Performance Enhancement Camp as a Pre-Commencement Tool to Bridge Knowledge Gaps

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Abstract—A Performance Enhancement Camp (PEC) aimed at enhancing engineering fundamental knowledge and to familiarize students with the CDIO concept in Project Based learning was held. A total of 62 students mainly comprising of school leavers participated in the camp that was held for 2 days. The camp was designed to be highly interactive with 3 assessments held to gage the attainment of students in engineering fundamentals and 6 projects aligned to the Grand Challenges were provided for students to demonstrate CDIO practice attainment. Results do show a significant enhancement in engineering fundamentals and CDIO practice.

Keywords—Performance Enhancement Camp (PEC), engineering fundamentals, CDIO, attainment, Project Based Learning.

I. INTRODUCTION

Many researchers [1,2] have advocated the thought that all students who proceed directly to work after high school possess at least college level education. Today’s rapid evolution in technological advancements require more occupations than ever to have at least a high school diploma [3]. President Obama in his speech to Congress (February 25, 2009) mooted the concern that a shrinking proportion of college education leavers coupled with a higher college dropout rates are symptomatic for an economic decline. However critics have often raised concerns regarding the academically unprepared college student population [4]. What is often missing in many educational policies is the empirical evidence on how well various nations prepare students through the K-12 education pipeline for a seamless transition into foundation years within a university [3]. What often seems to be the question is whether all students are academically ready for and thus can benefit from post K-12 education [5] suggested that knowledge attainment gaps begin at entry level into schools and widen over the course of K-12 schooling. The widening of knowledge attainment may prove to be detrimental in achieving a seamless transition into post K-12 education. [6-9] performed research on post K-12 readiness for college students. Their studies revealed the fact that K-12 education has been largely disconnected from post K-12 education and that significant amounts of fragmentations exists within the K-12 education as well. Conventional views of post K-12 education readiness have focused narrowly on students’ first year college performance as predicted by college admission rates, which remains to be separated from K-12 standards based educational assessments [10,11].

II. METHODOLOGY

PEC was conducted for a total of 2 days. The first half of the first day was spent on introducing the three disciplines of engineering at Taylor’s University (TU) whilst the second half was aimed at introducing key engineering fundamentals across Physics, Chemistry and Mathematics. The next day involved exposing students to the framework used in facilitating teaching of engineering at Taylor’s University based on the Project Based Learning pedagogy which is the Conceive, Design, Implement and Operate (CDIO) framework. To facilitate teaching of CDIO, four different stages emphasizing key elements in each stage of CDIO were incorporated to create a highly interactive atmosphere nurturing skills required to CDIO an engineering product or system. During the “Conceiving” session students were taught methods to conceive which include best practices in brainstorming [12], blue ocean strategy [13], “SCAMPER” [14] and random entry [15]. The next session emphasized the “Designing” phase. Here students were exposed to basic principles in designing for engineering. This session emphasized on a systematic framework in designing an engineering product or system based on architectural design, conceptual design, integrated design and detailed design (ACID). Once the design stage was completed the session proceeded to introduce students to the “Implementation” stage. In this session students were taught concepts on element creation and integration of systems and the subsequent simulation tests that may be required for design verification. In the final “Operating” stage, students were exposed to support services needed to remain competitive in the market such as sales and service, operations and logistics, maintenance, repairing and upgrading options that can be provided to the user of any engineering system or product. At the end of the 2 day session, 2 assessments were carried out to gage the effectiveness of the camp as a whole. The first assessment was an individual assessment based on the fundamentals of engineering concepts across Physics (P1 to P10), Chemistry (C1 to C10) and Mathematics (M1 to M10) whilst the second assessment was based on CDIO practice attainment. For the second assessment, students were separated into groups formed randomly. Brainstorming [16], technique was used as an introduction for students to learn how to conceive effectively in a team. Students were subsequently separated into 6 teams and were given each a challenge that was aligned to the Grand Challenges (GC).
advocated by the National Academy of Engineers (NAE) in 2008 [17]. A brief description of the challenges that students addressed to CDIO an effective solution are provided below:

1) **Block-Bridge Design Challenge** (7th GC). Teams were given an incomplete bridge model, built from toy blocks. Teams are required to restore the structure within a stipulated time frame. The complexity of the challenge was evident when teams were required to improve the capability of the structure to withstand a certain load.

2) **Engineer The Missing Pieces** (14th GC). Each team was equipped with a set of puzzle pieces which needs to be assembled. Upon assembly, teams would discover that there are missing blocks. By using proper measurement tools and computer aided engineering design (CAED), teams were required to 3D-print the missing block. The complexity of the challenge was to familiarize members among a team with CAED code language.

3) **Hydroponic Self-watering System** (12th and 13th GC). A model of a basic hydroponic watering system was shown to teams. Subsequently, teams were required to improve the design so that process efficiency, spatial considerations, cost, environment and safety would be optimized. The complexity is introduced when team members begin to plan the orientation of the system and the fluid flow.

4) **DIY Aloe Vera Gel** (5th GC). Each team was introduced to methods that enable the extraction of aloe vera gel from a fresh aloe vera leaf. Mensuration techniques and the importance of units will be the main focus points for this game. Teams were briefed that the extracted gel, will be used as body lotion. Through this teams will realize the importance of the ratio of each ingredient for safety reasons.

5) **Design of Water Filtration System** (9th GC) Teams were to use the materials provided to design a water filtration system so that they can gather a bottle of clear water from a muddy source. The quality of the filtered water was tested by a water turbidity sensor with 5 NTU as the baseline of clean water as recommended by the World Health Organisation (WHO). Other parameters of water quality measurement were introduced to the participants subjected to the availability of measuring equipment and time.

6) **Arduino Robot Cleaners** (1st GC) Teams were provided with a set of arduino robotic toy-cars and the working principle of the toy car were explained to them. Teams were then required to make modifications that would enable the toy car in completing a specific challenge such as beach (artificial) cleaning, room cleaning, tennis ball transporter and others.

Once all teams have completed the challenges that teams chose randomly, a Likert survey assessing the understanding of team members on CDIO concepts was administered.

III. RESULTS AND DISCUSSION

Pre and post individual test scores (assessment 1) was used to evaluate knowledge attainment of the engineering fundamentals whilst a pre and post survey (assessment 2) was used to assess the effectiveness of the CDIO session camp. High school students were asked to complete the survey instrument prior to the camp activity and the same instrument was then re-administered to the students at the end of the 2 day camp. Figs. 1, 2 and 3 depict the mean knowledge attainment based on learning pillars for Physics, Chemistry and Mathematics respectively.

An interesting observation can be made regarding the results for the pre and post Physics individual exam. The mean based on 10 learning pillars in Physics (P1 to P10) for the pre camp was 59.5. The mean grew by 16% during the 2 day camp to achieve a value of 70.8. The increase in the mean is an indication of the higher individual understanding that students attained regarding the 10 learning pillars in Physics which emphasized on Dimensional Homogeneity, Newton’s Laws of Mechanics, Dynamics, Statics, Gas Laws, Fluid Mechanics, Circular Motion, Simple Harmonic Motion, Gravitation and Radioactivity. The relatively lower error values for the pre camp data are an indication of the evenness in knowledge with regards to the 10 learning pillars. The higher error values seem to indicate that a larger number of students have gained enhanced insight during the camp whereas with the exception of a small number of students who have yet to digest the newly attained knowledge in Physics. Overall teaching of the 10 pillars in Physics has been effective as it can be seen that each learning pillar had enhanced scores when compared to the pre camp results. The maximum enhancement occurred in the 5th and 6th learning pillars (Gas laws and Fluid Mechanics) with a value of 16.1% respectively. The lowest enhancement was seen in the 8th learning pillar (Simple Harmonic Motion). It may be concluded from this data that students were well exposed with the concepts of Simple Harmonic Motion during the K-12 education but lacked understanding in Gas Laws and Fluid Mechanics.
For Chemistry, the mean for the pre camp was 59.2. The mean increased by 29% during the 2 day camp to a value of 83.1. Higher individual understanding that students attained regarding the 10 learning pillars in Chemistry which emphasized on Atomic Structure, Trends in Periodic Table, Chemical Bonds, Intermolecular Forces, Reaction Kinetics, Chemical Equilibrium, Thermochemistry, Organic Chemistry, Isomerism and Inorganic Chemistry is evident from this result. Overall teaching of the 10 pillars in Chemistry has been effective as it can be seen that each learning pillar had enhanced scores when compared to the pre camp results. The maximum enhancement occurred in the 7th learning pillar (Thermochemistry) with a value of 40.6%. The lowest enhancement was seen in the 6th learning pillar (Chemical Equilibrium). An interesting finding that can be observed is that thermochemistry has not been taught to students in the Malaysian, United Kingdom K-12 curriculum which would be the main reason as to why the enhancement is very significant.

For Mathematics, the mean for the pre camp was 51.2. The mean increased by 29% during the 2 day camp to a value of 73.1. Higher individual understanding that students attained regarding the 10 learning pillars in Mathematics which emphasized on Logarithms, Indices and Surds, Complex Numbers, Partial Fraction, Polynomials, Calculus, Trigonometry, Vectors, Linear Programming and Matrices is evident from this result. Overall teaching of the 10 pillars in Chemistry has been effective as it can be seen that each learning pillar had enhanced scores when compared to the pre camp results. The maximum enhancement occurred in the 6th learning pillar (Calculus) with a value of 67.4% whilst no enhancement in test scores were seen for the 9th learning pillar (Linear Programming).

As indicated in Figure 4, high school students were able to grasp a better understanding in every category assessed at the camp with the most significant gain in an understanding of engineering design. This could be attributed to the increased levels of interest that students had after being briefed about the basic principles in engineering design and the CDIO concept which was systematically applied to guide teams in converting ideas and thoughts into reality.

IV. CONCLUSION

PEC was able to engage 62 students from a variety of national and international K-12 curriculum. Students were exposed to numerous fundamental and engineering design activities. Participants worked in teams of 4 from different educational backgrounds and were assisted by engineering undergraduates from the 3 different engineering disciplines at Taylor’s University. PEC which was held as an innovative approach to bridge the gap between high school studies and tertiary education has been a success given the increased attainment in the basic sciences that govern engineering principles such as Physics, Chemistry and Mathematics. Students were also exposed to the concept of CDIO which assisted the conversion of ideas and thoughts into reality in a systematic framework. Student were also introduced to the various disciplines of engineering and the importance it had on sustaining humanity in the 21st century. Future plans will focus on efforts to increase number of participants, refine camp offerings and to align activities held during the camp to national STEM initiatives in order to attract external funding and subsequently boost entry of students into engineering based programmes at Taylor’s University.

REFERENCES


