The Canadian Journal for the Scholarship of Teaching and Learning

Volume 10 | Issue 1 Article 9

Spring 5-31-2019

Analyzing Implicit Science and Math Outcomes in Engineering and Technology Programs

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https://doi.org/10.5206/cjsotl-rcacea.2019.1.7994

Analyzing Implicit Science and Math Outcomes in Engineering and Technology Programs

Abstract
One of the key steps when developing pathways between baccalaureate and diploma programs is comparing learning goals between the programs. This paper presents application of a seven-dimensional framework (cognitive process, transferability, depth of analysis, interdependence, question novelty, scaffolding and communication) to analyze the implicit learning outcomes in 11 of Ontario's post-secondary programs in engineering and engineering technology. We collected 319 calculus questions (179 from six technology programs and 140 from five engineering programs) and 205 physics questions (122 from two technology programs and 83 from four engineering programs). Content specialists assessed each question in the first four of these dimensions, and instructors from the participating institutions scored random questions from their own disclosed questions on the remaining dimensions. Analysis of scaffolding in physics questions showed that engineering questions mostly required the students to choose from or synthetize a range of approaches while technology questions often required the students to use a specific approach. The study found that technology programs focused more on discipline-specific physics concepts and their applications than physics courses in engineering. Calculus questions from both sectors mostly required application of mathematical concepts in non-contextualized scenarios or a general engineering context, with no significant difference in question novelty, scaffolding and level of communication. From a credits perspective, these results suggest that direct credit for bidirectional transfers may be warranted, and that small bridging learning modules targeting missing outcomes may be able to support efficient transfer pathways.

Une des étapes principales lors du développement de trajectoires entre les programmes menant à un baccalauréat et ceux menant à un diplôme consiste à comparer les objectifs d'apprentissage entre ces programmes. Cet article présente l'application de sept cadres dimensionnels (processus cognitif, possibilité de transfert, profondeur d'analyse, interdépendance, nouveauté de la question, échafaudage et communication) pour analyser les résultats d'apprentissage implicites dans 11 programmes d'enseignement post-secondaire d'Ontario en génie et en technologie. Nous avons recueilli 319 questions de calcul (179 de six programmes de technologie et 140 de cinq programmes de génie) et 205 questions de physique (122 de deux programmes de technologie et 83 de quatre programmes de génie). Des spécialistes du contenu ont évalué chaque question dans les quatre premières de ces dimensions et les instructeurs des établissements participants ont noté des questions prises au hasard de leurs propres questions divulguées pour les dimensions restantes. L'analyse de l'échafaudage pour les questions de physique a indiqué que les questions de génie exigeaient principalement que les étudiants choisissent parmi une variété d'approches ou qu'ils en fassent la synthèse, alors que les questions de technologie exigeaient souvent que les étudiants utilisent une approche spécifique. Cette étude a montré que les programmes de technologie se concentraient davantage sur des concepts de physique spécifiques à la discipline et sur leurs applications par rapport aux programmes de physique en génie. Les questions de calcul des deux secteurs exigeaient

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principalement l’application de concepts mathématiques dans des scénarios non contextualisés ou dans un contexte de génie général, et il n’y avait pas de différence significative en ce qui concerne la nouveauté de la question, l’échafaudage et le niveau de communication. D’un point de vue des crédits, ces résultats suggèrent que le crédit direct pour les transferts bidirectionnels peut se justifier et que des petits modules d’apprentissage de relais qui ciblent les résultats manquants peuvent permettre de soutenir des trajectoires de transfert efficaces.

Keywords
transfer, pathways, learning outcomes

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Unlike many other jurisdictions, Ontario's post-secondary system was not intended to support efficient transfer between the college and university sectors (Trick, 2013). British Columbia and Alberta, for example, have long developed working groups to provide guidelines, policies and procedures to facilitate transfer among post-secondary institutions (Fitz Gibbon, 2014). The Ontario Council on Articulation and Transfer (ONCAT) is working to build a more systemic process by supporting relationships between individual institutions and small clusters of institutions within the province (Ontario Council on Articulation and Transfer, 2011).

The fact that Ontario is late to the systematic transfer game does present an opportunity to learn from other approaches (Fitz Gibbon, 2014; Trick, 2013), and leverage activity underway at the institutions. There is a rich body of literature on different transfer models and systems in North America and Europe (Finlay, 2009; Laugerman, Rover, Shelley, & Mickelson, 2015), and the role and responsibilities of learning outcomes in articulation and transfer (Goff et al., 2015; Lennon et al., 2014; Ontario Ministry of Training Colleges and Universities, 2010; Timney, 2010). Learning outcomes can potentially enhance the credit transfer systems by providing evidence-based comparison of course content and the context of learning (Carter, Coyle, & Leslie, 2011; Fitz Gibbon, 2014). However, non-standardized descriptions of learning outcomes and lack of alignment with the course content or assessment make the successful implementation and comparison of learning outcomes a complicated task (Fitz Gibbon, 2014).

Transfer into accredited programs like Engineering also places restrictions on students, as the accreditor may limit how much credit can be granted. For example, to become a professional engineer, individuals must demonstrate that they have earned certain academic qualifications as required by the Canadian Engineering Accreditation Board (CEAB) (Canadian Engineering Accreditation Board, 2017). The shortest path to attain these qualifications is through graduation from an educational program that has met the academic standards as identified by CEAB.

CEAB enforces the use of a common framework of high-level program expectations known as *graduate attributes* set by an international agreement known as the Washington Accord (International Engineering Alliance, 2013). This requirement directly affects the process of transfer and implementation of any bridging program into accredited Engineering programs, as it requires the degree-granting institution to verify and provide evidence that the criteria are met by transfer students as well.

Under the Washington Accord Engineering programs must develop students' ability to work with complex problems that require understanding of fundamental principles, have wide-ranging or conflicting issues, and require abstract thinking. In contrast, Engineering Technology programs develop within their students the ability to work with broadly-defined problems that involve application of developed technology and can be solved by application of well-proven techniques (International Engineering Alliance, 2013). Generally Engineering programs emphasize more theory whereas Engineering Technology programs emphasize more application, and hands-on activities. The Engineering and Engineering Technology programs in Ontario were designed so that the skillsets and knowledge profiles developed in one type of program are not necessarily transferrable to the other. Due to these differences and the design of Ontario's post-secondary system, no system-wide pathways exist for transfer between these qualification levels.

This paper reports on the application of a framework that can be used to support development of pathways using both explicitly stated outcomes and implicit expectations on significant course requirements. Learning outcomes provided for a course or program usually include the cognitive process expectation (e.g., describe, apply, evaluate, etc.). However, programs may have particular expectations about the degree of novelty in problems that their students need to be able to solve without making that explicit. Additionally, many university programs, including most Engineering programs, are still formalizing course and program learning outcomes so explicit learning outcomes were not always available. For these reasons, this study only identified implicit outcomes by examining summative assessments, specifically final exams, and did not use explicit learning outcomes.

This study focuses on applying our framework to analyzing outcomes in fundamental science and mathematics courses such as physics and calculus in Engineering and Engineering Technology programs in Ontario. There are no data available on the exact times that most transfers happen within the Engineering and Technology disciplines in Ontario. Students often wish to transfer mid-stream from diploma to diploma, degree to degree, diploma to degree, or degree to diploma. This makes assessment of learning outcomes in introductory courses such as calculus and physics of highest priority as they are taken by the students in both sectors.

Although the framework developed for this work, along with the analysis process, has here been applied specifically to credit transfer between Engineering-related disciplines, it is also adaptable to virtually any field that has comprehensive summative assessments since it relies primarily on learning outcome comparisons. As such, this methodology will be of value to the broader post-secondary community, and the results of the present study represent a specific example of how the approach may be applied.

Method

After approval by the relevant institutional General Research Ethics Board, the researchers contacted nine of the 16 programs offering Engineering degrees in Ontario, and seven of the 14 institutions offering electrical or mechanical Engineering Technology advanced diplomas, representing a range of size, institutional mission and institutional reputation. We focused on the institutions with which we had some contact in the past. The programs were asked to provide examples of summative assessments (final exams) in calculus and physics used over the previous five-year period (exams were provided as written by the instructors; no student responses to exam questions were used). We also used publicly available exam banks or course websites to gather exam questions. Final examinations were selected as a reasonable representation of course goals because they are commonly the most heavily-weighted assessment in most introductory physics and calculus courses and are commonly used as a final summative assessment that addresses most, if not all, of the course learning goals. A total number of six Technology programs and six Engineering programs were included in this study, each contributing the course material for at least one of the courses. We collected 319 calculus questions (179 from six Engineering Technology programs and 140 from five Engineering programs) and 205 physics questions (122 from two Engineering Technology programs and 83 from four Engineering programs). Instructors from those programs were asked to also score their own questions on the framework, and representatives from four programs agreed to do so.

Several approaches have been suggested for determining equivalency of learning outcomes (Moskowitz & Stephens, 2004). For assessing course-level learning outcomes, analysis of course content and context are best suited to this purpose: they provide information on general properties of a course, can be performed without any information about other courses, and can be assessed independent of socio-cultural or environmental factors. Here, two analyses were performed on the material: (a) content analysis, which included course topics and order of material drawn from course outlines and program information, and (b) context analysis, which examined the level of expectation, novelty, and other factors.

Content Analysis

Programs may deliver similar content but in a different order, as curriculum is developed to meet the needs of a particular target group. For example, the content covered in an introductory physics course at a university might be equivalent to a combination of courses at a college program. Instead of matching specific courses, we started by an assessment of equivalency between courses that collectively cover similar content, regardless of their chronological placement within the program. We used BCCAT's articulated content areas for calculus and physics (British Columbia Council on Admissions and Transfer, 2016) to benchmark course content:

- Calculus: Limits, continuity, intermediate value theorem; Differentiation; Taylor polynomials and special Taylor series; Curve sketching; Integration; Improper integrals; Separable differential equations; Sequences and series; Additional applications of integration; Additional differential equations topics; Complex numbers; Continuous probability density functions; Polar coordinates and parametric equations; Additional numerical methods; Related rates; L'Hopital's Rule.
- Physics: Vectors, Kinematics, Dynamics, Work and energy, Rotational motion, Rigid-body equilibrium, Oscillatory motion, Travelling waves, Physical optics, Geometric optics, Electrostatics, Electric field, Electric potential, Current and conductivity, AC circuit, DC circuit, Magnetic field, Induction.

Context Analysis

Comparing programs through assessment of "explicit" learning outcomes is challenging as they are often described in a sector-specific language (Fallon, 2015) and are not necessarily aligned with the course content or assessments (Biggs & Tang, 2011). Such short-comings call for a more comprehensive analysis of unstated or "implicit" learning outcomes as measured on significant assessments like final exams, and the context in which they are assessed. The context varies between different courses, different disciplines, and different programs. This makes finding a single approach to effectively assess the context of learning outcomes very difficult.

A comparison framework was used to identify characteristics of summative assessments in seven dimensions, adapted from taxonomies and outcome principles from the literature (Zakani, Kaupp, Turner, & Frank, 2017). The dimensions of the framework, and references to their origin, are:

- cognitive process (Bloom, Englehard, Furst, Hill, & Krathwohl, 1956)
- transferability (Daggett, 2014)
- depth of analysis (International Engineering Alliance, 2013)
- interdependence (International Engineering Alliance, 2013)
- novelty (Sweller, 1988)
- scaffolding (Willison & O'Regan, 2007)
- communication (Association of American Colleges and Universities, 2009).

Table 1 shows the dimensions and levels in the framework. Assessment of the implicit learning outcomes was divided into two steps. Firstly, three content specialists coded each question to the list of content areas, then assessed dimensions that could be done independently of course instructors using the framework. Content specialists were graduate/postdoctoral teaching assistants or course instructors from either sector. Each specialist was trained in a practice session scoring sample questions using the framework and went through a discussion of terms and definitions for calibration purposes. They were then provided with anonymized questions from a mix of institutions. In addition to calculating percentage of exact agreement, we defined inter-rater reliability using Gwet's AC1 (Gwet, 2008) statistic to consider the possibility of raters guessing on at least some variables due to uncertainty, leading to chance agreement (Cohen, 1960). This method is also shown to account for the number of levels within each dimension, and captures the correlation between the number of levels within each dimension and marginal distribution (Feng, 2015). With an overall percentage agreement of 79% and inter-rater reliability of 81% in scoring physics questions, the framework was shown to be highly consistent.

The remaining three dimensions (levels of novelty, scaffolding, and communication skills) were scored by instructors from participating institutions through an online survey where each instructor was asked to score five random questions from their previously disclosed example questions.

For example, final exam questions in physics look like:

Question 1 - Which of the following is not a vector quantity?

A. Electric charge
B. Electric field
C. Acceleration
D. Force

Question 2 - The system below is in equilibrium, what is the mass of M? Assume weightless pulleys and rope.

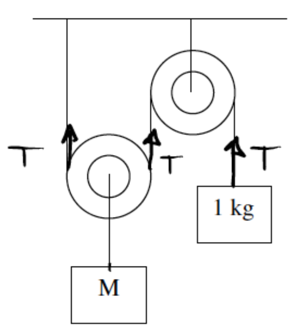


Table 1

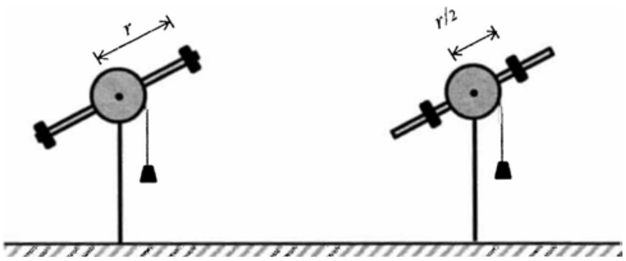
Outcome Comparison Framework for Content in Mathematics (Calculus) and Sciences (Physics)

<table>
<tr><th>Dimension</th><th colspan="16">Spectrum</th></tr>
<tr><td>Cognitive Process</td><td colspan="1">Remember</td><td colspan="4">Understand</td><td colspan="4">Apply</td><td colspan="3">Analyze</td><td colspan="3">Evaluate</td><td colspan="1">Create</td></tr>
<tr><td>Transferability</td><td colspan="3">Mathematics/Physics knowledge</td><td colspan="5">Apply in a disciplinary context</td><td colspan="2">Apply in other engineering context</td><td colspan="4">Apply to real-world predictable contexts</td><td colspan="2">Apply to real-world unpredictable contexts</td></tr>
<tr><td>Depth of Analysis</td><td colspan="6">Solved by standardized ways</td><td colspan="5">Solved by well-proven analysis techniques</td><td colspan="5">Originality in analysis, no obvious solutions</td></tr>
<tr><td>Interdependence</td><td colspan="6">Discrete components</td><td colspan="5">Parts of or systems within complex engineering problems</td><td colspan="5">High level problems including many components, parts or sub-problems</td></tr>
<tr><td>Novelty[1]</td><td colspan="4">Familiar problem</td><td colspan="8">Reorganized problem</td><td colspan="4">New problem</td></tr>
<tr><td>Scaffolding</td><td colspan="2">Prescribed problem</td><td colspan="5">Constrained problem</td><td colspan="6">Scaffolded problem</td><td colspan="3">Adopted problem</td></tr>
<tr><td>Communication</td><td colspan="1">Interpretation</td><td colspan="4">Representation</td><td colspan="4">Calculation</td><td colspan="3">Application</td><td colspan="3">Assumption</td><td colspan="1">Communication</td></tr>
</table>

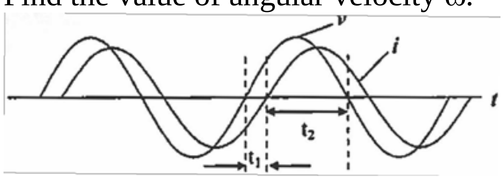
[1]Highlighted rows indicate dimensions that require instructor input

Question 3 - The two rotating systems shown in the figure below differ only in that the two identical movable masses are positioned a distance r from the axis of rotation (in the left case), or a distance r/2 from the axis of rotation (in the right case). If you release the hanging blocks simultaneously from rest and the system (bar + weights + cylinder) is free to rotate:

A. The block on the left lands first.
B. The block on the right lands first.
C. Both blocks land at the same time.
D. It is impossible to say which lands first without more information.



Question 4- The sinusoidal voltage waveform shown is v=50*sin*(ωt+34°) V. The period of current wave form *i* is 3.0ms and its rms value is 4.66, and is 42° out of phase with the voltage waveform. Find the value of angular velocity ω.



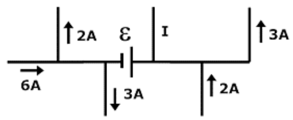
Using the framework, content specialists can identify the following information: (a) Cognitive process: the highest cognitive process required in question one and two is at remember and understand, while questions three and four fall under apply; (b) Transferability: questions one to three only address a problem in physics, while question four was given to electrical Engineering Technology students and has discipline specific implications; (c) Depth of analysis: all these questions can be solved in standardized ways and do not require combinations of approaches or non-obvious solutions; and (d) Interdependence: all these questions are addressing a single discrete problem and do not involve introducing new information or cognitive processes in the middle of question. The information regarding the level of novelty, scaffolding and expected communication is not available and requires instructor input.

Table 2 provides example questions under the first four dimensions of the framework that can be scored independently of the course instructor by content specialists for contextual analysis of course-level learning outcomes in introductory physics courses. Of the material collected we did not find any questions that would require the last three levels of cognitive process (analyze, evaluate, or create), or the last levels in depth of analysis or interdependence, which are consistent with the findings of a previous study on post-secondary calculus in the United States (Tallman, Carlson, Bressoud, & Pearson, 2016). The same approach was used for analyzing calculus questions, and a table similar in approach to Table 2 was generated for calculus questions, though that is not the focus of this paper.

Table 2

Example Physics Questions for the First Four Dimensions of the Framework Marked by Content Specialists

Dimension	Spectrum					
Cognitive process	Remember What property of an objects causes it to maintain its motion?	Understand Compared with a 1 kg block of solid iron, what does a 2kg block has twice as much of?	Apply Friction on a sliding object is 18 N. What is the applied force needed to maintain a constant velocity?	Analyze Investigative questions	Evaluate Investigative questions	Create Investigative questions
Transfer	Physics knowledge T or F: a particle moving in a straight line with constant speed has acceleration.	Disciplinary For Elec Eng/ Tech: The charge across a capacitor is $q = 2e^{-t}\sin(225t)$ Find the current in the capacitor at $t = 35ms$.	Other engineering For Elec Eng/ Tech: It is known that bridges in an area with frequent thunder storms will acquire a linear charge density of $\lambda = -1\ \mu C/m$. Calculate electric potential at P for the following arc designs?	Real world predictable Solve for the current in a circuit for a design project with specific requirements.	Real world unpredictable Design energy supply for an area that is off grid.	

Dimension	Spectrum		
Depth of Analysis	Standardized ways Consider the circuit shown in the figure. What is the magnitude of the current *I*? 	Well-proven analysis techniques What is the effective capacitance *C(eff)* of this infinite chain of capacitors? 	Originality in analysis Investigative questions
Interdependence	Discrete components The acceleration of a particle moving along the x axis is given by $a_x = -4\pi^2 cx$. What is the period of the motion?	Systems within complex engineering problems In a horizontal capacitor, the dielectric (K) slides frictionless and is attached via a massless string and pulley to a block of mass m. The block pulls the dielectric from the capacitor as it falls. The voltage after dielectric removed is *100V*. Compute the speed of *m* as the dielectric leaves the capacitor.	High level problems Investigative questions

Results

Content Analysis

Figure 1 summarizes the course content in the introductory calculus courses taught in participating institutions (six Technology programs and five Engineering programs). It was assumed that the final exams covered all the course content since the possible missing content would equally impact both Technology and Engineering final exams. As expected, we found the focus of introductory calculus courses was on differentiation and integration. Interestingly, there was distinct variability amongst institutions even within sectors. For instance, while some institutions (Engineering Technology 4 and Engineering Technology 5; Engineering 1 and Engineering 2) covered a wider range of content areas in their final exams, some focused on a limited list of topics (Engineering Technology 2 and Engineering Technology 6; Engineering 3 and Engineering 5).

Figure 2 summarizes the course content in the introductory physics courses taught in participating institutions (two Technology programs and four Engineering programs). Again, it was assumed that the final exams were representative of what was taught in the course and all the contents were examined in the final exams. Due to the small number of sample questions, comparison between physics courses is less certain. Regardless, similar to calculus courses, there was distinct variability amongst content areas covered by Engineering programs. While some institutions (Engineering Technology 3; Engineering 2) covered a wide range of content areas in their final exams, other institutions focused on fewer topics (Engineering Technology 6; Engineering 3 and Engineering 6). These findings contradict the notion of smaller variation amongst Engineering programs compared to the differences between Technology programs and Engineering programs.

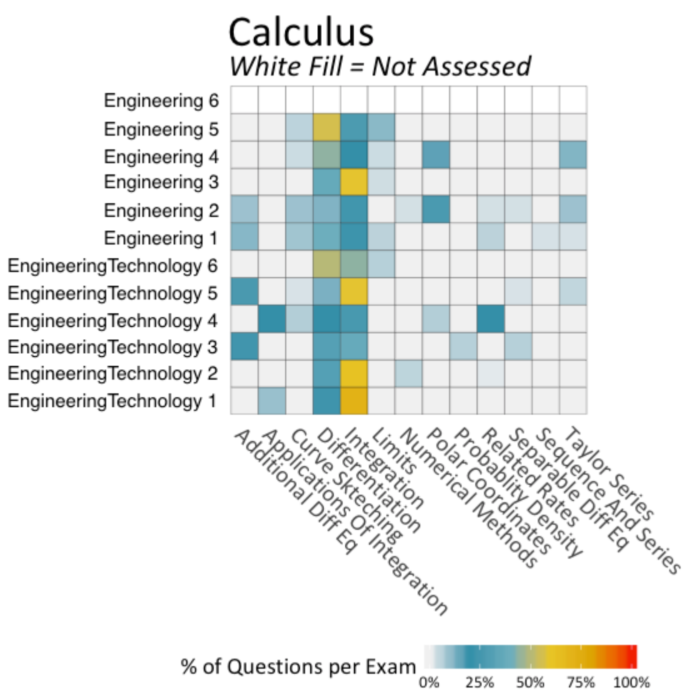


Figure 1. Percentage of questions in each calculus content area per exam from each institution. Content areas are drawn from BCCAT Articulation Committees.

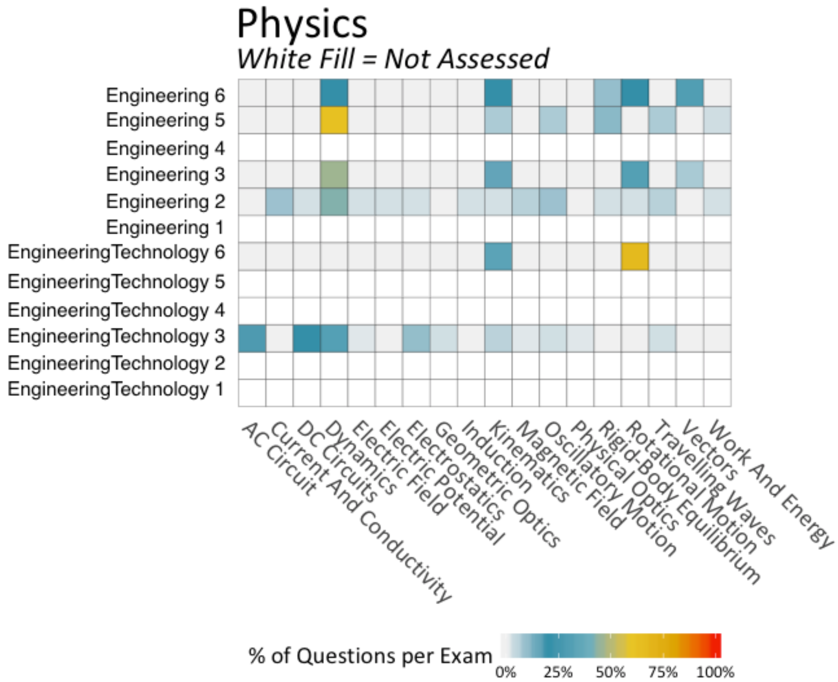
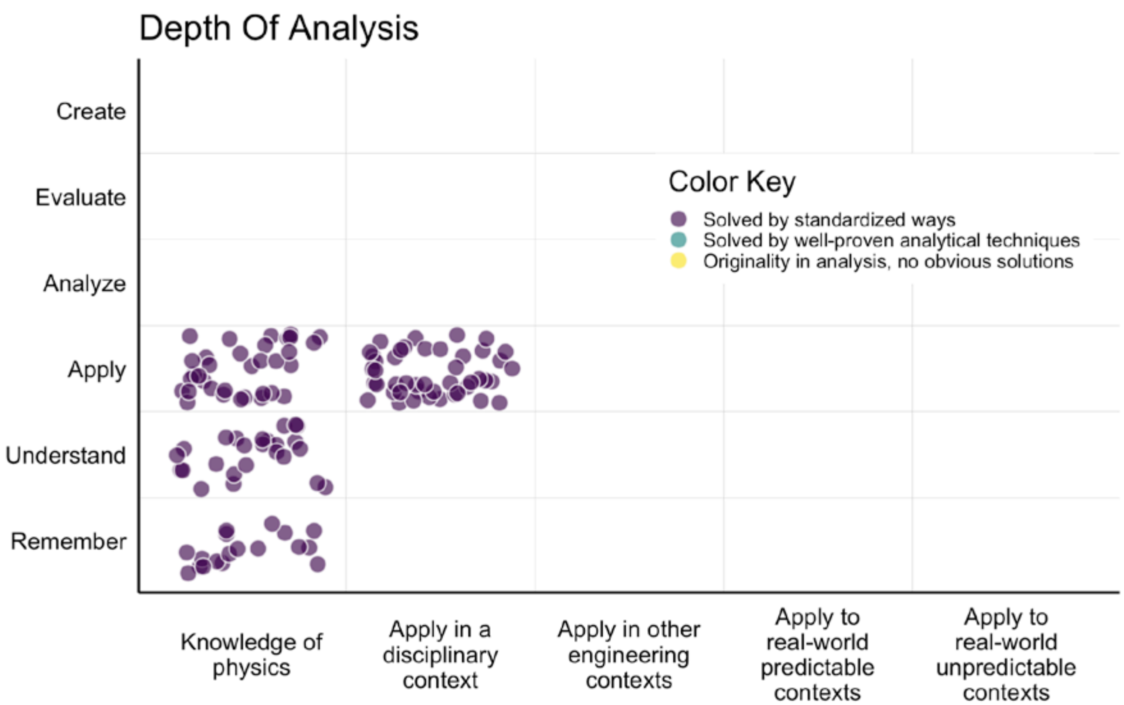


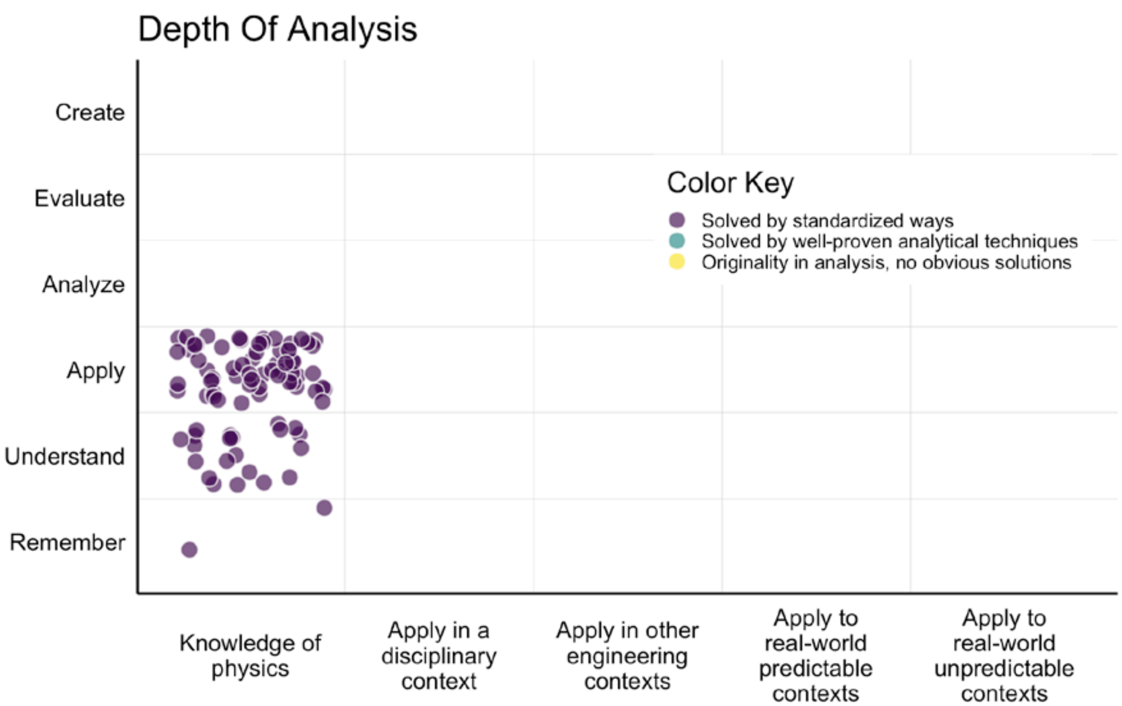
Figure 2. Percentage of questions in each calculus content area per exams from each institution. Content areas are drawn from BCCAT Articulation Committees.

Figures 3a and 3b show the different levels of depth of analysis plotted in the rigor-relevance grid for representative physics questions from the participating Engineering and Technology programs, respectively. Within Technology programs, the content of physics courses and their importance to the specific discipline play a significant role in determining which cognitive processes are emphasized. For example, in Engineering Technology program 3 with a focus on Electronics Engineering, the cognitive processes required to answer questions in mechanics are remember and understand. The same program examines topics in electricity and magnetism at the application level.

Instructors from Engineering Technology 3 and Engineering Technology 6 and Engineering 2 and Engineering 5 participated in an online survey reflecting on their course design, question novelty, scaffolding and expected levels of communication in five random questions from their own sample questions. Figures 4a and 4b summarize the results in the survey questions; 10 questions from universities and eight questions from one college were included since one of the colleges only provided three sample questions. The location of dots represents content-specialists' assigned scores for depth of analysis in the rigor-relevance framework. The conclusions drawn from this very small sample are very weak. However, it is worth noting that exam questions from Engineering Technology programs were often found to require higher scaffolding compared to questions from Engineering programs. Questions from Engineering programs mostly required the students to choose from or synthetize a range of approaches while questions from Technology programs often required the students to use a specific approach. The differences between the exam questions from the two types of programs in novelty and level of communications were found to be insignificant

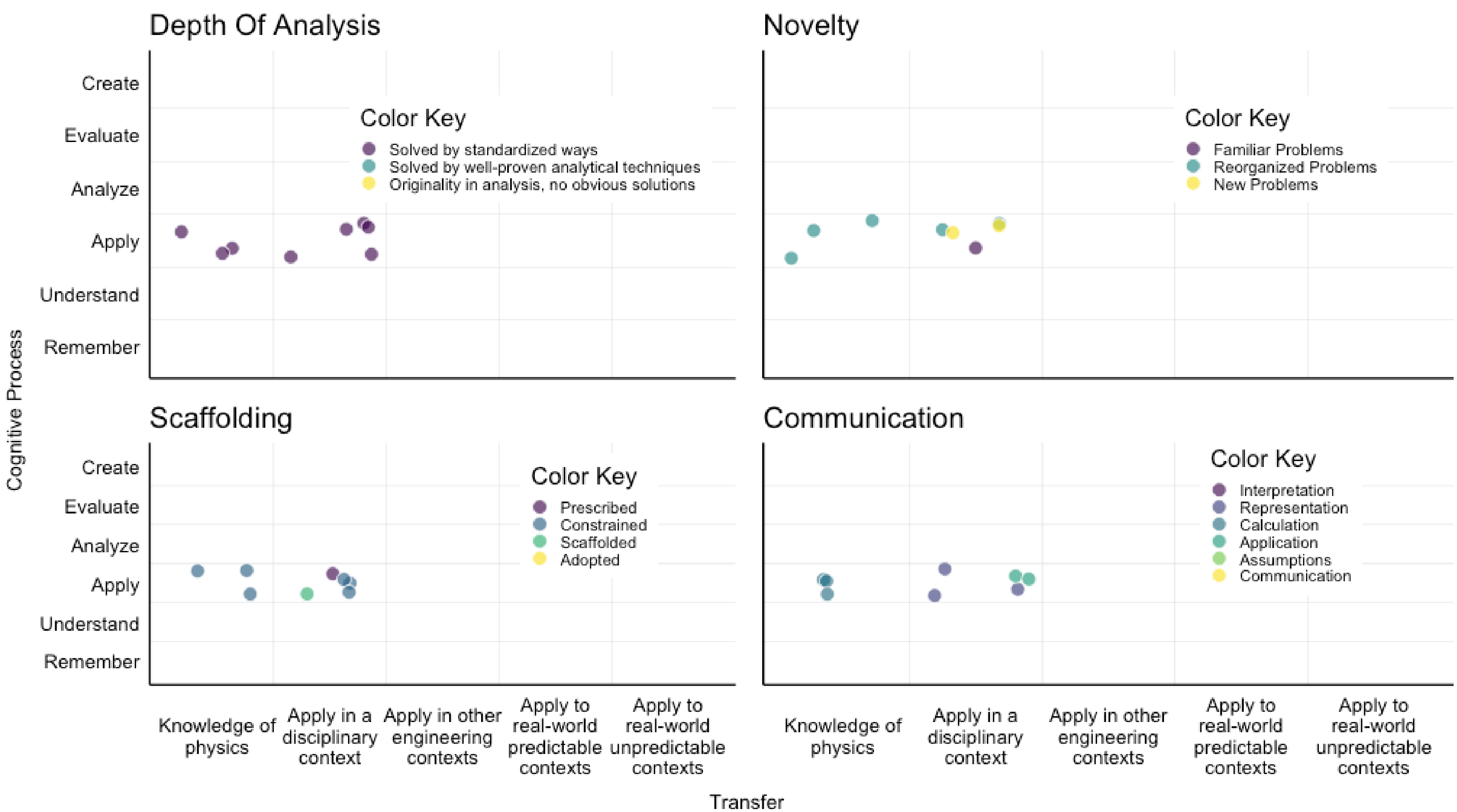


(a) Depth of analysis in physics questions from Engineering Technology programs

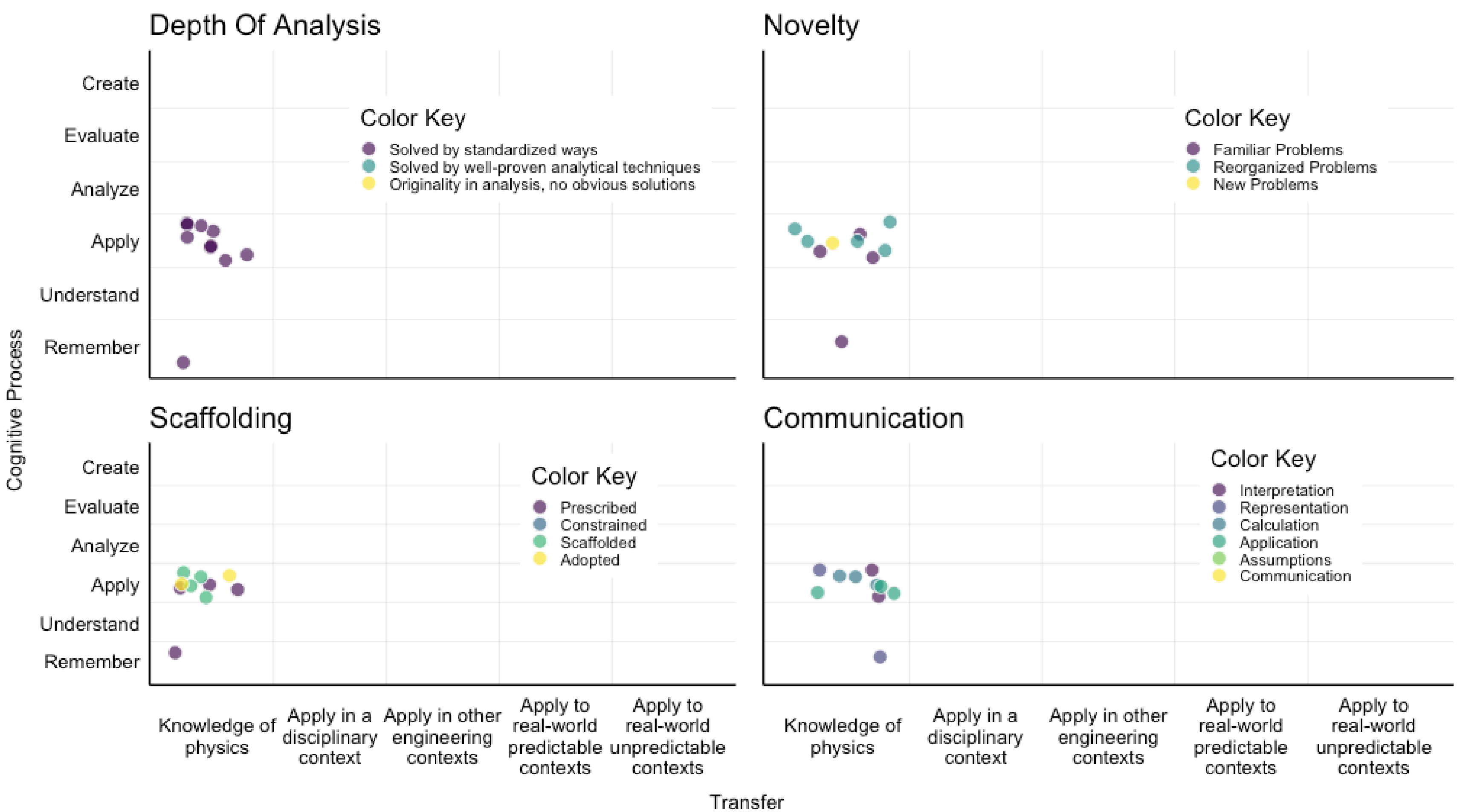


(b) Depth of analysis in physics questions from Engineering programs

Figure 3. Depth of analysis for physics questions in Engineering Technology and Engineering exam questions. Each dot represents the median of the scores assigned by three content specialists for one question; the dots are jittered to give a better visual representation of the intensity. Color of the dots represent the depth of analysis required for answering that question (purple: solved by standardized ways; blue: solved by well-proven analytical techniques; yellow: originality in analysis, no obvious solutions).



(a) Learning outcomes assessment of physics questions from Technology programs



(b) Learning outcomes assessment of physics questions from Engineering programs

Figure 4. Learning outcome assessment for physics questions in Engineering Technology and Engineering exam questions as scored by instructors from programs Engineering Technology 3 and 6 and Engineering 2 and 5. Location of each dot is the median of the scores assigned by three content specialists for one question; the dots are jittered to give a better visual representation of the intensity. Color of the dots represent different levels of novelty, scaffolding and communication skills as determined by the instructors in the online survey.

Discussion

Ontario's colleges of Applied Arts and Technology were established at the time when any vocational program was considered "terminal education" (Hogan & Trotter, 2013; Skolnik, 2010, 2016) with no plan for the students to move from a college program to a university program (Skolnik, 2010). With changes in the labor market, an increase in demand for higher education, student interest in transfer for employment, and differences in earnings between university graduates and college graduates (Frank & Walters, 2012), there is greater need for transfer pathways.

Credit recognition has been at the forefront of transfer guide development in British Columbia, Alberta, and Saskatchewan (Marshall, 2010). However, there are variables other than course content and GPA that can affect transferability of credits between programs. In assessing prior learning, the context of learning and the specifics of student experience in a program are important in determining what the student knows or is able to do upon completion of a given course or program. There are no studies to date that can link the context of learning and student experience to credits.

Here, we used a framework for assessing implicit learning outcomes to identify similarities and differences between courses offering similar content in physics and calculus. The content and context analysis of calculus courses showed as much disparity between courses offered within the group of Engineering programs (that is, within their own sector) as between courses offered by Engineering and Engineering Technology programs (across sectors). One noticeable difference between the Engineering and Engineering Technology programs was the timing and role of the calculus courses in the curriculum. Engineering programs typically provide the mathematical toolbox in the first year while Engineering Technology programs tend to teach calculus in the second or third year. This may be because Engineering Technology students often take prerequisite courses in algebra, geometry, and trigonometry in the first year in preparation for calculus. However, it was mentioned by Engineering Technology instructors that calculus is often heavily integrated into the program and delivered within that context as needed - even though calculus as a stand-alone course might be deferred to the last two semesters, students use different calculus concepts in the context of other courses.

The differences between physics content covered by the two types of programs were no more significant than the variability amongst Engineering programs. The contextual analysis in the depth of analysis showed that all of the questions in introductory physics courses in both Engineering and Engineering Technology programs can be solved in standardized ways. The cognitive process required to answer physics questions in an Engineering program ranged from "understanding" to "applying" the physics concept. However, in Engineering Technology programs, the cognitive process required was heavily dependent on the content. Programs tend to examine topics directly related to their focus areas (e.g., for Electronics Technology these would include electromagnetics and circuits) at a higher cognitive level such as understanding or applying within a disciplinary context. As for other topics, remembering or understanding a physics concept not directly applied in the program would be sufficient. Unfortunately, due to the limited number of survey responses, we could not find any distinct differences or similarities between the two types of programs in other dimensions such as question novelty, scaffolding and communications.

Although this study did not directly link learning outcomes to credits, it provides a new approach that could be applied to the design of bridging transfer models. Conventional bridging models require the students to complete a few bridging courses at the university to *upgrade* their knowledge and skills in those courses (Kirby, 2007). These bridging programs often include a few first year and second year courses, which in turn usually extend the post-secondary education by one semester and reduce the cost advantages of the college-to-university transfer (Trick, 2013).

One possible alternative could be a prior assessment of the learning outcomes at a provincial level, identifying the differences between course learning outcomes and content across different institutions. A provincial system involving prior knowledge assessment and flexible online learning modules may be sufficient to address the relatively small number of missing outcomes, or outcomes for which the contextual expectations of first year courses differ (e.g., novelty, scaffolding). These modules would be designed specifically to match the missing pieces of learning outcomes in either the university or college courses from the original institution. For example, for students transferring from a Technology program to an Engineering program, a learning module that focuses on developing problem-solving skills with minimal scaffolding would be of great value. These learning modules do not necessarily have to be conducted in a classroom setting and could be part of an online training program with laboratory or classroom practice sessions that are devised to meet the needs of specific group of students transferring from one school to another.

Although the present study focuses on applying a new analysis framework to a particular set of Engineering courses, specifically calculus and physics, the approach is clearly applicable to most Engineering subjects. In fact, since the methodology employed here primarily involves careful analysis of learning outcomes, it can be applied still more broadly and should be adaptable to most disciplines. The results presented here therefore represent a specific example of how the methodology may be applied in general to facilitate post-secondary credit transfer.

Program chairs commonly compare calendar descriptions and course outlines when considering transfer. However, these resources are generally not written to support comparison with other courses, and generally do not spell out the task complexity that students must meet in order to pass the course. As a result, there may be questions about whether one course, which covers the same topics and may have similar learning outcomes, is as difficult or rigorous as another. The framework we have developed is intended to allow that comparison.

The results of this study should be interpreted in light of the limited pool of responding programs (twelve across the province) and use of final exams as a proxy measure of implicit learning outcomes in courses.

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