



Volume 19, 2020

EFFECTIVE ASSESSMENT OF WORKPLACE PROBLEM-SOLVING IN HIGHER EDUCATION

Maurice Danaher Zayed University, Abu Dhabi, UAE maurice.danaher@zu.ac.ae
Kevin Schoepp* Tulum, Mexico kevinschoepp@gmail.com
*Corresponding author

ABSTRACT

Aim/Purpose	Within higher education, graduating students who are able to solve ill-structured, complex, open-ended, and collaborative, workplace problems is recognized as paramount. Because of this, there is a need to assess this skill across the curriculum.
Background	This paper addresses this issue by assessing problem-solving across a computing curriculum using an assessment instrument shown to be reliable and valid.
Methodology	The method is based upon the implementation of the assessment instrument that uses a scenario-based asynchronous discussion board measuring the ability of student groups to solve workplace problems. The sample are computing students from the 2 nd , 3 rd , 4 th year, and master's levels at a UAE university.
Contribution	This paper shows the problem-solving skills of students over four years of study across a computing curriculum and demonstrates the effectiveness of the instrument.
Findings	There was a general increase in student problem-solving performance from the 2 nd , 3 rd , 4 th year, and master's levels, but students often failed to meet the expected level of performance for their year of study. In addition, the instrument was effective in assessing problem-solving.
Recommendations for Practitioners	This assessment instrument, or one similar, that uses a scenario-based asynchronous discussion board can be used to measure the ability of student groups to solve workplace problems.
Impact on Society	Students must be prepared to solve workplace problems to meet the needs of 21 st century employment.
Future Research	Further research should be conducted with this assessment instrument, or one similar, outside of this fairly unique UAE- based context.

Accepting Editor Kay Fielden | Received: December 4, 2019 | Revised: January 24, 2020 | Accepted: January 25, 2020.

Cite as: Danaher, M., & Schoepp, K. (2020). Effective assessment of workplace problem-solving in higher education. *Journal of Information Technology Education: Research*, 19, 1-16. <https://doi.org/10.28945/4496>

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Keywords workplace problems, computing education, asynchronous discussion

INTRODUCTION

Prior to the start of the 21st century, the term 21st century skills, soft skills, or professional skills had long been a buzzword for governments, employers, and academics (Accreditation Board for Engineering and Technology [ABET], n.d.). Though in no way a true divider, the advent of the 21st century was used as a way to promote the need for meaningful change in education and particularly tertiary education in the sciences, engineering and computing. In combination with the expansive growth in the Internet and the availability of information, access to data and information had been transformed so that access to knowledge was no longer the issue. The ability to interpret information, work effectively in teams, communicate ideas, and solve complex problems was becoming more of the challenge. If these challenges are to be met, learning outcomes pertaining to the 21st century skills need to be integrated into the curriculum. Worldwide in fields such as computing and engineering, a historical curricular emphasis on theory, technical skills, and knowledge production rather than these more applied 21st century skills has left the fields open to criticism from employers (Ellis & Petersen, 2011; Farr & Brazil, 2010; Stawiski, Germuth, Yarborough, Alford, & Parrish, 2017). Specific to the Middle East, employers have found that engineering graduates are weak in 21st century skills (Batiyeh & Naja, 2010). Because of these issues, not only do 21st century skills need to be integrated into the curriculum, they need to be assessed regularly.

This paper aims to assess computing students' proficiency in one of the key 21st century skills, problem-solving. This is accomplished through the implementation of the Computing Professional Skills Assessment (CPSA), an assessment instrument that uses a scenario-based asynchronous discussion board to assess student groups' ability to problem-solve (Danaher, Schoepp, Rhodes, & Ater Kranov, 2019). The ability to solve problems has been rated with top importance and as a core activity within the engineering field (Passow & Passow, 2017). These problems are workplace problems, not word problems with a single answer. They are ill-structured, complex, open-ended, collaborative, have multiple solutions, and may have conflicting goals (Jonassen, Strobel, & Lee, 2006). The ability to solve such problems is key to successful employment and being able to contribute in a meaningful manner to a knowledge society.

The remainder of this article provides the overall background and description of the instrument and method used to assess problem-solving, followed by a discussion of the findings. Results show that for the three problem-solving criteria, problem identification, recommendations for solutions, and stakeholder perspective that students often failed to meet the target level of performance even though there was a general increase in performance from the 2nd, 3rd, 4th year, and master's levels. All of this points to the need for more robust integration of problem-solving ill-structured workplace problems throughout the computing curriculum.

RESEARCH QUESTIONS

The importance of 21st century skills, especially the ability to solve ill-structured, complex, and open-ended problems within the fields of engineering and computing is paramount to academic and workplace success. Because of this, an overarching research question along with a set of sub-questions pertaining to the amount of, types of, and sophistication of problem-solving have been devised.

1. What are the abilities of students to solve ill-structured, complex, and open-ended problems within the computing program?
 - 1.1. What is the prevalence of problem-solving within the discussions?
 - 1.2. How does problem-solving manifest itself throughout the discussions?

- 1.3. Are there differences in the way problem-solving is manifested based on students' year of study?

LITERATURE REVIEW

Research into computing and engineering student problem-solving consistently brings forth two major themes. The first theme is that the ability to solve ill-structured, complex, workplace driven problems is essential to employment. The second theme is that curricular modifications are needed if students are going to meet learning outcomes pertaining to problem-solving. Jonassen, Strobel, and Lee (2006) noted that learning to solve well-framed problems in the classroom does not lead automatically to graduates to be able to solve the complex, multidimensional types of problems they will encounter in the workplace. Because of this, real world problems need to be integrated into curricular experiences to prepare graduates for 21st century employment.

The ability to solve problems in the workplace has always been recognized as imperative to workplace success, especially for computing and engineering graduates where problem-solving is often a main responsibility. In fact, researchers have recently stated that “problem solving is the core of engineering practice” (Passow & Passow, 2017, p. 475), and others have noted previously that practicing engineers are hired and retained for their ability to solve problems (Jonassen et al., 2006). Passow and Passow’s (2017) review of what engineering programs should emphasize found that an engineer’s ability to solve problems was the most important skill and core engineering practice. Regarding time usage, Robinson (2012) discovered that practicing engineers spent nearly 39% of their time understanding information and problem-solving, which were by far their most dominant skills. In essence, engineers are seen as problem-solvers and engineering as a method of solving problems (Korte, Sheppard, & Jordan, 2008).

The issue that arises is that while employers view engineering graduates as bright and technically sound, they also view them as weak in the 21st century skills such as teamwork, leadership, critical thinking and, most importantly for our purposes, problem-solving (Ellis & Peterson, 2011). Part of this issue seems to occur because of the misalignment between the types of problems faced in educational programs and the types faced in the workplace. Many of the problems faced by engineering students lack the complexity, ambiguity, and contextualization that make workplace problems so challenging. Most workplace problems also require extensive teamwork in which different knowledge and skills are distributed amongst team members and can be solved in numerous ways with project success rarely measured by only engineering standards (Jonassen et al., 2006). The problems most often faced by engineering students when they are in school are end-of-chapter textbook problems designed to assess knowledge of important concepts that follow a systematic path of reasoning (Douglas, Koro-Ljungberg, McNeill, Malcolm, & Therriault, 2012; McNeill, Douglas, Koro-Ljungberg, Therriault, & Krause, 2016; Shaw, 2001). Hence, it is important to ensure that the curriculum embeds workplace problem-solving because learning to solve well-structured [classroom] problems does not necessarily transfer to solving ill-structured workplace problems (Jonassen et al., 2006).

Though there are certainly schools and programs that embed ill-structured, workplace problem-solving into the curricular experiences of students, this remains an area in need of improvement in engineering and computing education. In response to this, it is generally agreed that “if we hope to educate a workforce and citizenry who will be equipped to thrive in an increasingly complex and interdependent world, we need to incorporate twenty-first-century skills into a wide range of educational curricula” (Stawiski et al., 2017, p. 336). As early as ABET’s Engineering Criteria 2000 document has the need for 21st century skills, including problem solving, been used as the impetus for curricular change (ABET, 1997). McNeill et al. (2016) have demonstrated that because students have difficulty solving ill-structured, complex, open-ended problems, students need engage with these types of problems early and throughout their coursework, so they gain experience dealing with constraints, ambiguity, and numerous possible solutions. Morin, Thomas, and Saadé (2015) also believe that these types of problems should be included when working in an online environment because

this is the future of much collaboration. Currently, many programs seem to include more open-ended problem-solving experiences in their first and final years of study, but this needs to be changed so that students practice these skills throughout their years of study (Douglas, et al., 2012). Besides incorporating this type of problem-solving throughout the curriculum, this type of problem-solving should also be collaborative because that is the type of problem-solving in which working professionals engage (Jonassen et al., 2006; Zou & Mickleborough, 2015). This may mean shifting to more of a problem-based curriculum that has meaningful collaboration, including evaluations, embedded into it (Jonassen et al., 2006). In fact, during such a course redesign Stawiski et al. (2017) found that students reported more improvement in “problem-solving suggesting creative and innovative solutions to help solve project challenges” (p. 344). Beyond the classroom, internships have shown to be effective mechanisms to promote numerous skills and competencies including problem-solving. Through a large-scale survey and a set of targeted interviews, Strayhorn & Johnson (2016) asserted that there is “persuasive evidence supporting the conclusion that engineering majors engagement in internships and co-ops produce significant learning gains in terms of problem-solving, communication, and learning more about work” (p. 10). In support of this, Floyd, Johnson, and Rabb (2017) have found that students recognize the importance of internships to enhance problem-solving skills. During a summer internship program with 2nd and 3rd year engineering students, Floyd et al. found that problem-solving was the skill students felt was most developed through their summer experience. If curricular modifications, whether inside or outside of the classroom are made, the disconnect between engineering and computing education and the focus on the technical skills will be minimized, so that students are better prepared to solve workplace problems.

METHOD

In order to collect student data pertaining to problem-solving this study utilized the Computing Professional Skills Assessment (CPSA). The CPSA is an assessment tool that has continually been improved over the past six years (Danaher, Schoepp, Ater Kranov, & Wallace, 2018) and has been used with both undergraduate and graduate students (Danaher, Schoepp, Ater Kranov, 2017). The CPSA is an assessment method able to assess all six of ABET’s Computing Accreditation Commission’s (CAC) professional skills learning outcomes that are problem-solving, teamwork, ethical, legal and security aspects, communication, impacts of computing, and continual learning. The CPSA learning outcomes have changed slightly to have different wording than that of the CAC in order to be better aligned with the CPSA method. Table 1 shows the alignment between the CPSA and ABET CAC as they pertain to problem-solving.

Table 1: Problem-solving learning outcome alignment

CPSA	ABET CAC
1- Students problem solve from a computing perspective.	(b) An ability to analyze a problem, and identify and define the computing requirements appropriate to its solution.

For the CPSA, the learning outcome of problem-solving has been simplified slightly, but the CPSA includes an expanded definition that is used to guide the criteria for the rubric (see Table 2). The criteria are 1) problem identification, 2) recommendations for solutions, and 3) stakeholder perspective. While problem identification and recommendations for solutions are obvious criteria for the skill of problem-solving, stakeholder perspective is also important because a focus on this forces participants to examine alternate perspectives which is frequently important to the development of meaningful solutions. The rubric has six levels of performance and is scored from 0 to 5. The five levels are 0- Missing, 1- Emerging, 2- Developing, 3- Practicing, 4- Maturing, 5- Mastering. Levels 1 and 2, and levels 3 and 4 share the same descriptors as they are seen as closely related.

Table 2: The problem-solving skill in the CPSA rubric

Definition: Students define and differentiate between the problems raised in the scenario with reasonable accuracy. Students recommend potential non-technical and technical solutions from a computing perspective. Students identify relevant stakeholders and explain their perspectives.						
	0 - Missing	1 - Emerging	2 - Developing	3 - Practicing	4 - Maturing	5 – Mastering
Problem Identification	Students do not identify the problems in the scenario.	Students begin to define the problems. Attempts to define the problems may be general, narrow, and/or inaccurate.		Students define the problems with reasonable accuracy and differentiate between them with limited justification.		Students do not identify the problems in the scenario.
Recommendations for Solutions	Students do not make any recommendations for potential solutions.	Students may recommend potential solutions that don't fit the identified problems. Students may make recommendations for potential solutions without identifying the problems first.		Students do not make any recommendations for potential solutions.		Students may recommend potential solutions that don't fit the identified problems. Students may make recommendations for potential solutions without identifying the problems first.
Stakeholder Perspective	Students do not identify stakeholders.	Students begin to identify stakeholders and their perspectives.		Students explain the perspectives of major relevant stakeholders and convey these with reasonable accuracy.		Students thoughtfully consider perspectives of diverse relevant stakeholders and articulate these with clarity and accuracy.

The CPSA is implemented through the use of an asynchronous online discussion board and is comprised of 1) a short computing-related scenario- there is a pool of equitable and similar-in-structure scenarios as different scenario topics are better aligned with specific courses, 2) a standard set of instructions and guiding questions, and 3) an analytic rubric with sections for problem-solving, teamwork, ethical, legal and security aspects, communication, impacts of computing, and continual learning. The procedure to use the CPSA is that small groups of approximately 4-5 students working online read a 1.5 page scenario related to computing in which an ill-defined, real-world problem that has no exact answer is addressed. Guided by the set of prompts and guiding questions, for 12 days students discuss the scenario and attempt to develop a reasonable solution to the problem posed. When the discussion ends, the discussion transcripts are evaluated according to the criteria presented within the CPSA analytic rubric by a team of trained faculty. In order to increase the students' familiarity with using the discussion board and the CPSA itself, prior to having a discussion formally assessed by faculty, students do a practice discussion where upon completion the strengths, weaknesses, and best practices of the discussion board transcripts are reviewed with their instructor.

The theoretical underpinning for the CPSA method comes from Vygotsky's sociocultural theory (Vygotsky, 1978) and the Communities of Inquiry Model (The Community of Inquiry, n.d.). The former states that social interaction is essential to learning and that it is in the *zone of proximal development* where learners can interact with peers to advance learning. The latter model, designed specifically for asynchronous online discussion boards, includes both cognitive and social presence. Cognitive presence represents socially constructed knowledge developed through continuous communication, while social presence represents open and honest communication that is required to facilitate the development of cognitive presence.

SAMPLE

Following approval from the institution's Research Ethics Committee, online discussion transcripts from courses appropriate for CPSA utilization, and where students had given consent to participate, were collected from the institution's learning management system. These transcripts were then collated and anonymized to ensure that student identities remain confidential.

At the time of this study, computing students from the 2nd, 3rd, 4th year, and master's levels had agreed to participate in this research. A number of faculty had agreed to utilize the CPSA in their courses. The process of sample collection was first to randomly select one participating course from each year of study and then randomly choose one group's discussion transcript from each of those courses. Each set of discussion transcripts represents a single student group of 4-5 students for a total sample size of 19 students.

The student population from where the sample was taken is highly homogenous in that all of the students are Emirati nationals, most are first generation tertiary students at the traditional post-secondary age, Arabic is the native language, English is a foreign language, and at the undergraduate level students study in a gender segregated environment. Through the process of randomization, the selected undergraduate sample were all female Emiratis ages 18-24, while the master's students were a mix of male and female Emiratis ages 24-35.

ANALYSIS

For the initial phase in data analysis, general data concerning number of posts, total word count, and the mean length of posts was calculated. For the main phase of data analysis, the discussion posts were analysed using the framework provided by the CPSA rubric. Because online discussions offer ready-made transcripts, a form of transcript analysis was used to analyze the texts (Garrison, Cleveland-Innes, Koole, & Kappelman, 2006). Breen (2015) describes transcript analysis as a way to make valid and reliable interpretations from texts to their unique contexts. In this instance, the context was that groups of computing students from a face-to-face environment were participating in an online discussion where they were expected to begin to solve a problem and propose workable solutions as part of a team.

The ratings process itself was iterative in nature and began through an initial reading and re-reading of all of the discussion posts. Posts that contained aspects of problem identification, recommendations for solutions, or stakeholder perspective were identified and labelled. These posts were then re-read and the pertinent aspects were color-coded according to the criteria represented. In the next phase, the entire group of a specific criteria, for example, problem identification, were re-read and given an initial rating of 0-5 using the pertinent descriptors from the rubric. These rated posts were then re-examined and any of the initial ratings that seemed incorrect were adjusted. When completed, all data for each year of study were tabulated.

Some of the posts have been included as examples within the results section in order to strengthen the findings by utilizing student voice. In using the student posts as examples any grammatical or spelling errors have been corrected to ease the readability, while at the same time ensuring that the meaning has not been altered. Because a variety of scenarios were used in different classes, there is a

selection of topics on display as part of the student voice, specifically illegal downloading, encryption, and privacy on social media.

RESULTS

Initial results are shown by year of study and include general numerical data about the posts, overall instances of problems, solutions, and stakeholders, and then concludes with specific instances and ratings of problems, solutions, and stakeholders. This data helps answer research question 1.1. *What is the prevalence of problem-solving within the discussions?* The data that follows assists in answering research questions 1.2. *How does problem-solving manifest itself throughout the discussions?* and 1.3. *Are there differences in the way problem-solving is manifested based on students' year of study?* Examined in their entirety, the data offers a robust representation of problem-solving as it emerges within the CPSA across a range of years of study and addresses the overarching research question 1. *What are the abilities of students to solve ill-structured, complex, and open-ended problems within the computing program?*

General data about the discussion posts are presented within Table 3. Though group sizes were similar, there were large differences in number of posts, total word count, and the mean length of posts. With the number of posts, both 2nd year and master's students had at least 33 independent posts, while 3rd year and 4th year had only 21 and 23 respectively. Total word count followed a similar pattern with master's students having written over 7000 words, 2nd year students more than 5500 words, while 3rd year students had only 2646 words and 4th year 4714 words. For the mean length of each post, master's students were at 214, 4th year at 205, and 2nd year at 165. The one anomaly was that the 3rd year students only averaged a post length of 126 words, which was far less than any of the others.

Table 3: Discussion post data

	Posts	Words	Post- Mean length
2nd year	34	5635	165.7
3rd year	21	2646	126.0
4th year	23	4714	205.0
Master's	33	7065	214.1

The next set of results illuminate the degree to which each group of students wrote about problems, solutions or stakeholders as these are the criteria that encompass the problem-solving component of the CPSA rubric. Each individual discussion post was analysed for these criteria and was labeled accordingly. Of course, it is possible that one post contains more than one criteria as it is quite natural for a student to write about both problems and solutions in a single posting, or describe how a problem might impact a specific stakeholder for example. Figure 1 presents this data as simple counts. Perhaps the most obvious count is that the 2nd year students had 28 instances of a post discussing the problems that was the highest number recorded across any of the criteria by year of study. Another data set of interest emerged from the 4th year students in that they had by far the fewest total number of posts referring to the three criteria with only 23 instances in total. Stakeholders, an important aspect of problem-solving in order to view the problem from multiple perspectives, was an area where all student groups but for the master's students recorded few instances. Master's students discussed stakeholders and their perspectives 13 times, while the other three groups combined only discussed them 18 times combined. The end product of effective problem-solving must be solutions, and with solutions it was again the master's students with the most posts discussing solutions at 25. Third year students were next with 23 posts, then 2nd year at 16 posts, and finally the 4th year group at only 6 solutions discussed. While instances help answer the first research question about prevalence of problem-solving in the discussions, prevalence is not an

indication of quality of the discussions. The quality construct emerges through the upcoming instances and ratings tables and the qualitative analysis.

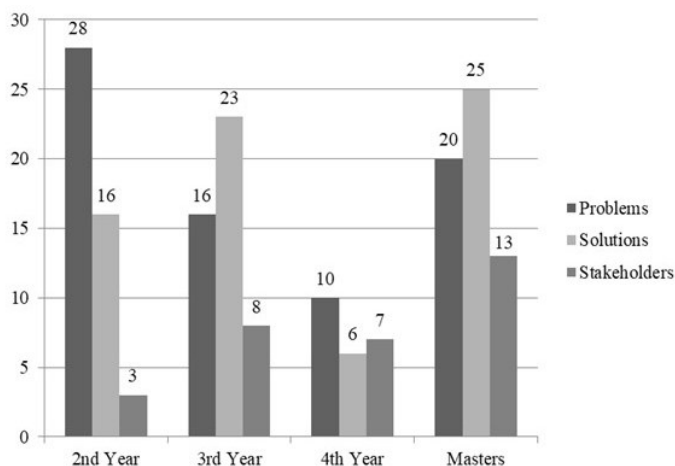


Figure 1: Instances of problems, solutions, and stakeholders

Taking the instances data and further breaking it down according to the actual ratings of each post is essential to identify the quality of the posts. This also allows us to illuminate differences in the quality of posts between year of study. Overall, whether analysing the constructs of problem, solution, or stakeholder there was a trend towards the more senior students achieving higher ratings for their posts. Given that the CPSA rubric has been designed in such a way as to roughly align with year of study, that is, the target for 1st year students is a CPSA rating of 1- Emerging, the target for 2nd year students is a CPSA rating of 2- Developing, and so forth, the ratings appear to support this alignment. Results will first be presented by problem identification, then recommendations for solutions, and finally stakeholder perspective. Each of these criteria are then described from 2nd year to the master’s level. As evidence to the ratings given, examples of student posts will be included throughout this section.

Table 4: Instances and ratings of problem identification

	Missing 0	Emerging 1	Develop- ing2	Practicing 3	Maturing 4	Mastering 5
2nd Year	5	23				
3rd Year		7	9			
4th Year		1	2	5	2	
Master’s		1	6	9	1	3

For Table 4, problem identification, 2nd year students failed to achieve even a single rating at the desired score of 2. In fact, on 5 occasions they were rated a 0- Missing because they were completely off topic. One student began to discuss issues surrounding security of information networks, an unrelated topic, while a number of other students contributed to this discussion thread without attempting to get the discussion back on track. For example, one student wrote the following about problems related to network security:

Security is important for home networks as well as in the business world. Most homes with high-speed internet connections have one or more wireless routers, which could be exploited if not properly secured. According to Georgetown University the risks that threaten the security of information networks are technology with weak security such as passwords, third party entry and lack of encryption.

While this post and some of the others were well-crafted and posed problems, they did not discuss the topic being examined and were scored accordingly. The remaining 23 posts were rated as a 1-Emerging. Also for problem identification seven of the posts of 3rd year students were rated as a 1 and 9 were scored 2. An example of a 1 from this group is:

The music and movie companies suffer from piracy because they lose sales and increases in intellectual property protection costs. Moreover, it affects the government in terms of lost tax revenue.

Though the students identified the associated financial implications of online piracy, it has been done in a haphazard manner with no additional evidence or details provided to support what they have written. For an example of a post rated as a 2, a student shared:

Illegal downloading is an issue that is not taken very seriously, probably because millions of people do it, and they get away with it. The primary issue in the article is illegal downloading, and the secondary issue is people not getting punished for their crimes. The problem isn't awareness, because in my opinion, all online users illegally downloading music or movies are aware that this is illegal and that they are stealing.

Through this post the student was able to present a more nuanced understanding of the issue because they recognized that downloaders know what they are doing is wrong but do not seem to care. The student understands clearly some of the problem, but they do not add any additional evidence as support, or to begin to delve into the other complexities that exist. Fourth year students had a single post rated 1, two rated 2, five scored 3- Practicing, and two at 4- Maturing with problem identification. Posts rated as a 3 or 4 in problem identification are described in the CPSA rubric as- students define primary and secondary problems with reasonable accuracy and with justification. An example of a post rated 3 is:

According to the article provided, the primary problem is the type of encryption used in some mobile apps like WhatsApp that is unbreakable. It makes it hard for the government to access data in any emergency that requires hacking. The secondary problem is that PKC (Public Key Cryptography) has some disadvantages regarding the privacy. As mentioned in the article, some countries spy on their citizens any terrorism related actions.

In this post the students is identifying both primary and secondary problems and begins to explain why these are problems. The post begins to get at the complexities and trade-offs between ensuring privacy and yet maintaining security especially as it pertains to terrorism. Two posts were rated as 4, this post is an exemplar:

I think that the primary issue that was discussed in the article, was whether or not governments had the right to spy on its citizens. It mentioned that some countries like Japan and Netherlands support strong encryption and give their citizens privacy of communication, while others - such as Turkey and Pakistan – have strict laws against that. There is a huge, globally scaled debate about this topic; with people either siding with it being acceptable or unacceptable. According to a poll conducted by... The second issue at hand here is that people in general think it okay for governments to monitor suspected terrorists, and anything that might cause a breach in national security. ...But they will not accept monitoring their own self.

Master's students had a range of scores from 1 to 5- Mastering, and though the majority of scores were rated as 2 (6 times) or 3 (9 times), they were the only group to achieve 5's for problem identification. The descriptor for a post to be scored a 5 is- students convincingly and accurately define the primary and secondary problems, providing justification. An exemplar of a 5 is:

The primary cause of the problem is that people do not want to pay for content. Most individuals who opt to download music, software or films illegally want the content for free, and whenever an opportunity presents itself, they take it. Torrent websites and other sites to illegally download files are fuelled by these type of people causing massive financial rip-offs to the content creators. Secondly, these people may not be in a position to purchase the files they want, and downloading illegally might be their only option. For example, the music subscription platform iTunes requires quite a substantial monetary commitment. Additionally, software like the Windows Operating system or Adobe Photoshop is very expensive. For individuals who defend copyright, the argument may be that if you cannot afford it, leave it alone. However, for as long as people want to access content that

they need and it is unaffordable, they will prefer to obtain it illegally if they can (Aguilar & Martens, 2016). Thirdly, many times music, films and software are not available legally in some regions or country. Content creators limit access for certain reasons, mostly economic and the populations there are deprived of a legal access.

In this post, the student shared three causes of the problem, and provided a justification that others did not when they recognized high cost and the lack of availability that may push people towards illegal downloading. In addition, to strengthen their argument, they have cited some supporting work.

Table 5: Instances and ratings of recommendations for solutions

	Missing 0	Emerging 1	Developing 2	Practicing 3	Maturing 4	Mastering 5
2nd Year		12	3	1		
3rd Year		17	6			
4th Year			2	3	1	
Master's		1	5	10	9	

Table 5 offers the instances and ratings for each of the student groups for the quality of solutions provided. Second year students discussed solutions numerous times, but the vast majority (12 times) of their discussions were rated as a 1- a rating of 1 means that potential solutions may be general or naïve. Four other posts were scored as a 2 or 3. Two examples of posts rated as a 1 are:

A solution to this problem is to monitor the teens' social media activity.

I recommend social media addicts limit their daily usage in social media and get a new hobby.

While these are certainly solutions, they are quite general and naïve in that the solutions sound simple but would be terribly difficult to implement or put into action. Monitoring a teen's use of social media would not be easy for parents and being an addict means one is stuck in an addiction cycle that is difficult to break. Third year students did not demonstrate much more proficiency in recommendations for solutions than the 2nd year students. In fact, they had no posting rated as a 3, but they were rated a 2 on six separate occasions. Though a 2 is again defined as general or naïve, these posts are superior in their sophistication:

The entertainment industry can consider lowering their prices since their competition (the Internet) is offering the same product for free even if it is illegal. Blocking access to illegal file sharing websites is also another way, but it won't stop new file sharing websites from popping up.

These are more sophisticated posts in that the solutions are solutions that have actually been implemented, but the complexity of lowering prices remains, for example, quite general. How, in what ways, and to what level, would prices be lowered to combat pirating are just some of the questions that arise. Though 4th year students only discussed six solutions, four of the six were rated as a 3 or 4, which is more in line of what would be expected for senior students. For a rating of 3, students are expected to offer evidence that they have begun to formulate potential solutions from a computing perspective. In discussing the topic of encryption, a student

mentioned the idea of creating a backdoor into these encrypted applications. That only a few could access with a court order, and in serious matters.

The student demonstrated an understanding of the serious nature of back doors for encrypted applications but still felt they are essential in important matters. Finally, for solutions, it was the master's students who provided the most advanced solutions in that 19 out of 25 were rated as a 3 or 4. Examples of some of the 4's are:

The facts about Internet piracy should be included in the school curriculum, that will give the next generation solid piracy awareness, and it also will make sure that they will be ready to make logical and conversant decisions about electronic theft. Education will emphasize the consequences of copyright infringement to the next generation, but parents also should participate in educating their children about the risks of Internet piracy before teaching them how to use a computer (Solutions for Digital Piracy, 2007).

Therefore, the awareness should start from the educational sectors in committing as part of their duty to plant the concept of copyright and its importance. This could be done through several methods like seminars, programs, awareness emails, and sessions. Additionally, universities should send warning emails to those detected of illegal downloading and set penalties for them.

These responses go far beyond less advanced posts where the solutions were often nothing more than raise awareness. Questions of to whom the awareness raising should be targeted or what the focus of awareness raising should be was rarely addressed. Unfortunately no students, master’s students included, had solutions rated as a 5 in which they suggest detailed and viable potential solutions from a computing perspective. While possibly viable, the two examples of a 4 could not be described as detailed.

Table 6: Instances and ratings of stakeholder perspectives

	Missing 0	Emerging 1	Develop- ing2	Practicing 3	Maturing 4	Mastering 5
2nd Year	2	1				
3rd Year		5	3			
4th Year			5	2		
Master’s		1	3		7	2

Stakeholder perspective, presented in Table 6 above are an area where again as students progressed through the program, many of their responses were rated higher than the previous year of study, and master’s students showed a much more mature understanding of stakeholder perspective. Beginning with 2nd year students, there is a clear lack of awareness where stakeholders are concerned. In fact, two of the three posts about stakeholders were rated as a 0 because students do not identify stakeholders. In the example post that was scored a 0 below, the student has simply copied a paragraph about stakeholders that is unrelated to the scenario under discussion:

Some examples of key stakeholders are creditors, directors, employees, government (and its agencies), owners (shareholders), suppliers, unions, and the community from which the business draws its resources. Not all stakeholders are equal. A company's customers are entitled to fair trading practices but they are not entitled to the same consideration as the company's employees. An example of a negative impact on stakeholders is when a company needs to cut costs and plans a round of layoffs.

Third year students had 5 posts rated a 1 and another 3 rated as a 2 for stakeholder perspective. A score of a one is described as students beginning to identify stakeholders and their perspectives. Unlike more highly rated posts, these posts lack depth even though they demonstrate a knowledge of some obvious stakeholders. For example:

another stakeholder for piracy issues are the singers and the actors because they will lose big amounts of money because of the drop off in music and movie sales, and they may lose their job also.

Of the 3 posts rated a 2, still below the target for 3rd year students, a student shared two clear stakeholders and were able to provide more than one explanation as to how a stakeholder is impacted. However, they were not able to provide much detail.

In my opinion, the stakeholders of music and movie piracy are the companies of these music and movies and the government of the country.... The music and movie companies suffer from piracy because they lose sales and

because of rising intellectual property protection costs. Moreover, it affects the government in term of lost tax revenue.

Students in the final year of the undergraduate program achieved two posts rated 3 and another five scored a 2, again below their target of a 4. To be rated a 3 students need to explain the perspectives of major relevant stakeholders and convey these with reasonable accuracy. An exemplar of a 3 from 4th year students is:

The major stakeholders are the government, but I would like to add that the users and the companies are also stakeholders in this case. The difference between the three stakeholders is the level of understanding how encryption works and why to use it. The companies are trying to satisfy the users' needs. In this case, the users are supporting the idea because they want to keep their own privacy safe, while the government has argued against this so they can investigate and predict any terrorist actions. The companies are trying to maintain the users' private life, but the government still has some other ways to gain access and keep track of any suspicious action.

This post has a few stakeholders and accurately conveys some of their perspectives. Master's students were the only students to be rated a 4 or 5, and so were the only cohort to achieve their target, which was a 5. To be rated as a 4, students need to explain the perspectives of major relevant stakeholders and convey these with reasonable accuracy but have this done to a more sophisticated degree than would be a score of 3. With seven posts having been rated a 4, there were many examples to choose from. One of the exemplars is:

Governments are major stakeholders in piracy. This is because they have the obligation to protect people's work and efforts. As my colleagues mentioned previously piracy affects the industry and by this economy is affected. So far governments have placed policies and sanctions to stop piracy. This is considered not enough as piracy is still growing every day. Governments cannot stop this because the Internet is a vast mass of communications and it cannot be stopped once it is online it cannot be stopped.

Though this post described other stakeholders, for the government stakeholder they demonstrated an obvious grasp of key elements as it relates to online piracy. To be rated a 5, students should thoughtfully consider perspectives of diverse relevant stakeholders and articulate these with clarity and accuracy as is done in the example below:

In my opinion, the primary stakeholders are the artists, end users, and the hardware industry. Firstly, the artists, as I describe them, include all of artists, singers, composers, songwriters, filmmakers, software developers, authors and publishers. Illegal downloads directly affect them financially, and it is therefore in their best interests to protect their intellectual property. These stakeholders view piracy as a significant financial barrier, which does not allow them to grow as content creators. For established stakeholders, piracy needs to be stemmed with strict copyright laws (Fetscherin, 2004). Secondly, end users are the interested parties in the industry, both individuals and organizations like schools and libraries. Individual consumers of digital content are against restrictions on content usage and access and perpetuate piracy, either knowingly or unknowingly. These users are against piracy laws and copyright regulation that paint them as criminals. Organizational consumers like schools and libraries are concerned with fair usage and privacy but are against excessive control as it may affect their activity (Fetscherin, 2004).

This example was one of two that achieved the target of 5 and showed the sophisticated levels of understanding possessed by the graduate students.

DISCUSSION

This discussion is framed around the answers to the four research questions as this provides an explicit narrative that targets the core elements of this study. After discussing the general prevalence of problem-solving within the discussions, the three criteria for problem-solving, problem identification, recommendations for solutions, and stakeholder perspective are discussed according to student performance.

In terms of number of posts there was no real trend as second year students posted more than any other group, while in terms of length of posts a more obvious trend appeared. Master's students had the longest posts trailed closely by the 4th year students. Perhaps it is that the more advanced learners had more to say when they posted which does point to more sophisticated and detailed postings, something which did emerge when the three problem-solving criteria were assessed. Further examination of the prevalence of problem-solving in the discussions showed both stakeholder perspective and recommendations for solutions had more posts from master's students than any other student cohort. Especially with stakeholders, the master's students seemed to have far more to say than any of the others in that the master's students had 42% of all the discussion about stakeholders. Conceivably, because the master's students are working professionals, they have a richer understanding of stakeholders and those impacted by computing decisions that they are involved in through the workplace. This could be an area where workplace experience is essential, so effective curricula needs to get students into work environments (Floyd, Johnson, & Rabb, 2017; Strayhorn & Johnson, 2016).

The first criteria represented within the CPSA is problem identification. Of course, the ability to identify a problem is the initial step in being able to effectively solve a problem, especially when the problem is ill-structured, open-ended, and with no obvious answer. One consistent theme that emerged with problem identification is that overall students did not achieve the targets as established in the CPSA. Accepting Passow and Passow's (2017) finding that problem-solving is an engineer's most important skill, this points to a serious weakness. Remembering that there is a rough alignment between year of study and rating on the rubric (5- Mastering for master's students, 4- Maturing for 4th year students, and so forth), while students at times reached the target, more often than not they fell short of their ratings. With problem identification only a few 4th year and master's students achieved their respective target ratings of 4 and 5. However, a pattern that did emerge is that the senior students outperformed consistently the more junior students even if the targets were not being met. Viewed holistically, it seems as though student skills in problem identification improve as they proceed through the program. Early in the program it is a skill with major deficiencies, but nearing graduation or in the graduate program, students are beginning to identify problems at a much higher rate. While it is certainly positive that improvement is occurring, the fact that targets are not being met suggests that curricular revision towards a more problem-based curriculum as proposed by Jonassen, Strobel, and Lee (2006) should be considered.

Recommendations for solutions is the second criteria for problem-solving represented in the CPSA. This criteria is of the utmost importance because it is where students actually put forth solutions to the problem they have encountered in the scenario, and researchers (Passow & Passow, 2017) have argued that problem-solving is the core skill for engineers, while others (Robinson, 2012) have noted that it is the skill in which they are most engaged. Similar to the problem identification criteria, recommendations for solutions was an area where most of the student groups did not meet the target. In fact, only the 2nd year and 4th year student groups had any ratings at or above their expected levels with the 2nd year student group having the only rating of a 3 which is above the target. In addition, investigating recommendations for solutions overall, there was a less obvious pattern where the more senior students put forth more sophisticated solutions than the junior students. While the master's students did have the most advanced solutions, they also had numerous solutions well below expectations. Clearly, this is a skill that must be improved across the entire range of students and needs additional curricular interventions because these are the types of problems, ones that are ill-structured, open-ended, and with no obvious answer that have been identified as key to workplace success (Jonassen et al., 2006; Passow & Passow, 2017). In addition, students have to work on with these types of problems early and throughout their coursework, not just at specific points or the end of their program as often occurs (McNeill, et al., 2016).

The final criteria that is used to describe the construct of problem-solving is stakeholder perspective, an important criteria since it provides a way to recognize and understand the perspectives of others. Viewing a problem through multiple lenses like this can only help one develop better solutions and

become a better problem solver. Like problem identification, the pattern that emerged is that the senior students regularly outperformed the more junior students even if the targets were mostly not being met. Moreover, this was the one criteria where the master's students were far superior to the other students. The master's students twice attained their target of 5, and also were the only cohort to even achieve a rating of 4. Again, while speculative it may be that the work experience of the master's students means that they have much more experience thinking about how a computing problem impacts stakeholders because this is an authentic issue one faces in the workplace. If this is the case, a curriculum that promotes work experiences through methods such as internships seems essential (Floyd, Johnson, & Rabb, 2017; Strayhorn & Johnson, 2016). Not only have students recognized that they improve their ability to solve problems, it is where they learn about work and, in turn, the impact of stakeholders.

LIMITATIONS AND FUTURE RESEARCH

There are two major limitations that should be considered when interpreting the results of this study. First is the use of an online asynchronous discussion board, and the second is the use of different scenarios amongst the student cohorts. With the discussion board, an issue may be that because the students lack familiarity with this medium in an academic setting, students are unable to perform to the best of their ability. However, to mitigate against this students engaged in a practice discussion board and received instructor feedback a few weeks prior to the formal assessment component of the CPSA. The scenarios are another potential limitation because a selection of scenarios were used in each of the courses. Different scenarios are used because they are chosen to best align with the curriculum of a particular course. Nevertheless, all of the scenarios are written based upon a set of guidelines and then undergo a rigorous review process before they are implemented into courses. The purpose of this process is to limit, besides the topic, any of the differences between scenarios.

With the current life cycle of the CPSA, the major area for future research has to do with the student population. Currently, research using the CPSA has only been conducted at a single institution with a fairly unique context. Though a pilot implementation has been done at an external organization, this has not led to formal research at this time. Hence, further research needs to be conducted at other institutions or organizations where further checks on instrument validity can be done.

CONCLUSION

Given the importance for the computing field to have working professionals who are able to effectively solve workplace problems that are ill-structured, complex, open-ended, collaborative, have multiple solutions, and may have conflicting goals, curricula that meet this need is essential. Having students practice these skills throughout the curriculum, not just in final year experiences is required if their education is to cultivate meaningful engagement in this 21st century skill. This paper described an instrument and method that uses an asynchronous online discussion board to assess these skills as students problem-solve in teams. Results showed that while students did increase their level of problem-solving from the 2nd, 3rd, 4th year and master's levels, they generally failed to meet the desired level of performance. This supports the proposition that ill-structured problem-solving should be more thoroughly integrated into the computing curriculum in order to meet the demands of the 21st century workplace. In addition, the instrument was effective in assessing problem-solving.

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BIOGRAPHIES



Dr Maurice Danaher is an Associate Professor in the College of Technological Innovation at Zayed University in the United Arab Emirates. He received his PhD in Information Systems in 2003 from Swinburne Institute of Technology, Melbourne, Australia. His research interests are in Information Technology and Quality Assurance in IT Education. He has published his work in these areas and has over 50 refereed publications. He has won a number of grants in the UAE totaling over US\$250,000 for research into quality assurance of IT education.



Dr Kevin Schoepp is currently working independently as a researcher. He has a M.A. in educational technology and an Ed.D. in higher education leadership from the University of Calgary, Canada. Until recently he held the position of Director of Academic Excellence at Jumeira University, Dubai, UAE. Prior to that he was the Director of Educational Effectiveness at Zayed University, UAE. He has published more than 35 articles and book chapters and delivered more than 40 conference presentations. His current research interests include assessment and learning outcomes in higher education.