Videos Focusing on Pivotal STEM Concepts in a "Freshmore" Curriculum:

Student Use and Learning Implications

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INTRODUCTION

Delivering on the goals of the Accreditation Board for Engineering and Technology (ABET) Engineer of 2020 calls for a reformed engineering education system [1,2] that will arm future generations of engineers with the necessary skills as well as the sophistication to be effective globally [1,3,4]. "To address this need, many preeminent research universities, with a strong commitment to international education, have not only established research and exchange partnerships, but have also made strategic choices to establish international campuses"[4]. "These collaborations are remarkable because they answer the call to address engineering grand challenges by fundamentally reforming traditional models of engineering education and promoting updated mentalities and practices, albeit within the boundaries of the new institutions" [4]

As part of its overall strategy to address this area of international and cross-cultural collaborations, the Massachusetts Institute of Technology (MIT) has collaborated with the government of Singapore to create a new university, the Singapore University of Technology and Design (SUTD). SUTD supports 4 pillars, namely Engineering Product Development, Engineering Systems and Design, Architecture and Sustainable Design, and Information Systems Technology and Design, and the first SUTD students began classes in May 2012. MIT has contributed to the development of SUTD's undergraduate curriculum in multiple ways, ranging from MIT faculty developing most of the initial course materials in SUTD's undergraduate curriculum to an intensive Faculty Development Program that brings SUTD faculty to MIT for yearlong residencies. Additionally, The MIT Teaching and Learning Laboratory (TLL) was also engaged to help support the curriculum development effort. This included producing a set of videos, called “concept vignettes,” that are designed to help students learn pivotal concepts in science and engineering. As described on their website, TLL “plays an important role in MIT-wide innovations in pedagogy, curriculum, and educational technology that both strengthen the educational experience for students and impact national and international initiatives in STEM teaching and learning.”

The purpose of this study is to explore how the videos have been used so far and how their use has supported student learning. The study also seeks to identify how the actual use of the videos meets TLL’s expectations, and provides TLL further insights on how this type of video can be used.

1 THE CONCEPT VIGNETTES

While attempting to reform engineering education the role of a) updated teaching practices, such as in-class multimodal active learning, or appropriately designed online learning [5], along with b) the role of technological and digital tools, have been highlighted as very critical [6,7]. While the advent of Internet has brought about a vast number of engineering-related educational resources, it has also become very clear to scholars that not all content is validated [8]. Therefore, when discussing digital tools there should be a clear distinction between tools such as curricula, lesson plans, activities, or digital simulations that have been developed by novices and the ones that have been developed by experts in pedagogy and the disciplinary field respectively [7-9].

With these discussions in mind, the MIT Teaching and Learning Laboratory first “identified pivotal concepts and critical skills from what is called SUTD’s ‘freshmore year,’ which encompasses the first three semesters of the students’ course of study,” [10] and then produced a set of videos [11], the *Concept Vignettes* that “are designed to help students learn pivotal concepts in science and engineering. Each video is part of a series that represents a cross-cutting theme in the disciplines that typically appear in first- and second-year engineering curricula (i.e., physics, mathematics, chemistry, biology), as well as in the social sciences and the humanities.” [12] By being exposed to the concepts presented in the Concept Vignettes, it is expected that students will be provided “with the foundation they will need to master more complex material in their upper-level courses” [12].

Every video is carefully designed by TLL in collaboration with one of more MIT faculty members teaching the relevant concept presented to provide the opportunity to support multiple stages of the course instruction and student learning process. An instructor’s guide accompanies every video to explain how the video can be used as pre-class, during-class, or after-class material. Guides promote active learning and contain instruction on how the videos are segmented, which parts are suggested to be used in class, and prompt questions. Twenty-four Concept Vignettes, as presented in Table 1, have been delivered and used by faculty and students during the first two semesters at SUTD. They are also available to public and can be accessed through the MIT TLL’s website. A second group of Concept Vignettes is currently under development and will be delivered to SUTD by end of May 2013.

Table 1. Set of 24 Concept Vignettes delivered and used by SUTD

Theme	Concept Vignette Title
COMMUNICATION: Successful professional communication begins with the ability to analyze situational variables and	• Strategy

make strategic decisions.	
CONSERVATION: As an isolated system moves toward equilibrium, some quantities are conserved.	• Conservation of Mass • Latent Heat
DERIVATIVES AND INTEGRALS: Derivatives describe the dependencies of change in a system. Integrals help quantify changing properties.	• Electric Potential • Flux and Gauss' Law • Motion
DIFFERENTIAL EQUATIONS: Differential equations model changing properties in engineering systems.	• Curl • Divergence • Enzyme Kinetics • Gradient
GOVERNING RULES:A small number of rules describe the physical and chemical interactions that are possible in our universe.	• Entropy • Kinetic Theory • Maxwell's Equations • Newton's Laws
LINEAR SYSTEMS: Linear systems have useful properties, such as superposition.	• Linear Approximation
PROBLEM SOLVING: Scientists, engineers, and architects must devise solutions to open-ended problems with technical and non-technical dimensions.	• The Process • Unit Analysis
REPRESENTATIONS: Information can be represented in words, through mathematical symbols, graphically, or in 3-D models. Representations are used to develop a deeper and more flexible understanding of objects, systems, and processes.	• Free Body Diagrams • Light • Torque • Vector Fields • Vectors • VSEPR

2 METHOD

2.1 Data Collection

Data used in this paper consists of electronic questionnaires completed by the very first cohort of SUTD “freshmore” students. Data was collected two weeks after the completion of the first and second semester. Twenty-nine students participated in the study. Questionnaires contain both structured and open-ended questions.

Furthermore, the TLL personnel participating in the development of the Concept Vignettes have been interviewed and the interviews were videotaped and then transcribed.

2.2 Data Analysis

Mixed methods were used to analyze the student data. Frequencies were counted in the cases of structured questions, while a general inductive approach [13] using qualitative open-coding analysis method was used to analyze the open-ended questions. As noted by D. R. Thomas in a presentation given in 2003 on the inductive approach for qualitative data analysis, “the primary purpose of the inductive approach is to allow research findings to emerge from the frequent, dominant, or significant themes inherent in raw data, without the restraints imposed by structured methodologies” [13].

The transcripts of the TLL personnel interviews were qualitatively analysed using open-coding analysis.

Codes that appeared from the TLL interviews describing TLL's expectations in regards to student use of the Concept Vignettes and possible affects on student learning, were then mapped with the codes that appeared from the student answers, to see if TLL's hypotheses and expectations were met.

3 FINDINGS

3.1 TLL's Use and Learning Expectations

According to TLL personnel, the Concept Vignettes are specially designed to be able to be used in multiple settings. Table 2 presents where and how TLL suggests the videos to be used, as well as the reasoning behind these suggestions.

Table 2. Suggestions and Reasoning for the Concept Vignette Use

Setting	Reasoning
By faculty in class	To spark interactivity and stimulate discussion Not to use as a stand alone package, but in conjunctions with other material Not to use as an entity, but as selected snippets To demonstrate the examples that could not be replicated in class To promote active learning
By faculty at home	To review how to teach a concept To get ideas about prompt questions To understand how to prime a system for a discussion that will follow in class To understand concept repeated learning objectives
By student/s at home as "pre-reading"	To generate questions To answer pre-imposed questions
By student/s at home after class	To support learning To supplement the information they get in class To use when they are stuck or confused To refresh their memory before exams To get a different view for the concept comparing to the instructor's To refresh their memory after years
Across disciplines	To bring perspective from multiple disciplines To reinforce knowledge

In regards to long term student learning, TLL personnel is expecting that systematic and appropriate use of the Concept Vignettes, in and out of class and throughout the complete cycle of the students' studies will lead to knowledge reinforcement, retention, and transfer. Use of the Concept Vignettes from faculty of all disciplines is also expected to assist students to build deeper conceptual understanding, but also to create tighter linkages between different courses within their selected Pillar, as they see the same Concept Vignettes appear in multiple contexts. Furthermore, deeper understanding is also expected to raise student excitement.

In terms of expected obstacles, TLL personnel shared some concerns in regards to young faculty being too overwhelmed with the plethora of educational materials either provided to them by MIT or that are available online. Furthermore, concerns regarding accessibility of the CV's were also raised.

3.2 Student Use

Out of the 29 students, 24 students responded that they used the Concept Vignettes in Math, Physics and Chemistry, while the rest of them mentioned they never used Concept Vignettes in class. More specifically 4 did not, and 1 did not but intends to do so in the future. Figure 1 shows students' responses in regards to how the instructors used or suggested the Vignettes to be used. At this point it should be noted that 2 students referred to videos presented in class that were not developed by TLL, but probably were some other educational resources the instructor chose to use in class so their responses are not included in the graph. Furthermore, 2 students mentioned that they were aware of and were actually using the accompanying guide developed by TLL for the instructors. As presented in Figure 2, when asked why they used the videos out of class, the majority of the students responded they used them either to refresh their memory or to enhance their understanding, and to do so they either read the guide, watched the whole or part of the video, kept notes, or tried to replicate some of the experiments.

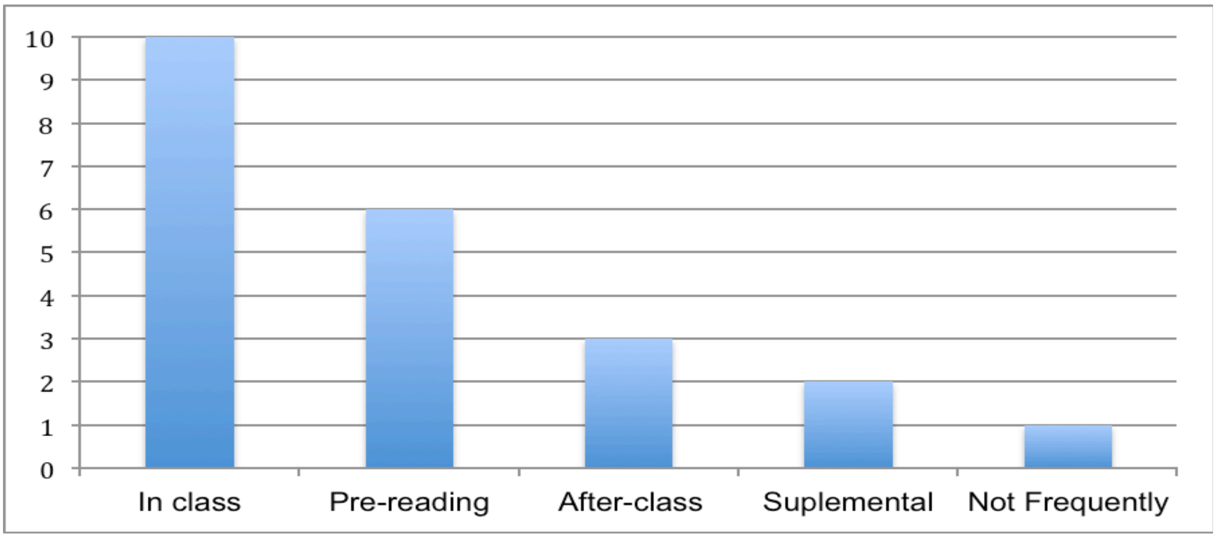

Fig. 1. Instructors' use or suggestion of use of the concept vignettes according to SUTD students' responses

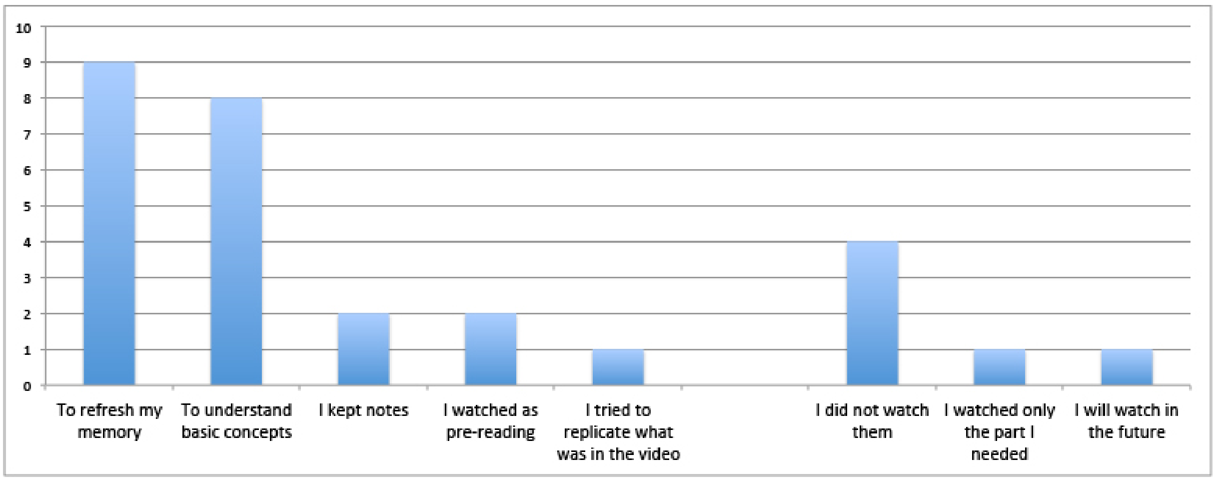

Fig. 2. Student responses regarding the concept vignettes use out of the classroom.

When discussing the effect on student learning, a wide variety of responses resulted, as presented in Figure 3. The most popular response was that the Concept Vignettes added to the classroom content, and that they helped them increase understanding. Some students, however, reported they were not sure the videos had any effect.

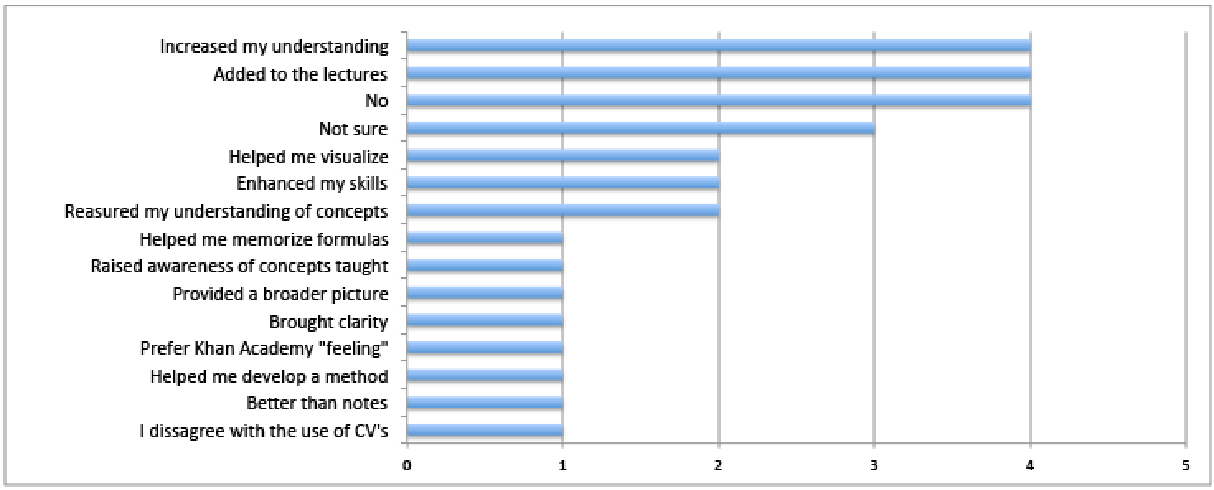

Fig. 3. Contribution of the concept vignettes use on student-learning / student-learning strategies according to the SUTD students

In regards to what might be the positive or negative outcomes from the use of Concept Vignettes, as presented n Table 3, there was again a wide variety of responses, but none appeared to be predominant. Factors that students identified as obstacles during the use of Concept Vignettes appear to be related to content (engaging vs. boring, simplistic vs. very elaborate, not directly related to homework), to allocation of student's time and priorities (too much homework, CVs are not mandatory), as well as with technical and accessibility issues (too long to download, not compatible with some devices).

Table 3. Positive or negative outcomes related to the use of concept vignettes

Positive	Negative
Faster understanding in class when CV used as pre-reading Enhanced understanding when used by peers (out of class) Enhanced understanding of concepts Enabled students to visualize concepts Enabled students to make connections Allowed practice Faculty saved time and thus go deeper into the concept Enhanced motivation Enabled students to make better connections with content presented in class across courses Enabled connections with real life applications Note sure None	Over - reliance on non-SUTD material Video was boring Video was counter-intuitive Video was "very American" or "western" The instructor, while using them, sticks to the basics None, cause use is not mandatory Might cause students to rely on videos and decide to skip class Disillusionment of higher education

4 CONCLUSIONS

When examining TLL's expectations on student use of the CVs both in and out of class, it seems that there is overlap in regards to the expected mode of use, as well as the reported positive outcomes. The fact that the majority of the students who used the CVs appear to find this experience useful is very encouraging both to the TLL personnel as well as to the rest of the MIT team. The number of the students reporting use of the CVs still appears to be relatively small. TLL and the MIT team, however, are hoping that both faculty and students will start using the CVs on a more frequent basis as the SUTD curriculum and teaching practices will reach relative stability and start to mature overtime.

In regards to factors identified as obstacles to student use, TLL expected faculty to be very overwhelmed at the beginning of a new University, and complementing that, listening to new students feel very overwhelmed as well does not come as a surprize. Accessibility issues were also expected, as SUTD is still in its infancy, and developing infrastructure or resolving current IT issues are on-going projects, expected to be finalized soon. Considering students' opinions in regards to use of material developed by another university in class as inappropriate, both for practical and cultural reasons, the MIT team would like to explore these factors more in depth in order to get a better understanding of the students perceptions, and use this knowledge to guide future content development and suggestions for implementation.

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REFERENCES

[1] National Research Council. (2004) The Engineer of 2020: Visions of Engineering in the New Century. Washington, DC: The National Academies Press.

[2] National Academy of Engineering. (2005). Educating the engineer of 2020: adapting engineering education to the new century. Washington, D.C.: National Academies Press.

[3] Adams, R.S., Dias de Figueiredo, A., Evangelou, D., English, L.D., Mousoulides,N., Pawley, A., Schifellite, C., Stevens, R., Svinicki, M., Trenor, J., and Wilson, D. 2011. *Multiples Perspectives on Engaging Future Engineers*, Journal of Engineering Education, Special Centennial Issue. 100, no. 1: 48–88.

[4] Sakhrani, V., Bagiati, A., Sarma, S, De Neufville,R. (2012) Intitutional Transplantation in Education- Cultural Transfusion to a New Institution. Conference Proceedings of the WEEF2012 forum held in October 15-18, 2012 in Buenos Aires Argentnina.

[5] Lawton, D., Vye, N., Bransford, J., Sanders, E., Richey, M., French, D., Stephens, R. (2012). *Online Learning Based on Essential Concepts and*

Formative Assessment. Journal of Engineering Education. 101(2). pp 244-287

[6] Johri, A., & Olds, B. M. (2011). *Situated engineering learning: Bridging engineering education research and the learning sciences*. Journal of Engineering Education, 100(1), 151–185.

[7] Mangana, A., Brophy, S., Bodner, G. (2012) *Instructors' Intended Learning Outcomes for Using Computational Simulations as Learning Tools*. Journal of Engineering Education. 101 (2).pp.220-243

[8] Bagiati, A., Evangelou, D. (2009). *An examination of web-based P-12 engineering curricula: Issues of pedagogical and engineering content fidelity*. Paper presented at the 2009 Research in Engineering Education Symposium, July 20-23, Palm Cove, Queensland, Australia.

[9] Magana, A. J., Brophy, S. P., & Bodner, G. M. (2009, June). *Are simulation tools developed and used by experts appropriate experimentation tools for educational contexts?* Paper presented at the 116th Annual Conference of the American Society of Engineering Education (ASEE), Austin, Texas

[10] J.French, D.Shah, J. Rankin, A. Bagiati, L. Breslow (2012) Identifying and Mapping Pivotal Concepts and Critical Skills Concept Mapping a “Freshmore” Engineering Curriculum. Proceedings of the SEFI Annual Conference 2020, held Sept 23-26 in Thessaloniki, Greece.

[11] Shah, D., French, J., Rankin, J. & Breslow, L. (2013) Using Video to Tie Engineering Themes to Foundational Concepts, Proceedings of the ASEE Annual Conference, Atlanta, GA,

[12] Teaching and Learning Laboratory (2013). SUTD Concept Vignettes. Retreived from http://tll.mit.edu/help/sutd-concept-vignettes-0 April 15, 2013.

[13] Thomas, D. R. (2003). A general inductive approach for qualitative data analysis. School of Population Health, University of Auckland, New Zealand. Accessed on 21 January 2013 at http://www.fmhs.auckland.ac.nz/soph/centres/hrmas/_docs/Inductive2003.pdf.