Constructivist Pedagogy Approach in Innovative Design of First Year Engineering Course on Skills and Ethics

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Abstract - **This paper reports on multiple practical suggestions for implementing constructivist and active learning approaches in introductory first year engineering course, this was conducted in the revision of the "Engineering Skills and Ethics 107" course at the College of Engineering, Qatar University. After laying down the contextual framework of the revision, the methodology for conducting this review is detailed. Followed by sections on lecturers' and students' feedback. Assessment of the course content and the design component is provided. Ideas for conducting constructivist teaching and learning approaches with potential benefits are explained. Then ideas for engineering design projects with examples and list of benefits for each one are detailed, finalizing with concluding remarks.**

Index Terms contextual framework, engineering skills, Engineering design projects, teaching approaches

INTRODUCTION

Qatar vision 2030 [1] and Qatar strategic development plan 2011-2016 [2] emphasize developing Qatar into a knowledge based economy by 2030. Local educational institutions would need to respond by changes in curriculum that meet specific needed skills of 21st century citizens. Qatar University and other local educational institutions have witnessed significant improvement since 2003, however, there is still space for extra work [2]. Engineering would be one of the most crucial fields in achieving Qatar vision 2030, a shared consensus among a number of key executive stakeholders in Qatar [3]. Enhancing soft and design skills, creativity, research skills, initiative and leadership of engineering graduates in Qatar would be necessary. Hence, revisions of some core/general engineering courses are taken within the College of Engineering, including the "GENG107 Engineering Skills and Ethics 107" course.

The contextual framework of this revision is based on pillars of constructivist pedagogy [4]; [5]; [6] best international practices in engineering and STEM education [7]; [3], and futuristic visions and recommendations of 21st century engineering education [8]. It is nationally contextualized taking into consideration the General Secretary for Development and Planning (GSDP) reports [1]; [2], intermediate findings of future engineering skills of Qatari engineers [3], and issues relevant to the Arabic and Islamic culture of the state of Qatar.

METHODOLOGY

The methodology of conducting this review has been as follows: Two meetings (100 minutes) between the author and the general engineering program Head were held to get a general overview. The course syllabus, textbook, two samples of course portfolios of teachers, and students' responses to end of course questionnaires for the past three years were surveyed. The author attended one lecture of the course and has conducted informal discussions with one lecturer and students. Desktop research for introductory engineering design projects and for introductory courses on engineering design has been achieved using relevant keywords in Google. Some courses were found; however search was narrowed down by typing the word "Design" in the Open Course Ware Consortium webpage (http://www.ocwconsortium.org/). Relevant literature research on design and creativity in engineering were conducted using Google Scholar. Informal discussions with other students and staff have given some extra insight. A number of ideas and recommendations for improvement have been generated.

LECTURER`S AND STUDENTS FEEDBACK

Probably the most notable concern of lecturers of this course is the relatively immature behavior of students, being fresh and in transition from K-12 into University. With such sample of students, further attention and guidance is needed as well as more control. One lecturer suggested reducing the maximum number of students in a section from 45 to 30 to solve this problem. The author also thinks that this could be reasonable for 1st year courses, in particular a course like this that has focus on design and skills development.

Another concern has been the low level of students compared with previous years, the high variance as some students from science and business enroll in this course as well, and these students don't take this course seriously.

In face-to-face discussions, students have not shown any major issue with the course. Instead, they revealed deep concerns about other matters.

ASSESSMENT OF THE DESIGN COMPONENT OF THE COURSE

Introducing the design project has been definitely an important update of the course. According to one of the course lecturers, students generally don't have difficulties in conducting the design projects. In the informal discussion with the students, they did not express having difficulty also in conducting their projects. According to the lecturer, the main aim of the project is to immerse the student in the experience of systematic design at early stage; implementing a tangible product is for sure welcome, but is not mandatory. Only around 40% of the finalized projects has an implementation phase.

The design project component of the course seems heterogeneous, one lecturer gave full freedom for the students to search for- and pick up a project topic (a male section). Another lecturer gave all students the same project (a female section). It was recommended to expand on design varieties, not restricting to one design project, this would help students to pick up a project that is suitable for their interests and learning styles; it may also open a space for students to be more creative. Ideas for design projects are presented in further details in later sections of this paper.

ASSESSMENT OF THE COURSE CONTENT

The course text book [9], and content are good and relevant, minor updates (in regard with contextual cultural ethics heritage and history of engineering in the Middle East) could be suggested. Regardless of the course content, the development of enhanced skills and design competencies is equally important and can't be achieved through passive delivery. It requires following constructivist, student-centered and experiential learning approaches as much as possible. Henceforth. This paper focus in demonstrating some technologies and ideas that can be used for this purpose.

TECHNOLOGIES AND TOOLS FOR IMPROVEMENT OF INTRODUCTORY ENGINEERING COURSE

Many technologies, solutions and tools can be embedded in the course for conducting constructivist activities and/or more creative engineering design projects. Examples of such solutions are: LabVIEW, Camtasia, Joomla, Moodle, Scratch, Audience Response System (ARS), LEGO Mindstorm, TETRIX Robotics, PITSCO Inc. products, etc. Many of the recommendations and ideas to be seen later on this paper are based on such solutions.

IMPLEMENTING CONSTRUCTIVIST AND EXPERIENTIAL LEARNING APPROACHES

Constructivism is one of the modern adopted approaches in education. Constructivist approaches such as interactive lectures, project based learning and experiential learning became popular in reforms of engineering education [10]; [11]. Some of the main Pillars of constructivist teaching and learning [4]; [5]; [6] are: 1- learning is a student-centered process, students' autonomy should be fostered; 2- learning should be contextualized and associated with authentic real-world environment and examples; 3- social interaction and discourse is an important part of learning; 4- the taught elements should be contextualized and made relevant to the learner; 5- the taught elements should be linked with the learner's previous knowledge; it is important to facilitate continuous formative assessment mechanisms; 6- It is important to facilitate self-esteem and motivation in students; 7- teachers should act as orchestra synchronizers rather than speech givers; 8- teachers should consider multiple representations of their teachings.

A couple of suggestions for course activities are proposed in the next section based on these eight pillars.

Skills acquisition is a core mission of the course; skills development require couple of iterative training loops, where a student: 1- immerse in a hands-on experience (e.g. presentation, discourse, debate, etc.), 2- feedback is provided (self-evaluation, peer- or teacher evaluation), 3- student reflect on the experience and feedback and learn lessons, 4- student work on bridging the gap between his/her actual performance and the standard one. One iterative loop of the previous four stages is not normally enough for a novice to reach a mastery level. For instance, one presentation is not adequately enough for a student to master presentation skills. Hence, some modifications to the way lectures are given could assist in enhancing skills acquisition by allowing multiple iterative training loops. This is not a difficult course, classical delivery of lectures in form of passive speech will not have significant difference to the case where students listen to a recorded video of the lecture. To allow further time for conducting constructivist and experiential learning activities in the classroom, passive delivery of content would be minimized in particular for the easy topics. Example: Lectures can be recorded in advance (e.g. using Camtasia or by using a classroom lecture capture recording facilities currently available in QU) and made available online. Students will be asked to view them as a preparation for the lectures. Quick formative assessment for about 10 min (preferably to be a part of the course grade, e.g. 10%) can be taken at the beginning of the lecture using ARS to make sure that students have viewed the online lectures. The next 40 minutes or so can be devoted for group discussions, debates, power point presentations, hands-on activities, technical training for some needed issues for the design projects, etc. This is a way for implementing Kolbs' (1984) experiential learning cycle, which has proved high efficiency in engineering education [12]; [13]; [10]. All these practices will enhance students' technical and soft skills and their ability to express their ideas. In the next section, a couple of ideas are proposed for implementing some of the constructivist pillars shown earlier and to allow further space for skills acquisition. For each idea, a number of key benefits is enumerated.

IDEAS FOR CONSTRUCTIVIST AND EXPERIENTIAL ACTIVITIES

The ideas below are prepared to give some concrete examples of conducting constructivist approaches for the course. They are not exclusive, activities creation is unlimited and many effective ideas can be proposed by the course lecturers having in mind the constructivist pillars presented earlier. For each idea, a number of benefits will be listed.

A. Organizing an Internal conference

In this activity, students work on organizing a conference. One group of students will work on establishing and populating the conference website (e.g. using Google sites, few hours of work can produce a professional look like website. See Figure 1 that shows a draft of a conference site has been developed in about 25 min, having no previous experience in Google sites; see https://sites.google.com/site/nurc2011/). Populating the conference website will need adding necessary information such as: "call for contributions", "venue", "registration", "keynote speakers", etc. This group will be responsible also for designing an "author kit", a "conference logo", promotional materials, etc. Another group will handle logistics relevant to the conference submission system (e.g. using easychair.org, this will add a professional submission administration system; an example has been installed, see https://www.easychair.org/conferences/?conf=nurc2011). They have to communicate with easychair.org to install specific system for the conference, they have to handle later on submissions, invitations for reviewers, assigning reviewing tasks and following progress according to specific deadlines. A third group will be responsible for co-ordination and logistics related for the conference such as inviting keynote speakers (e.g. lecturers from QU, industry or the Educational City), book in rooms and halls for presentations, arrange for meals, conduct marketing and outreach of the conference in QU, Educational City, Industry, etc. to attract audience, and any other relevant duties. Ten to 15 students could form a reviewing panel, each of the submitted papers should be reviewed by three reviewers who have to provide critical and constructivist review in line with a guiding criteria set by the lecturer. One group will form an editorial board to produce the conference proceedings book. All students have to produce and submit papers (4 to 6 pages) according to specific themes. The papers would be rather essays (given students novice level) but should follow a scientific scholarly writing approach (e.g. including abstract, keywords, intro and literature review, methods, discussion, conclusions, proper citation and referencing such as Harvard style, etc.). The themes could be set by the lecturer in a way that feedback into the course itself. For instance, the following themes could be useful: Ethics in engineering, engineering for community service, emergent engineering disciplines, creativity in engineering, etc. Two conferences could be organized every semester in a form of competition (male sections vs. female sections). Criteria of success will be set by the lecturers, this could be according to the professionalism of the conference web presence and promotional materials, the quality of attracted keynote speakers, the number of attending audience, the quality of presented papers, the quality of presentations, etc. Conference can be organized as a weekend informal activity (e.g. on Saturday), and this was beneficial in: 1- Students will have exposure to an essential research academic practice at the very early stage of their degree; 2- This is a hands-on experiential approach that improves a variety of soft skills (academic writing, oral communication, literature search, research skills, presentation skills, logistics, etc. 3- Success in achieving this event will increase self-esteem, confidence and motivation towards an engineering or an R&D research career; 4- Competition between male and female sections would foster creativity to come up with the best product that wins the competition; 5- Organizing a conference is a design project as well, this will enhance the design soft skills allowing an extra iterative training opportunity.

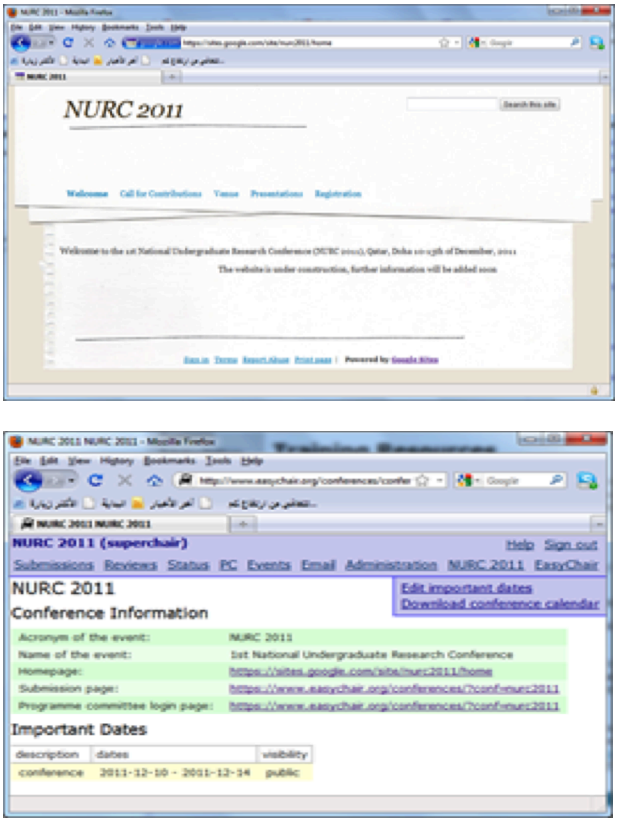


FIGURE 1: A DRAFT OF A CONFERENCE WEBSITE CREATED WITH GOOGLE SITES FREE SERVICE (TOP). THE CONFERENCE AUTOMATIC SUBMISSION SYSTEM (BUTTOMO) HAS BEEN INSTALLED ON EASYCHAIR.ORG.

B. Students as Lecturers and the Lecturer as a Quality Assurance Personnel:

This is an effective and constructivist approach that has resulted in enhanced outcomes. Example: In a lecture on the

topic "The engineering and engineering disciplines", the lecturer will ask different groups of students (4-5 students each) to prepare 5 minutes presentation about specific engineering discipline and explain to their peers in the classroom. For instance, one group will talk about electrical engineering, another group will talk about mechanical engineering, third one about chemical engineering, and so on. Once a group finishes its 5 min presentation, an additional 5 minutes of discussion and Q&A will follow whereby the lecturer can correct any incorrect information and the rest of the class will ask for questions. This approach would be beneficial in: 1- Enhance presentation skills; 2- Enhance research skills; 3- Enhance teaching skills; 4- Reveals misleading concepts about specific engineering disciplines in students' minds

C. Scenarios and Role Play

Teachers may ask students to invent scenarios and role play scenes in the classroom. This approach enhances creative thinking and oral communication skills. Example: In a lecture on the topic "Engineering Ethics", groups of students (4-5 each) are asked to design and play on stage in the classroom scenarios (e.g. 5 min) of imaginary unethical situations preferably relevant to engineering. After the play finish, the lecturer will instill a classroom discussion about what has been unethical? Why? What actions should have been done instead? Etc. This approach would be beneficial in: 1- enhancing creativity; 2- Enhancing communication oral skills; 3- Enhance classroom discourse; 4- Enhancing classroom engagement, students are less bored.

D. Students' Peer-Feedback

Peer feedback is an effective method to integrate for many reasons. First, peer-feedback reduces pressure on teacher to provide individual feedback for each student. Second, peer-feedback encourages critical thinking in students' minds, it puts students in a teacher-role and enable them to think of issues never thought about before. Example: Students can be asked to do organize Project Presentations among themselves in the mid of the semester. For instance group A presents their projects to group B which will provide feedback to group A in regard with their presentations skills and in regard with their project. Group B will also do presentation in front of Group A which will provide feedback as well. Beneficial in: 1- Reduce pressure on teachers; 2- Enhance critical thinking; 3- Allow multiple feedback and formative assessment loops; 4- Enhances communication skills; and 5- Allow multiple training opportunities.

E. Some Tips for enhancing Self-esteem, Confidence and Motivation

Students' self-esteem, confidence and motivation towards engineering could be enhanced through different ways as: 1- Organize field trips to advanced engineering labs in the University and/or to engineering companies in Qatar and Showing engineering documentaries, e.g. a video of breakthroughs that took place because of engineering. There is a research evidence that viewing a challenging documentary in a STEM subject has resulted in significant enhancement in exam performance, enhancement in retention rate, increased risk taking and thoughtful reflections [14]; 2-- Showing exemplars of peers performance, e.g. invite a local successful engineer from industry to give a short talk on how engineering has changed his/her life (could be a video recording); 3- Teachers to affirm that students are knowledge builders and it is a student-centered process in the University unlike school, in particular while working on their projects. Nevertheless, this should be made clear for students through separate outreach workshops at the very early stage of their first academic year; 4- Give students more freedom in expressing their opinions, picking up design projects; 5- Challenge students.

IDEAS FOR THE DESIGN PROJECTS

In this section, a couple of ideas for enhancing the design component of the course are presented. These ideas are not exclusive, many innovative approaches can be proposed by the course lecturers. It worth mentioning that training students on engineering design would be expected to continue in later semesters, either in dedicated courses for design or by introducing extra components that emphasize on design in other courses. For instance, the mechanical engineering curriculum at Steven Institute of Technology, USA, contains 8 design courses, each every semester. In Aalborg University, Denmark, starting from the third semester, students spend one third of their engineering curriculum on theory while two third of curriculum is spent on design projects.

A. Team Creation:

Teachers would be recommended to make sure that there are at least one or two well-motivated students in the team (Champions). Try to have team members of different ethnics or nationalities, include in each team ONE Qatari citizen.

Benefits: Having members of different backgrounds enhances the team creativity, sense of responsibility of each member, communication skills and also cultural exchange and understanding. Future Qatari engineers would be working in highly multicultural environments, cultural understanding is a skill needed in such context.

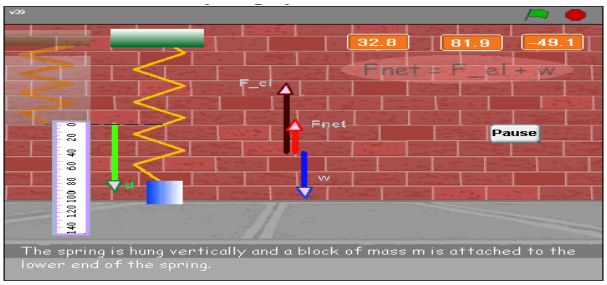
B. Competitions:

Competition would be performed on two levels, the first one is within the course whereby the best three projects will qualify to the finals. The finals will be within sections, whereby the best project of all sections will win. Assessment of the projects could be a combination of peer assessment, e.g. with WebPA and lecturers evaluation. Proper rewards should be given, for instance, a recognition rewards (e.g. putting the team picture in the University news banner Excel), extra grades, and/or financial reward.

Benefits: Design projects competitions can be used to foster putting more effort and increase creativity of the teams.

C. *Projects for Engineering Outreach in K-12:*

In these projects, students work on designing items to be used in K-12 for engineering outreach and for demonstrating the applicability of taught math and science courses during the school in real life.



Example: These projects can range from developing virtual labs (e.g. using LabVIEW or Scratch) to design of interactive toys for kindergarten and school grades from 1 to 5 (e.g. with LEGO Mindstorm and Picocricket) . Projects that involve designing kindergarten toys, could be particularly suitable for females. Implementing such projects can be facilitated using LabVIEW, Scratch, and engineering components sold by PITSCO Education. Figure 2 shows examples of physics simulations designed for K-12 education with Scratch. Another example is to ask students to design 2D games for teaching and learning of mathematics of school grades 1 to 6 using Scratch. Benefits: Apart from learning about design, this approach will: 1- It will provide training of concepts such as service-learning and engineering leadership at the very early stage of the engineering degree curriculum; 2- Enhance communication skills by having an authentic professional experience where students should professionally communicate in writing and orally with different stakeholders (e.g. teachers, pupils, admins) during the project process; 3- This approach could help in enhancing interest of STEM subjects in schools and increase ratio of students who choose to go into higher education and/or to continue a STEM career. This would be necessary for achieving Qatar vision of 2030 [2].

D. *Lab-VIEW based Projects:*

LabVIEW is a graphical programming language perceived easy to learn by engineers [15]; [16]. LabVIEW has launched an Education version in 2009 targeting fresh University students, high school students and other audience with no previous programming experience. Remote control via the internet can be easily facilitated using LabVIEW. In such projects, students will create a LabVIEW based software that is able to monitor and/or control hardware remotely. LEGO Mindstorm and TETRIX Robotics products can be used for building necessary artifacts that are programmed and/or controlled via LabVIEW.

Examples: LabVIEW based projects can range from pure simulations (e.g. virtual labs, or engineering interfaces) to projects that involve data communication or control of hardware or engineering structures, either on-site or remotely. LabVIEW Education version has easy-to-use data acquisition functions with products produced for fostering design, inquiry based learning, and innovation in STEM education, such as MINDSTORM LEGO, TETRIX Robotics (a PISCO product). Figure 3 shows two TETRIX based projects, a night vision system and a robot for assisting special need persons. In remote control projects, students can utilize laboratory hardware kits (that are suitable for remote operation) from the college of engineering, creating a set of operational remote labs to be used by lecturers in a classroom lectures for instance. Alternatively, students can work on implementing a remotely meaningful operation for appliances in their house. Benefits: 1- Most likely that students will use LabVIEW in a way or another later on in their degree or in their future career. Hence, this early introduction to a simplified version of LabVIEW would be very useful; 2- Graphical programming with LabVIEW enables rapid prototype and development of engineering applications; 3- Similarly to Scratch, programming with LabVIEW enhances systematic thinking, creativity, critical thinking, etc.; 4- Using components from LEGO Mindstorms/TETRIX robotics with LabVIEW in design projects enables producing engineering products at the very early stage of the curriculum, without the necessity of have much of theoretical knowledge. This will motivate students more towards engineering and reduces drop-out rate; 5- Such projects will enhance students' technical skills' 6- Remote control projects via the internet shows students another dimension of modern engineering applications, also is considered as fun and imagination and thought provoking.

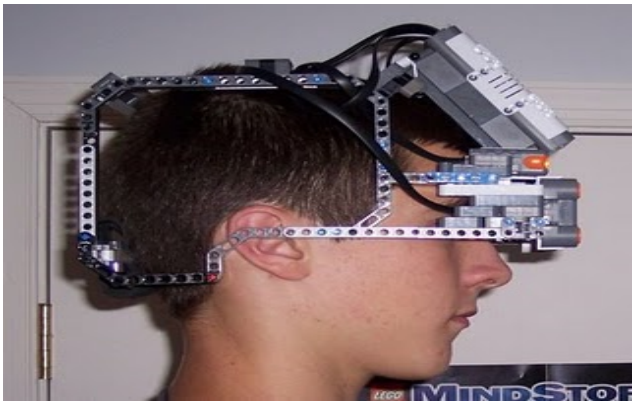


FIGURE 3: TWO ENGINEERING PRODUCTS DESIGNED WITH LEGO MIND STORMS, TETRIX ROBOTICS AND LABVIEW; A NIGHT VISION SYSTEM (LEFT) AND A

E. Web Design Projects & Virtual Learning Environments (VLE) Projects:

Web design has become an easy process with the emergence of web content management systems, such as Joomla, Drupal, Word Press, etc. Many of these systems are open source, free to use, and are accompanied with large pool of third party add-ons. These add-ons enable implementing sophisticated websites out or preliminary components with no need of any web programming experience. Students can be asked to conduct web design projects, e.g. websites for their former schools, engineering outreach website for the public, an engineering students' club website, an engineering company website, etc. Joomla is easy system to configure and develop meaningful website with, it would be a suitable web content management system for junior students to use in projects.

Virtual Learning Environments (VLEs) are considered an integrated and important component of modern teaching, learning and training institutions. Moodle is free open source VLE launched in 2005. Currently Moodle have the largest share world wide of VLE market (more that 50%) taking over Blackboard and other VLE systems. Installing, configuring and working with Moodle is relatively easy when following guides, manuals, or relevant text books. In such projects, students work on building VLE websites for their schools or for engineering companies (e.g. for the training department). Benefits: 1- Web design projects will enhance students' IT skills; this is one of the recommendations for future Qatari engineers [3]; 2- Apart from communication and negotiation skills; such projects will enhance a variety of soft skills depending on the context of the website, e.g. ethical responsibility and community service (school website), career and business skills (engineering company website), initiative and leadership skills (students' club website), etc.; 3- Using open source and freely available solutions (e.g. Joomla and Moodle) open students' thinking of choosing alternative options that reduces cost and enable more saving. This is a very important practice in engineering. Also, this is a practice in context with the Qatar's GSDP strategic plan of reducing losses and increasing savings on the way towards achieving a knowledge based economy [2].

F. Integrated Curriculum Design Projects:

These are integrated projects created from curriculum components taken from one or more courses (e.g. computer programming, engineering graphics, math, physics, etc.). In this approach, engineering projects that require programming, graphics, and mathematical modeling skills are proposed and are carried out by students who have taken these courses previously. Lecturers of various courses may sit together in a committee and produce few integrated projects. Benefits: 1- Students will realize the importance of different taught courses of the curriculum showing that they are not taught distinct topics of no relevance; this will reflect on participating and studying future courses more seriously; 2- This might reflect on the lecturers design of courses, by further contextualizing them to the needs and aspirations of engineering students; 3- Redesign engineering curriculum to be more integrated is one of the most important recommendation for enhancing future engineering education [8].

CONCLUSIONS

This paper aimed to provide a number of constructivist and active learning approaches to be implemented in introductory engineering courses, with a case revision of "GENG 107 Engineering Skills and Ethics", a general engineering course at the college of engineering in Qatar University. Minimizing time devoted for passive delivery of content and maximizing spent of conducting hands-on constructivist activities were recommended.

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