Developing Metacognition in First Year Students through Interactive Online Videos

Dr. Peter M Ostafichuk P.Eng., University of British Columbia, Vancouver

Dr. Peter M. Ostafichuk is a professor of teaching in Mechanical Engineering and the Chair of First Year Engineering at the University of British Columbia in Vancouver, Canada. He teaches introduction to the engineering profession and practice, and design in mechanical engineering. He has extensive experience in Team-Based Learning (TBL), curriculum development, and teaching innovation.

Dr. Susan Nesbit, University of British Columbia, Vancouver

Before receiving a doctoral degree in Chemical Engineering from the University of British Columbia for research on colloidal ink particle detachment mechanisms during paper recycling, Dr. Nesbit obtained a Bachelor or Arts degree in History and a Bachelor of Applied Science in Chemical Engineering, then worked as a research engineer studying novel methods of chlorine dioxide production. Dr. Nesbit is dedicated to the development and delivery of sustainability education. She has developed and taught several undergraduate and graduate courses that focus on the context of engineering decision-making. In 2010/11, she was awarded an inaugural Sustainability Teaching Fellowship at the University of British Columbia. Dr. Nesbit's teaching achievements have been cited by engineering educators across North America for their excellence.

Prof. Naoko Ellis P.Eng.,

Naoko Ellis is a Professor in the Department of Chemical and Biological Engineering at the University of British Columbia (UBC). She holds a Ph.D. (UBC, 2003); M.E.Sc. (Western, 1993); and a B.Sc. (Honours, Waterloo, 1991). She is a member of the Association of Professional Engineers and Geoscientists of BC. Her expertise lies in the area of multiphase reaction engineering with emphasis on biomass utilization. Some current projects include: biomass gasification and pyrolysis; CO_2 capture, including chemical looping combustion; pyrolysis product utilization; and biofuels. She is also interested in sustainability education and transdisciplinary learning.

Mr. Gerald Tembrevilla, University of British Columbia

Developing Metacognition in First-Year Students through Interactive Online Videos

Abstract

This complete research paper examines the use and impact of a series of optional interactive online videos ("screencasts") to develop metacognition and learning perspectives in first-year engineering students. In 2018, eight screencasts were distributed once per week at the start of an introduction to engineering course; this was expanded to nine screencasts in 2019. The effectiveness of the screencasts was assessed using a mixed methods approach, including pre- and post-interviews coded using a threshold concepts framework, pre and post deployment of the Metacognitive Awareness Inventory, an online survey, and general course observations. Student utilization of these optional resources was strong, particularly in 2019, with 70% of students on average viewing each weekly screencast, 98% viewing at least one of the nine screencasts, and 48% of students viewing at least eight. Viewership was found to be sensitive to incentivization. Analysis of interview responses, survey responses, and course grades revealed a statistically significant benefit to metacognitive awareness and academic performance of completing the screencasts. Students generally perceived the screencasts as helpful and impactful towards their learning, independent of their self-reported wellbeing or GPA.

1. Introduction

The transition to first-year at a post-secondary institution can be challenging for students, and can negatively impact wellbeing [1]. In addition to changes in social environment, living arrangements, and other personal factors, there are numerous academic changes students must negotiate. These include increases in class sizes, changes in instructional methods and assessment, and shifts in student-teacher and student-student relationships. Significantly, post-secondary education also involves a much higher degree of self-responsibility and independence in learning (and personal activities) than most students have previously experienced. This strongly relates to metacognition.

As described by Schraw and Dennison [2], metacognition refers to "the ability to reflect on, understand, and control one's learning." Sometimes described by the informal shorthand "thinking about thinking," a more formal definition of metacognition typically includes elements of *knowledge of cognition* (declarative knowledge involved with understanding learning processes and strategies, and knowing when to adopt a particular strategy), and *regulation of cognition* (procedural knowledge of planning, monitoring, and adapting one's learning) [3]; although many other distinctions for elements of metacognition exist [4].

Metacognition is a key asset as students transition to the more independent post-secondary learning environment; however, students vary in their approaches and ability to acquire metacognition [2],[5]. It is well established in the literature that metacognitive awareness is positively correlated to favorable course outcomes [6]-[9]. Further, introducing students to metacognition and related concepts has also been shown to lead to improved learning outcomes

[10]-[15]. Importantly, benefits have been observed with minimal interventions consisting of simply introducing concepts of metacognition to students [16].

With the above in mind, a series of online resources was developed and deployed within a core first-year engineering course at the University of British Columbia, a large Canadian research-intensive university. The intent was to aid students in their academic transition to university with a series of optional, easy-to-access, and inexpensive-to-deliver resources implemented within the context of a core first-year course. Ultimately, a series of online interactive videos ("university learning screencasts") were developed and deployed starting in 2018.

To assess the impacts of these screencast resources, a mixed methods study design was adopted. Several approaches to measure changes in student metacognition were used, including the Metacognitive Awareness Inventory, a qualitative interview process, a beliefs questionnaire, and correlation between utilization and course performance. Other aspects of effectiveness of the screencasts were assessed through exploration of student perceptions and usage rates.

The Metacognitive Awareness Inventory (MAI) [2] was used as one of the quantitative elements in this study. The MAI is a widely-used self-reporting instrument for assessing metacognition. It consists of 52 binary (true/false) questions relating to elements of the knowledge of cognition and regulation of cognition domains; in this study, only the 17 items from the knowledge of cognition subscale were used. The MAI is a simple, easily-deployed tool; however, questions exist regarding validity [17], and the Dunning-Kruger effect [18] suggests students with low metacognitive ability in particular will tend to inflate their self-assessments.

To complement the quantitative assessment through the MAI, qualitative interviews inquiring about metacognitive development were conducted. The interview responses were assessed through the lens of threshold concepts [19]. Threshold concepts are ideas that are difficult to comprehend, but that permanently alter a learner's understanding once grasped. In the threshold concepts framework, a learner progresses through three main states: preliminal, liminal, and postliminal. In the preliminal state, the learner encounters a troublesome and difficult concept, often that challenges prior understanding. In the liminal state, the learner begins to integrate new knowledge or perspectives, thus shifting their understanding. Finally, in the postliminal state, the learner and their understanding have been irreversibly transformed [20]. As acquiring metacognitive awareness can be challenging and troublesome for learners [2],[5],[13], the use of threshold concepts was seen as an appropriate framework to use in gaging development.

The sections that follow in the paper outline the purpose of this study (Section 2), the institution and course context (Section 3), and the university learning screencasts (i.e., the metacognitive interventions) that were developed (Section 4). The remaining sections detail the methods used (Section 5) and the results obtained (Section 6), before concluding (Section 7).

2. Purpose

The overall purpose of this study is to assess the effectiveness of metacognitive interventions in the form of short, interactive, online videos (screencasts). This led to one primary research question (the first), and three secondary questions

1. Do these interventions enhance metacognition in first-year engineering students?

2. Do the interventions enhance academic ability in first-year engineering students?
3. How do students perceive the interventions in terms of utility and impact?
4. How do students use the interventions when provided as an optional student resource in a first-year engineering course?

3. Institution and Course Context

The University of British Columbia has a common first-year engineering program with approximately 1000 incoming students per year. Approximate demographic data for students entering in 2019 is shown in Table 1, based on surveys and information in the student database.

Table 1. First Year Program Demographics (2019)

Demographic Criterion	Approximate Proportion of Student Population
Gender identity (self-identifying)	Female 27% Male 70% Non-binary* 1% Prefer not to disclose* 2%
Nationality	North American 64% (Canadian 63%) Asian 30% (East Asian 12%, South Asian 12%) African 2% South and Central American 2% Western European 2% All other nationalities < 1%
Indigeneity (self-identifying)	Non-indigenous* 98% Indigenous* 1% Prefer not to disclose* 1%
Entry into program	Directly from high school* 93% After time working / a break* 4% Transferred from another school/program* 2% Another route* 1%

* values estimated from self-disclosure on optional survey

All incoming engineering students take APSC 100, an introduction to engineering course in the first term. The course covers a broad array of engineering topics including design, decision-making, sustainability, professionalism, and ethics. APSC 100 is the only engineering-specific course taken by all first-year engineering students in the first term. As such, it is used as a platform for delivering general first-year engineering information and content, and was used to deliver the interventions described in this paper. Approximately 90% of the students in APSC 100 continue on to a second course, APSC 101, delivered the following term and similar in structure, content, and utilization to APSC 100.

The APSC 100 course is delivered in a flipped-classroom format, with content introduced each week through interactive screencasts. Each screencast includes approximately 6-10 minutes of video (graphics-rich PowerPoint slides narrated by one of the APSC 100 course instructors), along with interactive elements and graded quiz questions. One to three screencasts were assigned each week. In class, the screencast content for the week was explored more deeply, and then applied towards class activities and course projects.

The interventions in this study consisted of a series of additional screencasts, designed, developed, and delivered in the same manner as the technical screencasts in APSC 100. (To differentiate the two sets of screencasts in this paper, the mandatory course screencasts are hereafter referred to as "technical screencasts" and the screencasts that make up this intervention as "university learning screencasts.") The intent with the university learning screencasts was to preserve the format, delivery, and look of the technical screencasts familiar to the students. Completion of the technical screencasts was required in the course; the approximately 25 screencasts for the term carried a combined course grade weight of 10%. The university learning screencasts were optional, although mark incentives were provided (described below).

In terms of creation and delivery, all screencasts were created in PowerPoint with minimal text and with extensive use of visual elements and animation. Video was captured and edited in Camtasia, packaged with embedded quizzes and activities in Articulate Storyline 3, and then integrated with the APSC 100 learning management system (Instructure Canvas) via SCORM. The quizzes allowed a single attempt and did not have a time limit (provided it was submitted prior to the screencast due date).

In total, eight screencasts were piloted in the 2018 year, with one screencast assigned per week starting in the second week of term. These were redeveloped for the 2019 year, with one screencast added and with the first screencast released in the first week of term. In both years the screencasts were optional in the APSC 100 course, but completion incentives were provided. In 2018, the grades from the quizzes at the end of the screencasts was compared to compulsory grade elements relating to professional development; students were offered a course grade bonus (capped at an overall maximum of 2%) in cases where a screencast grade was higher than their professional development grade. In 2019, this incentive structure was refined such that the grade from any university learning screencast would be used to replace a lower non-zero technical screencast grade, along with an additional flat bonus of 0.11% to the course grade per university learning screencast attempted (i.e., 1% bonus for completing all nine). The reason for the change was threefold: the new structure more logically related to course activities; the new structure increased the size of the incentive; and the flat bonus of 0.11% was offered regardless of when the screencast was completed. Where the other forms of bonus only applied if the screencast was completed by its initial due date, the flat bonus was intended to incentivize students struggling academically who had not yet viewed the screencasts by the deadline.

4. University Learning Screencasts (Metacognitive Intervention)

In total, eight university learning screencasts in 2018, expanding to nine in 2019, were delivered at a frequency of one per week in the APSC 100 course. The overall goal of the university learning screencasts was to support and guide students through the transition to their first year of post-secondary study, and to prepare them to be more effective and more efficient learners. The screencasts can be broadly divided into two groups: development of metacognition, and development of perspectives on university learning. The screencast topics, in the same order they were delivered to students, are listed below in Table 2. The screencast number in the first column also refers to the week of the term it was delivered in the 2019 implementation (i.e., the first screencast was due during the first week that year). In 2018, the initial schedule was shifted by one week and screencasts 4 and 5 were combined (i.e., the first screencast was due during the second week that year, but the final screencast was still due in week 9).

Table 2. Screencast series: University learning screencasts from 2019 are shown in order. The "type" refers to either development of metacognition (M) or development of university learning perspectives (P).

#	Type	Title	Key themes
1	P	Mindset and grit	• Explore growth mindset [21] and grit [22] • Develop a healthy view of failure • Promote the deliberate practice approach [22] • Optional: activity to assess mindset and grit
2	P	Learning perspectives	• Introduce Bloom's Taxonomy and explore implications for university learning [14] • Explore intellectual development through Perry's Scheme [23] • Contrast surface and deep learning approaches [24] • Optional: activity to assess intellectual development [25]
3	M	How learning works 1 (Neuroscience)	• Describe the neuroscience behind learning • Explore strategies for robust, longer-lasting learning • Relate to screencasts 1 and 2
4	M	How learning works 2 (memory)	• Explore learning through model for memory (including short- and long-term, encoding, retrieval, and forgetting) • Introduce distributed practice • Relate concepts to screencasts 1 to 3
5	M	How learning works 3 (focus)	• Dispel myths related to multitasking using published data and a "multitasking game" • Explore the importance of attention to learning, with reference to screencasts 3 and 4
6	P	Healthy body, healthy mind	• Explore the roles exercise, diet, and sleep play in learning from a science-based perspective [26] • Quantify impacts of lifestyle habits on learning and GPA
7	P	Understanding and managing stress	• Develop a balanced view of stress • Explore strategies for managing elevated stress • Optional: assess current stress and compare to typical first-year stress students using the 10-item Perceived Stress Scale (PSS-10) [27]
8	M	Metacognition	• Define metacognition in terms of knowledge of cognition and regulation of cognition • Revisit screencast 1 to 7 topics with lens of metacognition • Optional: complete the full 52-item MAI [2]
9	M	Implementation	• Review concepts and strategies from prior screencasts • Introduce time management strategies and constructive alignment [24] from a student perspective, and relate to screencast series

The format of the screencasts and the associated activities most strongly aligned with elements of knowledge of cognition: understanding how learning works, knowing which strategies tend to be more effective, and knowing when those strategies should be used. However, the series did also model and discuss elements of regulation of cognition, including planning, information management and comprehension monitoring strategies, and evaluation.

Each screencast was designed to be viewed independently, although there was extensive cross-referencing between screencasts to highlight the interconnectedness of the various topics and to reinforce learning. Each screencast concluded with a summary of the key concepts and a discussion of the implications towards university learning, usually as a series of study strategies. At the end of each screencast there was an assessment consisting of multiple choice, multiple response, matching, and hotspot-style questions. Each student received a random selection of approximately eight questions on a screencast. The student performance on these questions was passed to the APSC 100 course learning management system (LMS) via SCORM, and was used towards the incentives described in the "Context" section above.

5. Methods

The effectiveness of the metacognitive interventions was assessed using a mixed methods approach [28], with emphasis on quantitative aspects. The primary methods of assessment included a qualitative study using interviews with students (coded using an a priori framework and analyzed quantitatively), and a primarily quantitative study administered through a survey. The interviews were run in a pre-post fashion with the screencast interventions, while the survey was post only. In addition, an analysis of screencast usage was conducted, including comparison with metrics of course performance and student wellbeing. Finally, the Metacognitive Awareness Inventory (MAI) was administered in a similar pre-post fashion to the interviews. The use of the interviews, the survey, and the MAI are described in further detail below.

Qualitative Interviews

The primary qualitative portion of the study was based on a series of semi-structured interviews conducted in the 2018 academic year as part of a larger study on transdisciplinarity [29]. The first set of interviews ("pre-interviews") were conducted at the start of term, in September 2018, roughly coincident with the release of the first university learning screencasts. The second set ("post-interviews") were conducted at the end of the following term, in March 2019, roughly five months after the final screencast. Participants were recruited from the APSC 100 and APSC 101 courses for the pre- and post-interviews, respectively, on a voluntary basis. There was no remuneration or explicit incentive provided for participating. The participant composition changed between pre- and post-interviews, but 70 students participated in each set. Both sets of interviews included the following prompt relating to metacognition:

> *"Can you describe any changes (positive or negative) in your learning strategies when you compare how you learned before taking APSC 100 with how you learn now? How do you explain such changes?"*

The interview responses were assessed considering metacognitive development using a threshold concepts framework. In total, four coders participated; no coder had a connection to the APSC 100 or 101 course, or the development of the university learning screencast series. Information on interviewees (including demographics, academic performance, and participation in the university learning screencast series) was blind to coders, beyond any information provided directly in interview responses. All coders demonstrated an interest in education, and otherwise came from a variety of backgrounds (Coder 1 from STEM education, Coders 2 and 4 from engineering, and Coder 3 from economics).

The four coders independently rated the metacognitive development expressed in each student response. They used inductive coding from an a priori framework [30] (i.e., threshold concepts) to classify responses on a five-point scale corresponding to the degree of liminality in metacognitive development (1 = preliminal, 3 = liminal, 5 = postliminal). Intermediate ratings of 2 and 4 were assigned to responses with elements of two adjacent categories.

Sample student responses coded at each of the three primary rating levels include

- Preliminal (1): *[Nothing has changed.] I operate in [the same manner for all my STEM courses]: Read material-notetaking-exercise-doing problem solving exercises-review-and repeat again from the start.*
- Liminal (3): *[I have] learned strategies such as revisiting work and trying to reteach the materials. Studying style has improved and so did memory.*
- Postliminal (5): *Now I am consciously thinking about my progress and method / techniques while I am studying. I found this has improved my learning as I am keeping track of my improvements and therefore I am able to set milestones for myself, to get everything done that I need to. I also think having various new learning techniques to rely on to engage me at every stage of my learning has helped, although I do need a little more practice applying them.*

Following a test for inter-rater reliability (Cohen's kappa), a series of two-tail independent t-tests using the pre-post change in metacognition rating were performed. The t-test groups were formed based on the degree of engagement with university learning screencasts (i.e., number of screencasts completed and average score earned). All statistical analyses were conducted using IBM SPSS 25.

The inter-rater reliability between the coders measured using Cohen's kappa and is shown in Table 3. The two values in each cell of the table represent the reliability for the pre-interviews (left) and post-interviews (right). Agreement between Coders 1, 2, and 4 ranges from roughly "moderate" to "strong," while agreement with Coder 3 is "minimal" to "weak" [32]. However, unless otherwise noted, Coder 3's ratings are included in the aggregate results that follow as the effect of removing Coder 3 is inconsequential, as will be shown.

Table 3. Inter-rater reliability: Cohen's kappa for the four coders for pre / post interviews

	Coder 2	**Coder 3**	**Coder 4**
Coder 1	0.660 / 0.880	0.467 / 0.405	0.843 / 0.791
Coder 2	-	0.413 / 0.390	0.539 / 0.693
Coder 3	-	-	0.396 / 0.330

Survey on Learning Attitudes and Perceived Screencast Impacts

An optional and anonymous student survey was administered the week after the last screencast (ten weeks after the first screencast) through the APSC 100 course in the 2019 academic year. In total, 220 students (22% of the cohort) completed the survey. Key topics on the survey included the following:

- The primary motivations for viewing (or not viewing) the screencasts
- A rating of the perceived helpfulness of each screencast viewed towards shaping or reaffirming learning practices
- A rating of the overall impact of the screencast series on learning
- Understanding of key themes from the screencast series

To the final bullet in the above list, students were asked to indicate their degree of agreement with a series of ten prompts relating to the screencast topics (labelled A to J in Table 4). A five-point Likert scale (strongly agree, somewhat agree, neither agree nor disagree, somewhat disagree, strongly disagree) was used for responses. Prompts were randomly ordered for each student, and included both positive and negative phrasing, as shown below. (In prompts with positive polarity, an "agree" response indicates alignment with the screencast topics; this is reversed for negative polarity prompts.)

Table 4. Survey prompts: APSC 100 survey prompts used to assess screencast impact.

Prompt	Polarity	Screencasts assessed	Prompt text
A	+	3,4,5,8,9	Being able to complete an activity easily and without errors is a sign you are NOT learning from that activity.
B	+	1	People have the ability to change how intelligent they are.
C	+	6	It is better to go to bed on time the night before an exam rather than lose significant sleep to study longer.
D	-	5	With effort, students can effectively divide their attention between closely following a lecture and simultaneously completing a homework assignment.
E	+	8	Reviewing how you did on a quiz or exam, and focusing on where you made mistakes, is an essential part of learning.
F	+	3	People who understand how the brain stores and retrieves memories tend to perform better academically.
G	-	3,4,5,8,9	Once you develop effective study strategies, learning requires minimal effort.
H	-	7	We should try to eliminate as much stress as possible from our daily lives.
I	+	3,4,5,8,9	It is more effective to study for three 30-minute study sessions with breaks between rather than one continuous 3-hour session.
J	-	3,4,5,8,9	One of the most effective exam study strategies is to reread the textbook or class notes.

In addition, the survey collected data on student academic performance (GPA) and student wellbeing (through the Warwick-Edinburgh Mental Well-Being Scale, WEMWBS [30]). This was done to determine if academic or personal circumstances contributed to usage or perceptions of the screencast series. Finally, items were added to the survey to verify students were reading the prompts; 17 of the 220 responses deviated and were deemed invalid and discarded.

Metacognitive Awareness Inventory Analysis

The 17-item knowledge of cognition subscale of the MAI is administered as part of other activities at the start of the APSC 100 course, and again near the conclusion of the APSC 101 course (seven months later). Data from these two instances of the MAI in the 2018 academic year were used as a quantitative self-assessment of the change in metacognition. Of the 888 students who completed one or both of the MAI activities, there were 405 paired samples (i.e., completed both activities) from students who gave consent for their data to be used in this study. A regression analysis was conducted using the pre-post change in MAI self-rating for each individual correlated against the number and type of university learning screencasts viewed.

6. Results and Discussion

Results are summarized below in sections corresponding to general screencast usage statistics, followed by findings from the qualitative interviews, from the survey, from the MAI, and from correlations to course academic performance.

General Usage Statistics

The screencast usage, as recorded by the LMS, is shown in Figure 1 for both the 2018 and 2019 years. The figure reveals a general trend for both years of decreasing viewership by week, although this is less pronounced in 2019. Anecdotal student comments suggest the primary reason for the decline is due to increasing demands on time from mandatory coursework across the first-year curriculum. Overall, in 2019, the weekly average screencast access rate was 70% of the class (50% in 2018). Furthermore, 98% of the class accessed at least one screencast through the term (84% in 2018); 81% of the class accessed four or more (45% in 2018); and 48% missed no more than one (21% in 2018). Also note that most students who accessed a screencast (as denoted by the lines with solid markers in the figure), completed that screencast and answered all associated quiz questions at the end (as denoted by the hollow markers in the figure). The average ratio of completion to access was 93% in 2019 and 84% in 2018. Screencast access rate and completion rate were found to be statistically independent of student GPA and student self-reported wellbeing (discussed further in the "Survey Results" section below).

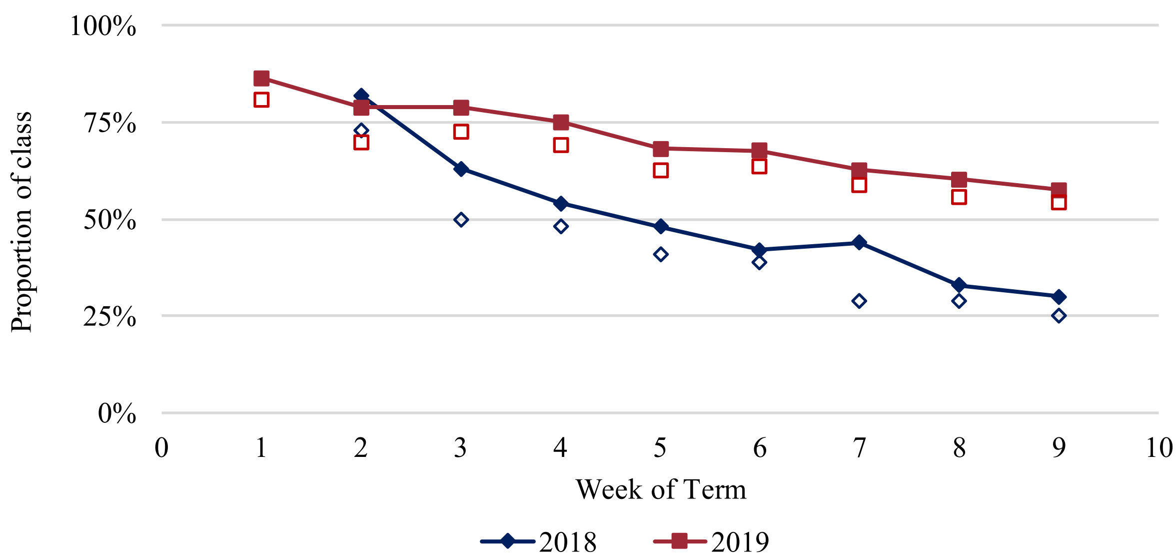

Figure 1. Screencast usage: University learning screencast access rates by year (solid markers with lines) and completion rates (hollow markers).

The screencast refinement and improvement efforts between 2018 and 2019 give one possible explanation for the changes in usage noted above; however, the most significant factor is likely the increased mark incentive provided in 2019. (As shown in the "Survey Results" section below, earning a possible grade bonus, even though small, was the primarily motivation students cited for viewing the screencasts).

Interview Findings

The changes in metacognition observed for 2018 from the pre-interview to the post-interview coded statements are shown in Table 5. In the table, students are grouped based on the number of metacognition screencasts they completed. The data reveal a general trend of greater metacognitive development associated with completing more metacognition screencasts (a linear regression gives $r = 0.92$, $p = 0.026$). Considering each case separately, only the last two groups (with at least three or all four screencasts completed) showed statistically significant changes.

Considering the case of 3 or 4 screencasts (i.e., more than half), the results were statistically significant when considering Coders 1 to 4 independently (+1.000, $p = 0.005$; +0.788, $p = 0.026$; +0.985, $p = 0.011$; and +0.982, $p = 0.005$, respectively). The same was true based on whether an individual accessed, but did not necessarily complete, a screencast (+0.956, $p = 0.002$). These changes roughly correspond to advancement of one half of a threshold concepts stage. On average, students move from slightly below to slightly above the liminal stage. Finally, there were no appreciable changes when Coder 3 was removed from consideration; the average metacognition delta values in the table did not shift by more than 0.06, and there was no instance that changed from statistical significance to non-significance, or vice versa.

Table 5. Metacognitive change: Pre-post delta in metacognition measured using threshold concepts and based on number of metacognition screencasts completed (2018)

Number of metacognition screencasts completed	Average metacognition level			p-value
	Pre-interview	Post-interview	Delta	
0	3.500	3.200	-0.300	0.665
1	2.813	2.458	-0.354	0.438
2	2.954	3.269	+0.315	0.547
3	2.583	3.719	+1.135	0.107
4	2.667	3.656	+0.990	**0.008**
3 or 4	2.644	3.677	+1.033	**0.002**

Using the average score earned on the screencast quizzes instead of the number of screencasts completed as a grouping variable did not impact the conclusions above. Those with an above average score saw a change in metacognition of +0.722 ($p = 0.007$), while those with a below average score saw a change of -0.283 ($p = 0.528$). Furthermore, when the same analysis is conducted using the four learning perspectives screencasts in the series (i.e., screencasts 1, 2, 6, and 7 in Table 2), and not the metacognition screencasts (i.e., 3, 4, 5, 8, and 9), no statistically significant difference is observed. This suggests the changes in metacognition observed through the interviews is associated with the metacognition content specifically, and not to other content related to university learning perspectives.

Overall, these results indicate that students who substantially engage with the university learning screencasts on metacognition benefit from a favorable and statistically significant impact on their metacognitive development. Other students do not show statistically significant changes.

Survey Results

The APSC 100 university learning screencast survey was administered in 2019 to better understand student motivations and perceptions of the screencast series, as well as to try to independently quantify differences in metacognitive development. Students who viewed at least one of the screencasts in the series were asked to indicate the two most important factors that lead to them viewing screencasts. The results, shown in Figure 2, reveal that grade incentives played the most significant role, followed by the perception that the screencasts would be academically beneficial. Other factors included learning about what to expect in university, personal interest about how learning works, curiosity about what was covered in the series, and the desire to not miss out on material other students were accessing. The most commonly cited reasons for not viewing the screencasts was lack of time, followed by lack of anticipated benefit.

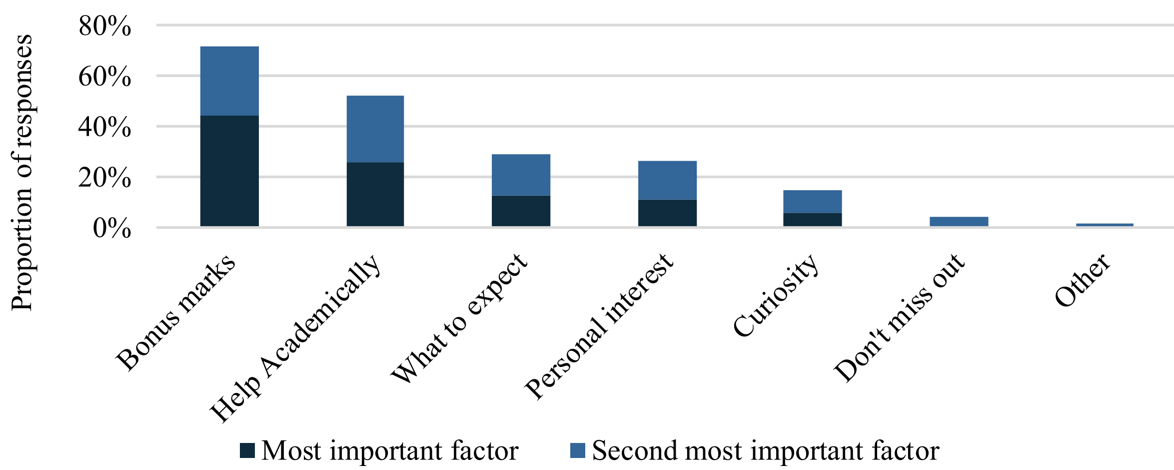

Figure 2. Motivations: Reasons for viewing university learning screencasts (2019).

In addition, students were asked to rate the perceived helpfulness of the screencasts towards their development as learners, separately for each screencast they viewed. Overall, there were only modest variations in helpfulness by screencast topic. Screencasts were rated "helpful" or "very helpful" on average 63% of the time, and at least "somewhat helpful" 90% of the time. On average, 6% of students reported that they found the screencasts "not at all helpful," with the remaining 4% of responses indicating "unsure." No significant differences were noted in perceived helpfulness based on an independent t-test using gender (binary identity only, $p = 0.82$), or nationality (Canadian compared to non-Canadian, $p = 0.93$).

The differences in survey responses to the Likert scale prompts related to the screencast topics (see Table 4) are shown in Figure 3 below. On the 1-5 scale, a 5 indicated a response highly aligned with the intended outcome from the associated screencast(s) (i.e., "strongly agree" to a positive polarity prompt or "strongly disagree" to a negative polarity prompt), while 1 indicated a response fully out of alignment (i.e., reversed). For prompts A, G, I, and J, the themes were developed across all five metacognition screencasts in 2019, rather than in a single screencast. For these four cases, students who viewed three or more of the five screencasts were assigned to the "viewed screencast" condition, and others to the "did not view screencast" condition.

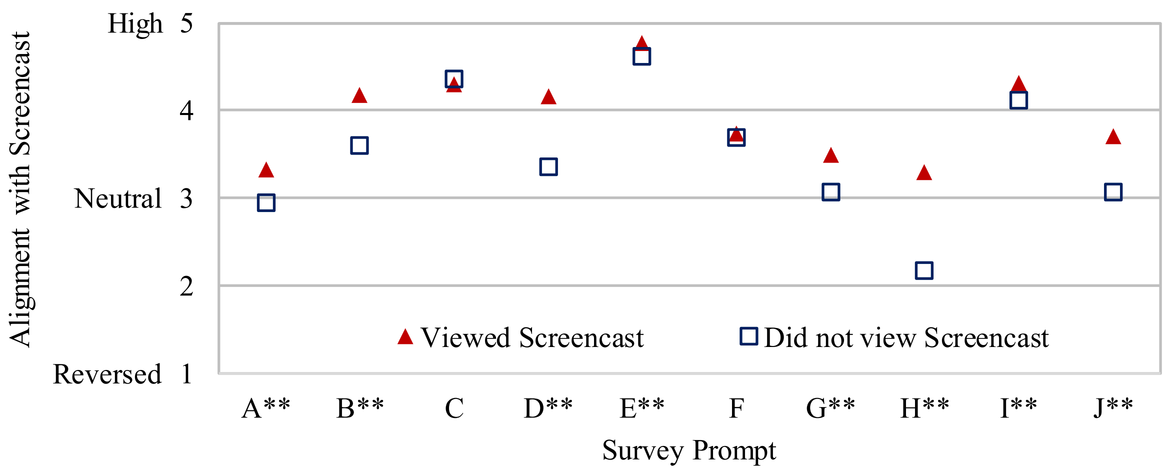

Figure 3. Attitudinal impacts: Alignment of responses to prompts from Table 4 to intended screencast messages, adjusted for prompt polarity ("" indicates p < 0.001).**

For eight of the ten prompts, students who viewed the associated screencast(s) had responses that were statistically significantly more favorable (with $p < 0.001$) than those who did not view the screencasts. Overall, this suggests the students who view the university learning screencasts possess attitudes more in alignment with the screencast messages than those who do not view the screencasts, or they at least have understood and are able to recall the key messages from the associated screencasts. Both interpretations suggest increased knowledge of cognition.

Figure 4 shows the correlation between perceived impact (i.e., academic benefit) of the screencast series against student wellbeing measured using WEMWBS [30]. Impact ranges from 1 = "very negative," to 7 = "very positive," and the bubble area is proportional to the number of students at each wellbeing level. The average impact rating is 5.6 (between "somewhat positive" and "positive"). Importantly, there is no statistically significant correlation in the data between perceived impact and wellbeing ($r = 0.027$, $p = 0.73$). Similar results were found correlating perceived impact to GPA ($r = 0.055$, $p = 0.48$). In other words, the academic benefit students see in the screencasts is independent of whether they are struggling, thriving or somewhere between.

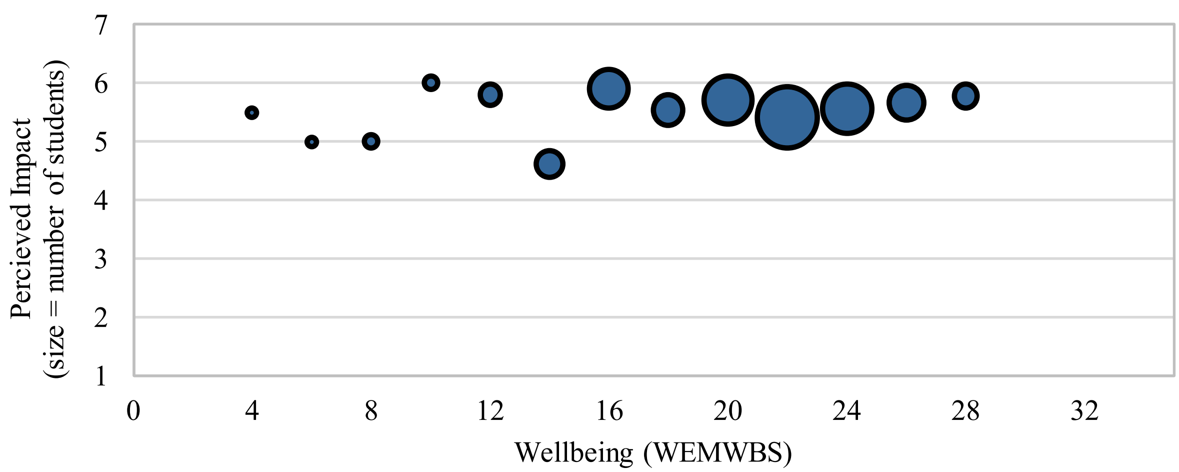

Figure 4. Impact and wellbeing. Correlation of perceived impact of screencasts to student wellbeing. Bubble size represents the number of students clustered at each wellbeing level.

Metacognitive Awareness Inventory Findings

Results from the MAI were inconclusive. The average change in MAI knowledge of cognition subscale score was -7.0% (based on 17 items on a 0 = false, 1 = true scale), which suggests, on the surface, an average drop in metacognitive awareness across the cohort. The drop in MAI score was relatively consistent against number of metacognition screencasts completed, as shown in Figure 5. A linear regression showed no significant correlation ($r = -0.017$, $p = 0.238$). It is believed the absence of a relationship between completing the screencasts and the MAI results is a consequence of the validity of the MAI [17],[18].

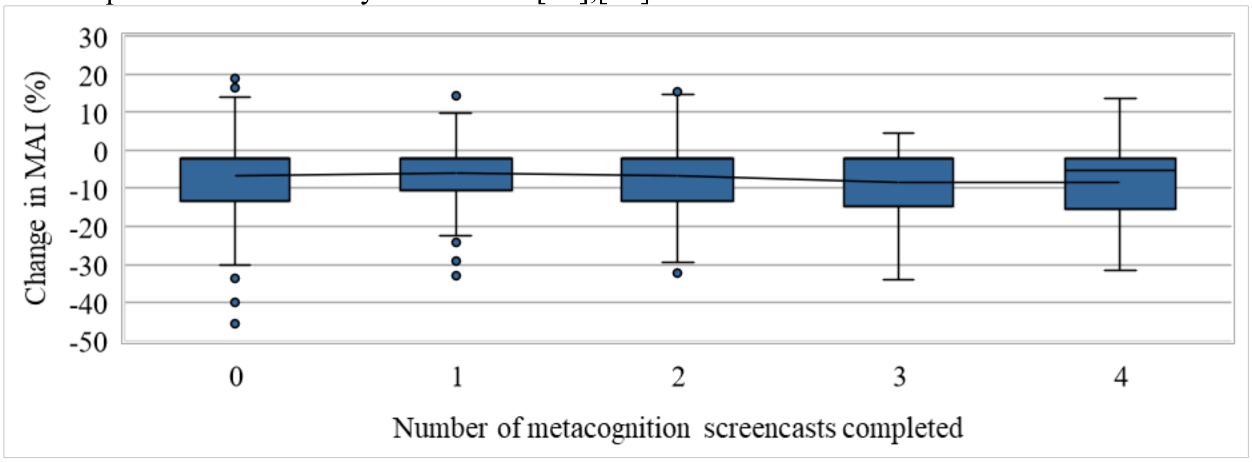

Figure 5: MAI box and whisker plot. The change in MAI score is shown based on number of metacognition screencasts viewed.

Correlations to APSC 100 Course Grades

An initial assessment of the impact of the metacognitive screencasts on academic performance was conducted using 2019 APSC 100 course grade elements. (This will be extended to APSC 101 grades in future, when available.) Each student's grade z-score (i.e., number of standard deviations from class mean) was used as an academic performance metric. A strong correlation between course grades and completion of the university learning screencasts was noted ($B = 0.121 \pm 0.009$, $r = 0.373$, $p < 0.001$). This corresponded to approximately a 1.3% course grade increase per screencast completed. When metacognition and learning perspectives screencasts were considered as factors in a multiple regression model, both screencast types were found to correlate positively with course grade z-scores (metacognition: $B = 0.099 \pm 0.025$ $p < 0.001$, roughly 1.0% course grade per screencast; perspectives: $B = 0.151 \pm 0.033$ $p < 0.001$, 1.6% per screencast; overall $r = 0.374$, $p < 0.001$). However, these correlations do not differentiate between direct academic benefit resulting from viewing the screencasts, and the potential that a student with higher academic performance would be more naturally inclined to engage with the screencasts. To examine this further, the change in z-score from the midterm exam (Week 8) to the final exam (equivalent to Week 14 in the course) was computed, noting that metacognitive development takes time [13]. A linear regression of the change in exam z-score against the screencasts still revealed a statistically significant correlation ($B = 0.026 \pm 0.008$, $r = 0.096$, $p = 0.002$). With a multiple regression ($r = 0.101$, $p = 0.006$), the metacognition screencasts showed a statistically significant relationship ($B = 0.045 \pm 0.022$ $p = 0.045$), while the learning perspectives screencasts did not ($B = 0.000 \pm 0.030$ $p = 0.997$). This corresponds to approximately a 0.44% exam grade benefit per metacognition screencast completed (i.e., a +2.2% improvement on average for completing the full set of five metacognition screencasts). These results suggest the metacognitive screencasts in particular contributed to enhanced academic performance, and that students with stronger academic performance were more likely to complete the optional university learning screencasts.

7. Conclusions

This study examined the use of short, interactive online screencasts intended to enhance first-year engineering students' transition to post-secondary, including their metacognitive development. The mixed methods approach adopted appears to confirm that this type of intervention can be effective in helping first-year engineering students. With reference to the specific research questions,

1. The interventions do in fact appear to develop metacognition in first-year engineering students. Both the pre-post semi-structured interviews (evaluated viewing metacognition as a threshold concept) and the survey (tracking alignment of responses to the screencast themes) provided strong evidence that students who completed the screencasts showed metacognitive awareness that was statistically improved over those who did not view the screencasts. Analysis of the MAI responses (knowledge of cognition subscale) in a pre-post activity was inconclusive, but that is not unexpected given the known issues with the validity of the MAI and other similar self-reporting instruments.

2. The initial investigation of academic impact of these interventions was limited to the course in which the interventions were deployed. A statistically significant benefit was revealed. Considering relative change in academic performance between course midterm and final exam, a linear model suggested students who viewed the series of five metacognition screencasts earned a grade advantage of roughly 2.2% over students who did not view the screencasts. In addition, viewing the screencasts was positively correlated with higher grades (5.0% higher for those who viewed all five metacognition screencasts versus those who did not view). Together, these suggest academically strong students are more likely to view the screencasts and to benefit from them.

3. Student feedback through a survey indicates a general feeling among students that the screencast series is moderately beneficial. In total, 63% rated the screencasts as "helpful" or "very helpful," and 90% rated them as at least "somewhat helpful" (average rating of 2.9 on a 1 to 4 scale). In terms of impact, 54% rated the screencast impacts as "positive" or "very positive," and 92% rated them as at least "somewhat positive" (average rating of 5.6 on a 1 to 7 scale). Impact was found to be independent of student GPA and mental wellbeing, suggesting perceived value did not depend on academic or personal circumstances.

4. Although presented as an optional resource, usage rate was high, with 70% of the class on average viewing the screencasts in 2019. The usage diminished from roughly 85% per screencast initially to 55% as the term progressed. Students cited the primary motivation for viewing the screencasts as a small course grade incentive that was provided; a jump in viewership from 2018 to 2019 was associated with a small increase

to the incentive structure. The primary reason cited for not viewing the screencasts was lack of time.

Future work will seek to replicate the survey findings, particularly in terms of alignment of attitudes and responses to the key university learning screencast themes. This will be done at the University of British Columbia, and research partnerships are being discussed with other programs and institutions who have adopted the university learning screencasts. In addition, further work will track students over several years to examine longitudinal impacts to academic performance, wellbeing, and retention.

References

[1] S. Fisher and B. Hood, "The stress of the transition to university: A longitudinal study of psychological disturbance, absent-mindedness and vulnerability to homesickness," British Journal of Psychology, vol. 78, no. 4, pp. 425-441, 1987.

[2] G. Schraw and R. Dennison, "Assessing Metacognitive Awareness," Contemporary Educational Psychology, vol. 19, no. 4, pp. 460-475, 1994.

[3] J.E. Ormrod, Human Learning. Upper Saddle River, NJ: Pearson Prentice Hall, 2004.

[4] M. Veenman, B. Van Hout-Wolters and P. Afflerbach, "Metacognition and learning: conceptual and methodological considerations," Metacognition and Learning, vol. 1, no. 1, pp. 3-14, 2006.

[5] S. Volet, "Modelling and coaching of relevant metacognitive strategies for enhancing university students' learning," Learning and Instruction, vol. 1, no. 4, pp. 319-336, 1991.

[6] National Research Council, How people learn: Brain, mind, experience, and school: Expanded edition. Washington, DC: National Academy Press, 2000.

[7] S.A. Ambrose, M.W. Bridges, M. DiPietro, M.C., Lovett, and M.K. Norman, How learning works: Seven research-based principles for smart teaching. John Wiley & Sons, 2010.

[8] A. Young and J. Fry, "Metacognitive awareness and academic achievement in college students," Journal of the Scholarship of Teaching and Learning, vol. 8, no. 2, pp. 1–10, 2012.

[9] M. Richardson, C. Abraham, and R. Bond, "Psychological correlates of university students' academic performance: a systematic review and meta-analysis," Psychological Bulletin, vol. 138, no. 2, pp. 353-87, 2012.

[10] Z. Mevarech and S. Fridkin, "The effects of IMPROVE on mathematical knowledge, mathematical reasoning and meta-cognition," Metacognition and Learning, vol. 1, no. 1, pp. 85-97, 2006.

[11] Z. Mevarech, and B. Kramarski, "IMPROVE: a multidimensional method for teaching mathematics in heterogeneous classrooms," American Educational Research Journal, 34, 365–394, 1997.

[12] T. Michalsky, M. Zion and Z. Mevarech, "Developing Students' Metacognitive Awareness in Asynchronous Learning Networks in Comparison to Face-to-Face Discussion Groups," Journal of Educational Computing Research, vol. 36, no. 4, pp. 395-424, 2007.

[13] Z. Mevarech and C. Amrany, "Immediate and delayed effects of meta-cognitive instruction on regulation of cognition and mathematics achievement," Metacognition and Learning, vol. 3, no. 2, pp. 147-157, 2008.

[14] S. Y. McGuire, Teach students how to learn: Strategies you can incorporate into any course to improve student metacognition, study skills, and motivation. Sterling, VA: Stylus Publishing, 2015.

[15] C. A. Farrington et al., Teaching Adolescents to Become Learners: The Role of Noncognitive Factors in Shaping School Performance--A Critical Literature Review. The University of Chicago Consortium on Chicago School Research, 2012.

[16] E. Cook, E. Kennedy, and S. Y. McGuire, "Effect of Teaching Metacognitive Learning Strategies on Performance in General Chemistry Courses," Journal of Chemical Education, vol. 90, no. 8, pp. 961–967, Aug. 2013.

[17] G. Harrison and L. Vallin, "Evaluating the metacognitive awareness inventory using empirical factor-structure evidence", Metacognition and Learning, vol. 13, no. 1, pp. 15-38, 2017.

[18] J. Kruger and D. Dunning, "Unskilled and unaware of it: How difficulties in recognizing one's own incompetence lead to inflated self-assessments.", Journal of Personality and Social Psychology, vol. 77, no. 6, pp. 1121-1134, 1999.

[19] J. Meyer and R. Land, "Threshold Concepts and Troublesome Knowledge: Linkages to Ways of Thinking and Practising within the Disciplines," Enhancing Teaching-Learning Environment in Undergraduate Courses Project. 4, pp. 1-12, 2003.

[20] J. Meyer, and R. Land, "Threshold Concepts and Troublesome Knowledge: Issues of Liminality." Overcoming Barriers to Student Understanding: Threshold Concepts and Troublesome Knowledge. Jan Meyer and Ray Land, eds. New York: Routledge, pp. 19-32, 2006.

[21] C. Dweck, "Mindset: The New Psychology of Success," New York: Random House, 2006.

[22] A. Duckworth, "Grit: The Power of Passion and Perseverance," First Scribner hardcover ed. New York, NY: Scribner, 2016.

[23] W.G. Perry, "Forms of Intellectual and Ethical Development in the College Years: A Scheme," San Francisco: Jossey-Bass, 1970 (updated and reissued in 1998).

[24] J. Biggs, and C. Tang, "Teaching for Quality Learning at University," Maidenhead, UK: Open University Press, 2011.

[25] D. Bateman and J. Donald, "Measuring the Intellectual Development of College Students: Testing a Theoretical Framework," Canadian Journal of Higher Education, Vol. XVII-1, 1987.

[26] T. Doyle and T Zakrajsek, The New Science of Learning: How to Learn in Harmony with Your Brain, Portland: Ringgold, Inc, 2013.

[27] S. Cohen, T. Kamarack and R. Mermelstein, "A global measure of perceived stress," Journal of Health and Social Behavior, 24, 385-396, 1983.

[28] R.B. Johnson and A.J. Onwuegbuzie, "Mixed Methods Research: A Research Paradigm Whose Time Has Come", Educational Researcher, 33(7), 14-26, 2004.

[29] T. Tan, S. Nesbit, N. Ellis, and P. Ostafichuk, "Crossing Boundaries: Developing Transdisciplinary Skills in Engineering Education," CEEA18, Vancouver, Jun 3-6, 2018.

[30] Warwick-Edinburgh Mental Wellbeing Scale (WEMWBS), NHS Health Scotland, The University of Warwick and University of Edinburgh, 2006.

[31] V. Elliott, Thinking about the Coding Process in Qualitative Data Analysis.The Qualitative Report, 23(11), 2850-2861, 2018.

[32] M. McHugh, "Interrater reliability: the kappa statistic", Biochemia Medica, pp. 276-282, 2012.