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Omareyah secondary school

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Integration of engineering design in teaching STEM

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Abstract

This practice was conducted to evaluate the learning experience of (13-16) year's female students from a privet Jordanian school that adapted the engineering-based model Massachusetts (2016) in STEM courses. A total of 549 of (13-16) year's female students started taking specific units of approximately one-month integrated STEM courses. This made them engaged in designing and building different prototypes as well as resolving higher order thinking questions relates to problem-solving activities. Students' responses on the UTAUT survey, and their teachers' opinions on implementing this practice through open-ended questions, revealed that the practice brought awareness to the school students of their potential as problem solvers, thinkers, creators, and collaborators. Students were able to simultaneously broaden their boundaries in knowledge and competency even though they experienced difficulties in tackling challenges associated with STEM activities. Findings suggested that the Integration of engineering design in teaching STEM practice can be applied as a means to increase the motivation towards learning STEM topics in addition to enhancing creativity, problem-solving skills, and thinking skills among (13-16) year's female students.

Introduction

The vision of Jordan 2025 aims at activating the Jordanian economy by providing the labor market with qualified graduates of the educational sector. To implement this vision, the educational sector was targeted with support and development (town, 1994). Decision-makers in the Jordanian Ministry of Education (MOE) believe that the education system must prepare and qualify young to be critical thinkers who acquire life skills in the changing world(MOE, 2006).

While studies have proved the need to integrate STEM disciplines, in multiple forms of integration, and the positive effect of integration on student achievement and performance (Hurley, 2001). The integration of technology with mathematics and science provides an opportunity for learners to effectively manage their learning tools during the learning process (August et al., 2016). While engineering is of an interdisciplinary and needs the use of knowledge in science and mathematics to solve problems faced by engineers and the industrial sector (Lachapelle & Cunningham, 2014).

In Jordan, STEM components are assessed by the content of each domain individually, and students are assessed for their narrow performance of the domain. As such, the vocational academic stream believes that literacy in STEM is generally poor for those who wish to join the secondary vocational stream. This indicates a general weakness in STEM delivery up to grade 10 (Development, 2017)

Changing the way STEM subjects are taught will improve students' soft skills and their creative abilities (Development, 2017). Integrated STEM education means; “the teaching and learning of the content and practices of disciplinary knowledge which include science and/or mathematics through the integration of the practices of engineering and engineering design of relevant technology (Moore et al., 2014).

Although Jordanian STEM curricula are redesigned; still, many students are not provided with the curriculum they require to develop and heighten their interests in science and mathematics skills and knowledge. The gap is rooted in finding intersections in STEM subjects and not connecting them in a remarkable way to both teacher and student. Through the experiences and training, the teacher has to teach STEM in an integrated and realistic way. Finding links between the concepts of STEM subjects are jurisprudence and may not be based on the scientific method, the absence of a guide or a framework makes the teaching of STEM subjects in an integrated way is a difficult task on teachers (Development, 2017).

On the other hand, education in Jordan has become increasingly content-heavy. Students are not given sufficient time in their primary years to develop functional competencies because they are overloaded with content which is irrelevant to develop their learning competencies. Thus, when more serious learning is required, such as STEM, students have not developed sufficient foundational competence in learning and the resulting STEM education is crippled. As such, Jordan should focus on developing and testing basic competencies instead of learning content.

Therefore, educators urging to propose new educational strategies to introduce the subjects and at the same time maintain educational visions that student is the center of the teaching-learning process. One of these strategies is to flip the class so that the students could engage class time in face-to-face activities with their teacher and peers to reinforcement of social skills, they could prepare for the subject before the lesson through the use of technology as their abilities that makes students enjoy learning while enhancing their self-learning skills and responsibility for what they learn.

So, this practice adapted integration science and mathematics through the engineering model since engineers and scientists do not work separately. Engineering is attracting national and international recognition in the K-12 classroom as a way of connecting STEM disciplines (Lead States, 2013; Lucas, Claxton, & Hanson, 2014). Building on the benefits of the technology offered by flipped classroom from pre-class computer-based learning.

Context of the practice

The participants. This practice covered the students' aged (13-16 years) their number has reached 549 female students. Implemented by eight qualified science teachers, who will apply engineering design in teaching the disciplinary core idea of (7^{th} -10^{th}) science subject integrated with mathematics concepts related to these core ideas. The school where the practice took place is Al-Omareyah school. Which is a privet school in Amman city the capital of Jordan.

The practice framework

The framework of the practice was set up by the science supervisor in cooperation with two expert teachers in science and engineering education;

- The supervisor: a Ph.D. in e-learning, 20 years' experience in supervision, teaching, training, and Curriculum designing in schools.

- The first teacher: an engineer, a master's degree in educational technology and 8 years' experience in teaching science subjects in schools.

- The second teacher: a master's degree in Life Sciences and 10 years' experience in teaching science subjects at the university and schools.

This practice was developed in three stages. **First**, Training teachers to employ engineering design in integrated STEM. **Second**, Choosing units of science national curricula from different academic stages to be implemented within project learning. **Third**, designing the instructional activities of flipped classrooms included of the engineering design process of Massachusetts (2016) during in-class face to face learning.

1- **Training teachers**

Training STEM teachers aim to make science teachers able to employ engineering design in integrated STEM disciplines, prepare plans that include employing engineering design in STEM teaching.

At this stage:

- The team consists of the ten science teachers under the supervision of Science Supervisor (Khadijeh Naser (supervisor), Esraa Harb, Amani Zuiter, Khadijeh Maani, Suha Qurani, Shoruq Hattab, Fedaa Alaqqad, Ruba Tuqan, Laila Awad, Maha Al-graisi, Lana owainat). draws a detailed lesson plans for each science subject (see appendix 1). Take inconsideration that science learning outcomes are derived from the NGSS standards. And determine learning outcomes for integrated STEM disciplines (science, technology, engineering, and mathematics)
- Training students to practice engineering design steps in their school (by their teachers).
- Preparing the appropriate learning environment (to ensure the availability of tablets and electronic devices, besides reused materials) for the required design.
- Preparation and displaying the educational pre-class videos on Edmodo/ WhatsApp groups - the educational platforms- besides determining the drilling exercises which allow interactions between students and their teachers to make sure of understanding the contents of the educational video.
- Defining the nature of in-class activities that focus on higher-order thinking and problem-solving skills through the engineering design model.
- Choosing the appropriate assessment strategies to determine students' performance through working on engineering design class activities.

2- **Choosing units of science national curricula**

Choosing units of science national curricula from different academic levels to be implemented within project learning. This was done by the supervising team with the help of the science subject teachers. These units were chosen based on the possibility of applying the engineering design steps in them.table1.

Table 1. An overview of the courses involved in this study.

Grade	Main STEM subject	Science core idea	Mathematics	Duration	Class size
7	Science	The force and the pressure	Algebra	one month	128
8	Science	The motion	Algebra	One month	132
9	Biology	The cell	Engineering and measurement	5 weeks	
9	Chemistry and Geology	water characteristics	Numbers and operations	3 weeks	140
10	Biology	The genetics	Engineering and measurement	5 weeks	149

- At the end of teaching subjects five different Competitions under the title "STEM Challenges" were held inside Al-Omareyah school based on team working, in these challenges students should solve a specific problem with engineering design, taking into account certain restrictions and conditions. The challenges are summarized in table 2.

- Each project's idea was circulated on a special blog for each age grade and on the official Al-Omareyah school page on Facebook. Follow the link.

Table 2. STEM Challenge projects held in Al-Omareyah schools

Challenge title	Target group	science Core idea	The problem that it solves
Hydraulic winch challenge	7th grade	Fluid pressure	design of a winch with specific dimensions and components raises the greatest weight by employing the concept of fluid pressure
Teleferic Challenge	8th grade	Movement and speed	Teleferic design with specific criteria and components that transfers the greatest weight by employing the concepts of movement, speed, and pulleys
Water purification challenge	9th grade	water properties	Design a water purification model with specific specifications and components that work to purify polluted water by employing concepts of the physical, chemical and biological properties of pure water
Protein challenge	9th grade	Protein’s structure	Design a model for different proteins in the human body by employing the concept of proteins’ structure
DNA Challenge	10th grade	Human’s DNA structure	Design a model for the genetic material in the human body DNA by employing the concept of DNA structure.

3- Designing the instructional activities

A typical flipped classroom involves two major components: (1) out-of-class computer-based learning and (2) in-class interactive learning.

3.1. Out-of-class computer-based learning

There were two essential instructional activities in the out-of-class learning component: pre-class video lectures and online follow-up exercises.

3.1.1. Pre-class video. The students watched instructional videos inorder be prepared well for class. These videos prepared by the science teachers themselves since there are no suitable short and free Arabic videos to achieve the goals of the subjects. Some teachers chose to upload the video to the Edmodo platform, and others to special groups on WhatsApp (see appendix2).

3.1.2. Online practice and drill exercise: Every video uploaded to the educational platform, the teacher asks questions to verify students' understanding of the main concepts of the course before engaging in the activities of the lesson.

3.2. In-class interactive learning. Three core instructional activities have been introduced, namely brief reviews of out-of-class learning, mini-didactic lectures, and engineering-based activities.

3.2.1. A brief review of out-of-class learning. Each teacher starts her lessons with a brief review of the out-of-class learning and reviewed students' performances through online drill and practice exercises. To identify misunderstandings concerning the out-of-class learning materials. The teachers were then able to provide necessary remedial teaching before moving on to more advanced learning activities.

3.2.2. Mini-didactic lecture. In-class short didactic lectures were still necessary to deliver some of the more complicated concepts. Through a quick explanation by asking quick oral questions, waiting for the answers of the students on them, and providing feedback to the students

3.2.3. Engineering design activities. By shifting parts of the course materials to outside the classroom, more in-class time can be spent on engineering design activities (see appendix 3) .

Where the teacher presents an issue/problem related to the subject of the lesson and asks the student to provide a solution using the nine engineering design steps that appear in Figure 1.

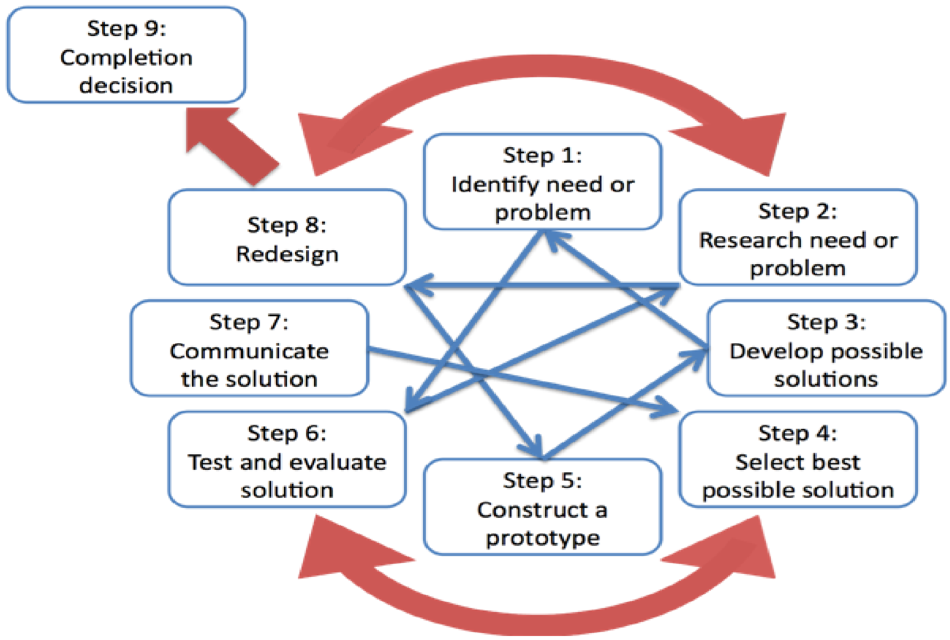

Figure 1. modified EDP for upper elementary and beyond (Massachusetts, 2016), pg. 100

Findings

This practice aims to implement instructional method deals with integration science core ideas and find the cross-cutting with the mathematical concepts and processes presented to the student during current and previous school years, benefit from technology that available from flipped learning approach while engineering challenges act as supported design process for solving real-world problems related to national Jordanian curricula of STEM.

Evaluating the usability of the practice based on:

1- Student's acceptance of engaging in this practice.
2- Teacher's opinion on the practice.

1- student's acceptance of engaging in this practice

The degree of student acceptance has been determined using the Unified Theory of Acceptance and Use of Technology [UTAUT] (Venkatesh et al., 2003). Student's acceptance is an important factor in determining the success or failure of Integration of engineering design in teaching STEM. UTAUT postulates four constructs that are direct determinants of the technology acceptance (behavioral intention) and use (behavior) performance expectancy, effort expectancy, social influence, and facilitating conditions.

The items were adopted from Venkatesh et al. (2003) and were modified to suit the context of this practice objective. The items were measured on a five-point Likert scale ranging from “strongly disagree” to “strongly agree”. To follow up the questionnaire presented by the students follow the link. Results of students' responses to the questionnaire, as in Table 3.

Table 3. Students' Acceptance to use Integration of engineering design in teaching STEM

Descriptions	Mean	SD	Number	Interpretation
Performance Expectancy	3.32	0.658	120	Moderate
Effort expectancy	4.32	0.642	120	High
Social influence	4.22	0.860	120	High
Facilitating conditions.	4.40	0.662	120	High

Note: SD = Standard Deviation

Table4. The interpretation of the means value

Mean	Interpretation
0.0-1.66	Low
1.67- 3.33	Moderate
3.34-5.00	High

Table 3. Shows the result of Students' Acceptance to use Integration of engineering design in teaching STEM. The findings show that all items received a positive perception with moderate to a high mean value of 3.32- 4.40 (SD = .658-.662) which proved that the students perceived engaging this practice would increase their chance to get better motivations, ability in solving real problems and find meaning for learning.

2- Teachers' opinions on the practice.

To extrapolate Teachers' opinions on the practice, a Semi-structured interviews were conducted. Teacher interviews lasting about 20 min each. There were two major aspects of these interviews: (1) how their students participate in the events. (2) What are the challenges faced by the teacher during implementation?

The responses of the teachers were positive and most of them emphasized the effectiveness of the framework and practice. Here are some of these responses:

"I could skip some parts and save time in the lesson, as some ideas could be learned by watching the videos, and handled well by the students, as reflected from their answers. Students are now more likely to ask questions, engage in teamwork activities, and search for knowledge from different resources, think like engineers. I think the practice enhances students' soft skills and increase their motivation to learn and interact in science classes". (Chemistry teacher).

"Preparation work on recording videos and searching useful related videos is a challenging task "(geology teacher).

"*Some students have low motivation to do the pre-lesson tasks, and inevitably they cannot gain the true benefits from the flipped classroom design" (*8th-grade science teacher).

"The challenge is to ensure that all of them watched the videos before the lessons…". "*Student ability is diverse. Therefore, a whole-class revision would waste the time of some students, especially the high-ability ones.* (The physics teacher).

"*Flipping the revision part outside the classroom is a good practice"* (7th-grade teacher).

Collaboration with the local community

- Transferring the impact of learning by holding training workshops for female public school (Sukina Bent Al Hussein Comprehensive school) on integrating engineering design in STEM disciplines, and keep cooperating with this public school to provide the needed support and materials see appx.4. The product of this cooperation was creating an exhibition in this public school. The exhibition included models designed by their female students to solve realistic problems, the basis of which was related to the STEM curriculum. See appendix 5.

- after Al-Omareyah school products exhibition, these designs will be gifted to a less fortunate public school in Amman city to be used in the educational process, so that the project idea will be presented to students in that school, due to the scarcity of resources in such these schools See appendix 6.

Conclusion and recommendations for future practices

This report conveys our experience of a two-stage study of the Integration engineering design in teaching STEM. By using this framework, students solving world problems were improved. For the most part, this model showed an important potential for informing teachers on how to design and implement their engineering-based courses. However, as our practice focused on science core ideas in integrated STEM disciplines at (7^{th} -10^{th}) grades. Further practices are necessary to examine the efficacy of this framework in other educational STEM subject areas (e.g., Mathematics, technology) core ideas.

Two other major limitations may affect the generalization of our results. First, due to school policy, the class sizes were large. Caution should, therefore, be exercised when interpreting our results, especially to the ability of the teacher to contact each student (Especially students with low achievement). Second, motivation, teaching experiences and ability to follow, all are factors vary from teacher to another. The result shows a teacher who had more teaching experience (15 years) applied educational practice so smoothly. This was reflected in the performance and motivation of his students. Therefore, we recommend conducting further practices that involve more qualified STEM teachers.

Some teachers indicated that we must upgrade the designs and integrate the robotics in future practices, we must study the integration of robotics in teaching some subjects of science specifically "movement" in physics.

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