STEM learning at the secondary and college level

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Poor school enrolment rates	288	82.3	82.3	82.3
	Shortage of teachers	62	17.7	17.7	100.0
	Total	350	100.0	100.0	

Appendix 6

Questionnaire Items

1. What is your age?
   18-29
   30-39
   40-49
   50-59

60+

2. What is your gender?
   Male
   Female
   Others
3. What is your educational level?
   a) Primary education certificate
   b) Secondary education certificate
   c) Undergraduate certificate
   d) Master's certificate
   e) PhD
4. Does the educational system in Egypt and Oman meet global standards in STEM?
5. What is your perspective on STEM education in Egypt and Oman?
6. Are teachers trained on the best pedagogical practices to augment STEM learning?
7. Have the educational reforms enhanced STEM learning or demonstrated the national government commitment to the STEM agenda?
8. Is there a link between STEM subjects at the secondary school level and university admission requirements?
9. Has the government strengthened research competencies in tertiary education in STEM subjects?
10. Which among the three approaches listed below is the preferred example-based learning method?
    a) Peer modeling
    b) Erroneous working examples
    c) Standard working examples
11. Which is the most effective modeling examples technique for STEM in Egypt and Oman? Choose from the items listed below.
    a) Observing an animation
    b) Natural performance by peer/adult
    c) Metacognitive skills
    d) (Psycho) motor skills
    e) Self-efficacy
    f) Learning/retention
    g) Highly structured problems
    h) Less structured problems/tasks
    i) Observing a screen-capture video
    j) Others (specify)
12. Should teachers optimize modeling and worked examples to maximize their effectiveness among students?
13. Under what circumstances are example-based and problem-based learning methods effective?
14. Which learning methods have enhanced the total cognitive load of the students?
15. What is your assessment of the cognitive load of STEM students?
    a) Intrinsic cognitive load is low.
    b) Intrinsic cognitive load is high.
    c) Extraneous cognitive load is low.
    d) Extraneous cognitive load is high.
16. What are the main pedagogical challenges in STEM learning at the secondary and college level in Egypt and Oman?

التأثير قصير وطويل المدى للتعلم القائم على حل المشكلات والتعلم المعتمد على الأمثلة في العلوم والتكنولوجيا والهندسة والرياضيات في تحسين العبء المعرفي بين المتعلمين المصريين والعمانيين

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المستخلص

إن الهدف الرئيس من هذا البحث هو الكشف عن التأثيرات قصيرة وطويلة المدى للتعلم القائم على المشكلات، والتعلم القائم على الأمثلة في خفض وتحسين العبء المعرفي بين الطلاب المصريين والعُمانيين. وتكونت عينة البحث من (٣٥٠) من المعلمين والتربويين ذوي الشأن الذين تتراوح أعمارهم بين (٢٥-٦٠ عامًا)، وعينة من الطلبة المشاركين، وتم اختيار عدد متساوٍ من المشاركين من كل من مصر وسلطنة عُمان. وقد استخدمت طريقة البحث المختلط لاختبار صحة فروض البحث ولكشف توضيح العلاقة بين نمط تعلم STEM والعبء المعرفي. وتمثلت أدوات جمع البيانات في هذا البحث في عدة أدوات منها: تقارير المعلمين عن أداء الطلبة وتقديرات الطلاب وتقارير المشاركة والاستبانة. ومن ثم تم تحليل البيانات بواسطة مجموعة من الأساليب الإحصائية الوصفية والمتقدمة مثل: معامل ارتباط بيرسون والانحدار الخطي واختبار مربع كاي. وقد أظهرت نتائج البحث أن أساليب التعلم القائم على حل المشكلات كان لديها التفوق، لا سيما في الأبعاد الفرعية كنمذجة الأقران، وأمثلة المهام ذات الأنماط الخطأ، وأمثلة المهام القياسية. كانت التدخلات التربوية الفعالة لنمذجة الأقران هي مراقبة الرسوم المتحركة، والمهارات الحركية النفسية، والكفاءة الذاتية، والكسب/ الاحتفاظ، والمشكلات شديدة التنظيم، وكان لدمج التدخلات التربوية في تعلم العلوم والتكنولوجيا والهندسة والرياضيات القدرة على إطلاق التفكير النقدي والمهارات الإبداعية بين المتعلمين، مما يؤدي إلى أعباء معرفية جذرية وجوهرية أفضل؛ هذا من شأنه أن يترجم إلى معدلات نجاح أعلى في تعليم العلوم والتكنولوجيا والهندسة والرياضيات والتنمية الوطنية. على الجانب السلبي، هناك قيود حاسمة لإطلاق إمكانات الطلاب مثل الرؤية والرسالة غير الواضحة لخريجي العلوم والتكنولوجيا والهندسة والرياضيات (STEM) بمستوى جامعي وأنظمة جديدة.

الكلمات المفتاحية : التعلم القائم على حل المشكلات؛ التعلم القائم على الأمثلة؛ تعلم STEM، العبءالمعرفي، التأثير قصير وطويل المدى