The Computing Professional Skills Assessment as a Learning Oriented Assessment Task

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Abstract

The Computing Professional Skills Assessment (CPSA) is a method developed by the authors for assessment of the non-technical skills prescribed by ABET, the accreditation body for engineering and technology for computing students. These non-technical skills, referred to here as professional skills, include teamwork, communication and problem solving. With the CPSA teams of about five students analyse a complex, ill-defined problem over a 12-day period through the medium of an online discussion board. The discussion transcripts are subsequently examined using a rubric. This rigorous assessment evaluates all of the professional skills simultaneously and has been proven to be valid and reliable. As it is a demanding assessment running over a period of almost two weeks the authors believe it to also be a very valuable learning activity representative of a learning oriented assessment. To ascertain the learning that occurs through use of the CPSA, it was implemented three times in three sections of a 3rd year computing course. The results which are presented here show that there was considerable learning and improvement in the students' targeted skills over the semester. The students were surveyed on their perceptions of the CPSA as a learning tool at the end of semester. They strongly believed that it is an effective teaching and learning method and that they benefitted significantly.

Keywords: ABET, online discussions, outcomes-based assessment, performance task, rubric, virtual teams

1. Introduction - Teaching and Assessing the Professional Skills

The professional skills, which are also known as 21st century skills, non-technical skills, or generic learning outcomes, refer to knowledge, attributes and abilities such as the ability to work well in teams, to communicate effectively, to solve problems, to think critically, and to understand ethical issues. These skills are desirable because they are transferable across contexts and are supportive towards modern work environments [1, 2]. In fact, some employers have stated that they view these skills as more important than pure technical skills or disciplinary knowledge [3]. The National Association of Colleges and Employers has recently found that three of the top career readiness competencies desired of college graduates are critical thinking/ problem solving, teamwork, and communication skills [4].

Within technical disciplines in the 1990's, reports began to call for reform and more integrated approaches to preparing graduates for a broader range of careers and challenges in an evolving society. For example, in 1995 the US National Science Foundation called for an educational transformation in "Restructuring Engineering Education: A Focus on Change" pointing to the need for a more holistic curricular approach that integrated professional skills [5]. In 1997 ABET adopted Engineering Criteria 2000, a document that placed professional skills at the forefront of accredited engineering programs [6]. This recognition of the importance of professional skills remains a focal point of accreditation to this day. More recently, the key competencies for STEM employees were identified as problem-solving (particularly ill-defined problems), social communication skills, system skills, and time, resource, and knowledge management skills [7]. Support for the assertion that the professional skills are paramount for technical graduates and need to be embedded in curricula is found in a survey of more than 2100 US-based engineering alumni [8]. The survey results identified teamwork, communication, data analysis, and problem solving as essential skills for workplace success. Competency in the professional skills extends to job retention where, in particular, interpersonal and intrapersonal skills, communication with diverse audiences and a commitment to life-long learning are keys to success [9,10].

In today's world these core competencies are cornerstones of most tertiary education programs. Though technical programs now work towards student attainment of the professional skills, effectively and efficiently teaching and assessing these competencies can remain a challenge [11,12,13]. This is not surprising given that many faculty may lack the experience to teach or assess the professional skills, especially since this may not have been a component of their own education or training [14]. This has led to situations where the professional skills are assessed separately rather than concurrently, and through indirect methods like opinion surveys [15]. Some examples of the ways in which professional skills have been assessed include, but are not limited to: reflective portfolios [16,17], take home written exams [18], and student internships [19]. One of the more reliable and comprehensive assessment methods is a scenario-based, small group, face-to-face, 45-minute discussion where students begin to solve an authentic, ill-defined, complex problem [15]. That method showed that all six professional skills identified by ABET could be assessed simultaneously in a reliable and valid manner.

Over the past four years the authors have developed a method known as the Computing Professional Skills Assessment (CPSA) for assessing the six ABET professional skills in the computing discipline. It is a rigorous assessment of the skills where students in teams of five analyse a complex, ill-defined problem over a 12-day period through the medium of an online discussion board. This paper demonstrates the effectiveness of the CPSA, a tool originally designed for program level assessment, as a classroom level teaching and assessment tool.

The research questions addressed in this study are: 1) To what extent do students attain the targeted skills over three implementations of the CPSA during a semester-long course? 2) What are student perceptions of the usefulness of the CPSA in developing the targeted skills?

2. Learning Oriented Assessment

As its name implies, learning oriented assessment is an attempt to frame assessment within the realm of student learning. Whereas previously assessment, especially summative assessment, was seen strictly as a culmination activity to measure student learning, it is now recognized that, if well-structured, assessments can serve a double duty as measures of achievement and as learning mechanisms [20]. Though there is an inherent tension when an assessment serves dual purposes, the emphasis on student achievement of learning outcomes, has meant that assessments should be a useful tool to both promote and measure learning. Leading researcher Carless [20] defined learning oriented assessment as

> an assessment where a primary focus is on the potential to develop productive student learning processes. In particular, the 'right kind' of summative assessment can be fruitful in stimulating appropriate student learning dispositions and behaviors. Summative assessment can be learning-oriented when, for example, it encourages deep rather than surface approaches to learning and when it promotes a high level of cognitive engagement consistently over the duration of a module [20, p. 964].

Carless has further conceptualized learning-oriented assessment as being framed by three interrelated principles: 1) learning-oriented assessment tasks, 2) developing evaluative expertise, and 3) student engagement with feedback [20]. With the first principle, learning oriented assessment tasks, it is imperative that the task be constructively aligned with the outcomes of the curriculum in order to promote worthwhile learning [21]. At a macro-level this is accomplished by the fact that the CPSA outcomes align with specific ABET student outcomes. At a micro-level this is accomplished by implementing the CPSA into courses that have the professional skills at the forefront of their outcomes. According to Carless such learning and assessment is in all likelihood not exam-based, but it is more authentic in that it means students engage with contextualized real-life disciplinary problems [22]. The assessment should promote the type of learning in which we want our students to engage [22].

The second principle, developing evaluative expertise, concerns the ability of students to better understand learning outcomes, so that they can better achieve them [23]. Activities such as examining exemplars and assessment criteria are key to aligning with this principle. As part of the CPSA implementation students review exemplars and discuss strengths and weaknesses of earlier posts and discussions in order to promote evaluative expertise.

The third principle, student engagement with feedback, is the idea that students need feedback in order to engage with it meaningfully which can lead to learning [23]. This means that timeliness and having students do something with the feedback are essential. This principle is manifested by the fact that students get feedback from participation in an earlier round of the CPSA implementation and can apply what they learned. Typically, students do two rounds in a course, and may also have participated during a previous course. Additionally, students receive feedback while taking part in the first round.

The CPSA possesses all the elements of an ideal learning-oriented assessment: it assesses ABET's professional skills; it is tightly aligned with the curriculum; it is rigorous; and it incorporates Carless's three principles of learning-oriented assessment tasks, developing evaluative expertise, and student engagement with feedback.

3. The Computing Professional Skills Assessment

The CPSA is a performance-based assessment that evaluates student attainment of a targeted set of computing professional skills [24, 25]. It does this by having groups of about five students participate in an online discussion forum where they are required to read a computing focused scenario and respond to a set of discussion prompts. The discussion transcripts are then assessed by a cadre of trained faculty using the CPSA Rubric.

The CPSA has been developed and utilized in a United Arab Emirates-based (UAE) computing program accredited by ABET. As an ABET accredited program the curriculum is aligned to ABET's student outcomes, and the CPSA itself is closely tied to ABET's professional skills student outcomes. This alignment means that the CPSA, though designed for UAE students, is appropriate for a much broader audience. In fact, it represents a learning-oriented assessment that is suitable for, not only ABET-accredited programs, but other technical academic programs that include generic outcomes such as the ability to work in teams, the ability to communicate effectively, and the ability to solve problems.

ABET's Computing Education Commission (CAC) have prescribed six professional skills learning outcomes that students should attain by graduation. These are given in Table 1 using the lettering assigned by ABET. After much thought and upon the announcement that ABET would be revising the wording of student outcomes, which would go into effect during a two-year transition period starting the academic year 2018-2019, the research team decided to reword the targeted outcomes in a way that would be more "evergreen" and less dependent on changes executed by external stakeholders. The CPSA student outcomes corresponding to those of ABET are given in Table 1. For example, because we wanted to focus on problem solving outside of a purely technical realm, in CPSA 1 we shifted the focus from defining computing requirements to problem solving from a computing perspective in the CPSA 1. While the CPSA outcomes are indeed task and measurement tool specific, as one would expect with a learning-oriented performance assessment, they can easily be mapped to a range of stakeholder valued learning outcomes.

Table 1. Alignment of ABET and CPSA learning outcomes

ABET CAC Student Outcomes	CPSA Professional Skills Outcomes
b. An ability to analyze a problem, and identify and define the computing requirements appropriate to its solution.	CPSA 1. Students will be able to problem-solve from a computing perspective.
d. An ability to function effectively on teams to accomplish a common goal.	CPSA 2. Students will be able to work together to perform a specific task.
e. An understanding of professional, ethical, legal, security and social issues and responsibilities.	CPSA 3. Students will be able to evaluate professional, ethical, legal and security considerations when solving a problem.
f. An ability to communicate effectively.	CPSA 4. Students will be able to communicate professionally in writing.
g. An ability to analyze the local and global impact of computing on individuals, organizations and society.	CPSA 5. Students will be able to analyse the local and global impacts of computing.
h. Recognition of the need for and an ability to engage in continuing professional development.	CPSA 6. Students will be able to recognize when they need to seek further information to extend their knowledge.

The CPSA consists of: a) a written scenario that includes discussion prompts, b) the rubric, c) a platform for the online discussion and, d) the users' manual. Based on trustworthy sources, the scenario outlines a current complex issue related to computing in broader societal context for student groups to be able to conduct an informed and meaningful discussion. The scenario, of around 750 words, is an authentic cross-disciplinary computing issue that is relevant to both global and UAE contexts. Each scenario includes a set of five discussion prompts which guide the discussion.

The rubric is a criterion-referenced rubric that aligns to the 6 professional skills- a rubric was selected as the scoring mechanism because they promote reliability [26] and they offer meaningful information as to strengths and weaknesses in student performance [27]. After the instructional title page on the rubric document, each of the learning outcomes is presented on its own page that includes the CPSA learning outcome, an expanded definition, and the rubric itself. The rubric is made up of performance indicator/s with a set of descriptors rated from 0 to 5 labelled as *Missing (0), Emerging (1), Developing (2), Practicing (3), Maturing (4) and Mastering (5)*. For example, from CPSA 3. Students will be able to evaluate professional, ethical, legal and security considerations when solving a problem, the descriptors are: *Missing (0)* Students do not identify ethical, legal, and security considerations; *Emerging (1), Developing (2)* Students give passing attention to related ethical considerations and/or may describe only the most obvious ethical considerations; *Practicing (3), Maturing (4)* Students identify relevant ethical, legal, and security considerations in context of the problem(s); *Mastering (5)* Students clearly articulate relevant ethical, legal, and security considerations and evaluate them in the context of the problem(s). The levels represent progressive levels of attainment roughly in line with the years of undergraduate and graduate study. For example, the target level for a 3rd year undergraduate course is 3 *Practicing,* and for Masters level it is 5 *Mastering*. The rubric also includes a comment section where raters are expected to note strengths and weaknesses in the transcripts and identify locations of these examples, so that the ratings are unmistakably evidence-based. The complete 7-page rubric is available by contacting the authors, but for easy reference a one-page version is included as an appendix.

While we use Blackboard as the platform for conducting the online discussion any system that supports online group discussion may be used. The user manual provides complete instructions for faculty on implementation of the CPSA. For example, it gives details on the discussion board setup, it guides faculty on how to coach and assist students, it gives examples of good posts, and it gives guidance on the rating process for the discussion transcripts.

As the CPSA was created for program level assessment the rubric is used for group evaluation. However, as the activity runs as an assignment within a course then the work of each student is evaluated separately for course purposes and feedback to each student. The group evaluation using the rubric is done by a rating team, whereas the individual student grading is done by the course instructor. Typically, the CPSA is run twice in a course due to the learning benefits for students and additionally the first run familiarizes students with the procedure.

4. Method

For this study 56 students in three sections of a third-year course, CIT 305 Information Technology in Global and Local Cultures, participated in three rounds of the CPSA over the spring 2017 semester. First, students received an explanation of the task and goals in the form of a written assignment accompanied by a presentation and class discussion. Examples from previous semesters were viewed so that the students were aware of the expectations. Then the students embarked on a monitored 12-day asynchronous discussion in groups of no more than five. During this initial round faculty closely observed the discussion to ensure that student groups completed the task. Coaching and feedback was given to the groups, but the instructors did not directly facilitate the discussion or participate in it online. Coaching was mainly concerned with explaining the steps in problem solving in line with the given prompts. Additionally, advice was given on how to improve teamwork. At the end of the discussion period, the instructor discussed with the class the strengths and weaknesses that he/she noticed. The work of each student was graded individually and each was provided feedback on how to improve. New student groups were then formed and assigned a new scenario and the discussion activity commenced again. This time there was little coaching unless students had some difficulty, but the instructors monitored the discussion. Again at the end of the discussion period the work of each student was graded and feedback provided. Then a third and final run was conducted with a different scenario. There was no involvement from the instructors in the final round. Each student's work was graded for the purpose of assigning course marks and feedback was given to the students.

Following the final round the students were asked to complete a survey on their perceptions of the benefit of the activity. The survey consisted of 9 Likert-scale items and 3 open-ended questions. The 9 Likert-scale items have been adopted from the Australian Course Experience Questionnaire [28] to enhance validity and reliability with an amendment where the word "course" was changed to 'activity". In this study, due to an implementation problem only two of the three sections completed the survey; nonetheless, this meant that 46 out of the possible 56 students participated in the survey.

At conclusion of the discussions, faculty raters used the CPSA rubric to evaluate the discussion transcripts. For research purposes, a total of 5 student groups, two groups each from two of the larger sections and one group from the smallest section had their transcripts analyzed from the first and third rounds of implementation in order to measure the achievements. In evaluating the discussions it is the group performance that is assessed, not the individual students. The rating team consisted of the three authors. To ensure inter-rater reliability when using the rubric, a consensus estimate approach to rater norming or calibration was adopted [29]. In this approach, individual raters reach consensus based on evidence provided through in the transcripts to get to within one point of each other on each of the six professional skills. This is achieved by rating a single transcript, sharing results, providing evidence from the transcript, and then discussing any discrepancies that may exist until consensus is achieved. After this initial rating session, the process is expanded to the entire set of transcripts. At completion, the result is a set of scores that do not differ by more than a single point on the 6-point scale.

5. Results

When examining the performance of students across the two implementations of the CPSA it is clear that recognizable improvements in student learning occurred. Tables 2 through 6 show the mean score of each of the 5 groups across each of the 6 CPSA learning outcomes and the two implementations that were measured, labeled Rounds 1 and 3. Improvements from the first round to the third ranged from a low of .67 to a high of 3.67 with the median and mode being 1.67, a number which occurred 11 times out of a possible 30 data points. Most strikingly, in each and every case, an improvement in learning was identified. The target score for each of the CPSA outcomes was 3.0, and within the first round this was achieved only once by Group 2 at the learning outcome CPSA 2. The remaining first round data points were below a 3.0. For the third round, the target of 3.0 was only missed two times and both with learning outcome CPSA 5. Groups 4 and 5 were scored as a 2.0, thereby not achieving the target.

Table 2. Group 1 mean scores and improvements

Round	CPSA1	CPSA2	CPSA3	CPSA4	CPSA5	CPSA6
1	1.33	1.67	1.67	1.67	1.33	2.0
3	3.0	3.0	3.0	3.0	3.0	4.0
Improvement	1.67	1.33	1.33	1.33	1.67	2.0

Table 3. Group 2 mean scores and improvements

Round	CPSA1	CPSA2	CPSA3	CPSA4	CPSA5	CPSA6
1	2.0	3.0	2.0	2.0	2.0	2.0
3	3.0	3.67	3.0	3.67	4.0	3.67
Improvement	1.0	0.67	1.0	1.67	2.0	1.67

Table 4. Group 3 mean scores and improvements

Round	CPSA1	CPSA2	CPSA3	CPSA4	CPSA5	CPSA6
1	2.0	2.0	1.67	2.0	2.0	2.0
3	3.67	3.33	4.0	4.0	3.67	3.67
Improvement	1.67	1.33	2.33	2.0	1.67	1.67

Table 5. Group 4 mean scores and improvements

Round	CPSA1	CPSA2	CPSA3	CPSA4	CPSA5	CPSA6
1	1.67	2.0	2.0	2.0	0	1.0
3	3.0	3.0	4.0	3.67	2.0	3.33
Improvement	1.33	1.0	2.0	1.67	2.0	2.33

Table 6. Group 5 mean scores and improvements

Round	CPSA1	CPSA2	CPSA3	CPSA4	CPSA5	CPSA6
1	1.33	1.33	1.67	2.0	0.67	0
3	3.0	3.0	4.0	3.67	2.0	3.67

Improvement	1.67	1.67	2.33	1.67	1.33	3.67

Besides investigating the performance of the individual groups, when examining the cohort as a whole similar trends emerged (Table 7). The overall mean scores for round 1 ranged from 1.20 to 2.0, and the overall mean scores for round 3 ranged from 2.93 to 3.6. The target of 3.0 was not attained with any of the learning outcomes in round 1, but it was achieved with 5 of 6 learning outcomes in round 3. Only learning outcome CPSA 5 at 2.93 failed to reach the threshold of 3. In terms of improvement, that is learning, the range was from 1.20 to 2.20, the mean increase was 1.67 and, in each and every case, improvement was evident.

Table 7. Mean scores and improvements

	CPSA1	CPSA2	CPSA3	CPSA4	CPSA5	CPSA6
Round 1	1.67	2.00	1.80	1.93	1.20	1.40
Round 3	3.13	3.20	3.60	3.53	2.93	3.60
Improvement	1.46	1.20	1.80	1.60	1.73	2.20

Figure 1 is a graphic representation of Table 7 on a radar chart, and visually presents strengths, weaknesses, and degrees of learning. It offers an overall profile of the cohort and shows areas where the greatest growth occurred and areas that may be in need of strengthening. For example, learning outcome CPSA 6 had a low mean score in the first round, but tied for the highest mean score in round 3.

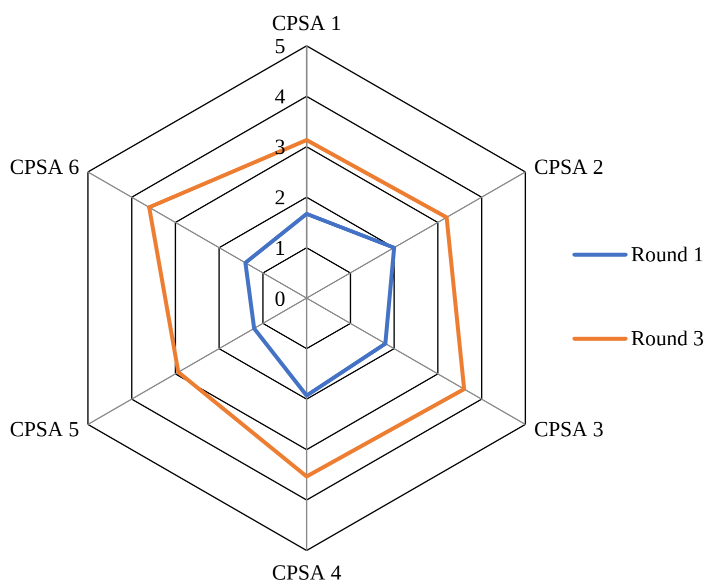

Fig 1. Graphic representation of mean scores from round 1 and round 3

In addition to the evidence of learning, data was also been collected on student perceptions of the CPSA through the use of a 12-item survey. Table 8 presents the nine Likert-scale items in ascending order of mean scores where 5 was *Strongly agree* and 1 was *Strongly disagree*. Additionally, the standard deviation and the dichotomous percentage have been included. The dichotomous percentage is the percentage that either *Strongly agree* or *Agree* was selected and is therefore a strong measure of agreement.

Overall, student perception of the CPSA was quite high. Six of the nine items had mean scores ≥ 4.0 and had dichotomous scores of ≥ 80%. Items related to ethics, impact of computing, communication, and problem-solving were all highly rated. Time management and teamwork were the areas rated lowest. Specifically, the item *The activity* *helped me to develop my understanding of ethical, legal and social issues* had the highest mean score at 4.24, while *The activity helped me develop my ability to work as a team member* had the lowest mean score at 3.67.

TABLE 8. Survey mean and dichotomous scores

	N	Mean	Std. Deviation	Dichotomous %
The activity helped me to develop my understanding of ethical, legal and social issues.	46	4.24	.87	86.96
The activity helped me to develop the ability to analyse the impact of computing on the world.	46	4.11	.85	84.78
The activity helped to improve my skills in written communication.	45	4.07	.94	82.22
The activity helped to develop my problem-solving skills.	46	4.07	.71	89.13
The activity helped to develop my ability to analyse problems.	46	4.04	.87	84.78
The activity helped me to recognize the limits of my knowledge and the need to continue to learn more.	46	4.00	.76	86.96
As a result of the activity, I feel more confident about tackling unfamiliar problems.	46	3.78	.94	73.91
The activity helped me to develop the ability to manage my time and plan my own work.	46	3.76	1.12	69.57
The activity helped me develop my ability to work as a team member.	46	3.67	1.16	65.22

The three open-ended items that were included in the survey had response rates ranging from 91% (42/46) to 83% (34/46). They asked students to share what they liked, disliked, and for ways in which the activity could be improved. Direct quotations from students have been included through the use of italics and, where necessary, have been slightly edited for readability to eliminate spelling or grammatical errors that might impede understanding.

The first open-ended item asked students what they liked about the activity and a few themes emerged. The most dominant theme, that was mentioned 18 times, was group work or being able to discuss and share ideas with one another. Comments like *it was good group work because we learned to* cooperate, *group members can communicate and share their posts together,* and *the way my group interacted together* were representative of this theme. It showed that although this type of discussion activity was new to most students, they appreciated it as a learning activity. The second most prominent theme that occurred 11 times had to do with problem solving and critical thinking. Students wrote things like it *helped me to improve both my analytical and problem-solving skills* and that it also helped *us to improve our critical thinking and solving problems.* It was clear that students recognized that the CPSA demanded these key professional skills from them. The last like that appeared to any significant degree was the positive impact that the activity had on their writing. Five students said things like it *improved my writing skills.* Finally, there were a number of other comments about various areas like leadership skills, the topics, and three comments where students stated they did not like anything about the activity. Given that only five students did not respond to this item, the activity seems to be very well received.

The second open-ended item was opposite to the first in that it asked students to share what they did not like about the activity. Forty-two students responded to this item. The most noticeable subject to emerge had to do with time. With 21 comments about time, students felt that they did not have enough time for the discussions. Comments such as *I wanted to have more time to explore the problem and find more reasonable solution, there wasn't enough time to finish our work,* and that they *need more time to understand* were illustrative of the time concerns that students held. Actually, this is the first time that the activity was run three times in a semester long course and it was primarily for the purposes of this research. The research team agree that three runs is quite onerous on the students. Interestingly enough, the second theme to emerge as a dislike had also appeared as a like- team or group work. As a dislike that was mentioned 8 times, students wrote things like *sometimes our team is not collaborating, group members post their* *replies late*, and *I did not like when people did not work*. A frustration on the part of some students towards team or group members is apparent, but part of effective group work is ensuring that all members participate. This is a skill that must be learnt. The final dislike was related to grades. Seven students felt that the grades were not high enough, but a statement such as *I did not like our marks* cannot be given too much consideration as it lacks justification. Other issues that were mentioned included but were not limited to the topics, the amount of reading, that groups were selected by the instructor, and difficulty of the task. Given the frequency of the lack of time, this will need to be a consideration for future CPSA implementations.

Having queried students for likes and dislikes, the final open-ended item sought feedback into ways to improve the activity. As would be expected, responses were often closely related to the dislikes. The most common suggestion that emerged 14 times was to either increase the time for each discussion or to do less discussions. One student summarized these concerns into a single post by writing *not three discussion boards*, *two would be enough, so we can have the ability and the chance to have more time.* The next most prevalent response occurring 8 times was to alter the discussion topics. This included suggestions to have *more useful topics*, *easy topics*, or *topics that are interesting*. Of course a great deal of deliberation goes into topic selection; the scenarios themselves are written according to strict guidelines, they are reviewed and edited, and curricular alignment is an utmost priority. Finally, four of the students thought that no changes were needed at all to the CPSA activity.

6. Discussion

In terms of addressing the first research question about student learning, Tables 2 through 7 and Figure 1 demonstrate unequivocally that significant learning occurred from rounds 1 to 3. In each and every case, an improvement in mean score was evident and the overall mean improvement was 1.67 or nearly 2 levels of attainment on the rubric. It can be said that the CPSA is a representative learning-oriented assessment since it is an assessment method that facilitates learning. Further, it may be said that repeated use of the CPSA significantly improves the targeted skills.

Concerning the second research question about student perceptions of the CPSA, it is clear that it has been very well received by students given that six of the nine Likert-scale items were rated 4.0 or higher and achieved a dichotomous score of more than 80%. This indicates that students recognize the role the CPSA plays in facilitating their learning and attainment of the professional skills. Via the open-ended response items, students indicated that they appreciated the group aspect of the assignment and that it fostered problem-solving and critical thinking. However, in a somewhat contradictory manner, they expressed frustration with some group members and also rated the teamwork item lowest. Finally, students shared a concern that they wanted more time for each discussion and suggested that this could be partially achieved through eliminating one of three. In previous implementations the activity was just run twice in a course as it is quite an onerous exercise for students. That said, it is clear that the students derived significant benefit through the three implementations and were effectively engaged in their learning.

7. Conclusion

At its inception, the CPSA was to serve as a summative assessment indicating the degree to which students in a computing program were attaining the ABET professional skills. As a group assessment covering all six of the professional skills, faculty, through the use of the CPSA, were able to identify areas of programmatic strengths and weaknesses as it pertained to these essential learning outcomes at different points in the program, including graduate [30] as well as undergraduate levels [29]. This information is useful for assessment and accreditation purposes and leads to curricular or pedagogical interventions if required.

Over time and through numerous implementations, it became clear that the CPSA was more than a traditional one-off assessment tool. Students were very engaged in the task and, besides assessment, real learning was occurring as has been demonstrated by this study. Students improve their abilities in the professional skills with each use of the CPSA. Additionally, the students themselves overwhelmingly agree that it is very beneficial to their learning of the skills. The CPSA has achieved this through adherence to the aforementioned three principles of a learning-oriented assessment: 1) learning-oriented assessment tasks, 2) developing evaluative expertise, 3) student engagement with feedback. In line with the first principle, the task is well-aligned with both the curriculum and ABET learning outcomes, and it is authentic in that students engage with contextualized real-life disciplinary problems. For the second principle, students review exemplars, and discuss strengths and weaknesses of earlier posts. Finally, principle three is manifested through repeated use and the corresponding feedback and discussion that occur as part of the CPSA process.

This study provides evidence that a collaborative problem-solving assessment can both assess effectively and promote meaningful student learning. Further it provides evidence that well-designed assessment tasks that are clearly aligned to learning outcomes can facilitate enthusiastic student participation and lead to enhanced learning and better achievement of outcomes. Given the importance of professional skills, the CPSA has application in computing programs worldwide

8. Limitations of the study

An obvious limitation of this study is that the sample size was quite small. Though CPSA research has previously been conducted with over 400 students [25] this was the first time it was implemented specifically to measure classroom learning within a single semester. Previously, the CPSA has been used to evaluate student proficiency of the professional skills at the program level. Now that the CPSA appears to be a useful learning-oriented assessment within courses, further research into this form of implementation should be conducted such as classroom implementations during other years of study.

References

[1] Falling short? College learning and career success, Hart Research Associates, https://www.aacu.org/sites/default/files/files/LEAP/2015employerstudentsurvey.pdf, Accessed 2 January 2018.

[2] Better skills, better jobs, better lives: A strategic approach to education and skills policies for the United Arab Emirates, Organization for Economic Cooperation and Development, http://www.oecd.org/countries/unitedarabemirates/A-Strategic-Approach-to-Education-and%20Skills-Policies-for-the-United-Arab-Emirates.pdf , Accessed 3 November 2017.

[3] It Takes More than a Major: Employer Priorities for College Learning and Student Success: Overview and Key Findings, Association of American Colleges & Universities, http://www.aacu.org/leap/presidentstrust/compact/2013SurveySummary.cfm, Accessed 24 January 2018.

[4] Job Outlook 2016: The Attributes Employers Want to See on New College Graduates' Resumes, National Association of Colleges and Employers, 2016, http://www.naceweb.org/career-development/trends-and-predictions/job-outlook-2016-attributes-employers-want-to-see-on-new-college-graduates-resumes/, Accessed 24 November 2017.

[5] Restructuring Engineering Education: A Focus on Change. Report of an NSF Workshop on Engineering Education. https://eric.ed.gov/?id=ED382119, Accessed 21 November 2017.

[6] Founding, ABET, http://www.abet.org/about-abet/history/, Accessed 24 November, 2017.

[7] H. Jang, Identifying 21st Century STEM Competencies Using Workplace Data, *Journal of Science Education and Technology*, 25(2), 2015 pp. 284–301.

[8] E. Pardede and J. Lyons, Redesigning the Assessment of an Entrepreneurship Course in an Information Technology Degree Program: Embedding Assessment for Learning Practices, *IEEE Transactions on Education*, 55(4), 2012 pp. 566–572.

[9] D. Deming, The Growing Importance of Social Skills in the Labor Market, *The Quarterly Journal of Economics*, 132(4), 2015, pp. 1593–1640.

[10] C. J. Weinberger, The Increasing Complementarity between Cognitive and Social Skills, *Review of Economics and Statistics*, 96(5), 2014, pp. 849–861.

[11] P. Griffin, B. McGaw, and E. Care, (Eds.) Assessment and teaching of 21st century skills. Springer, London, 2012.

[12] L. J. Shuman, M. Besterfield-Sacre, and J. Mcgourty, The ABET 'Professional Skills' - Can they be taught? Can They Be Assessed?, *Journal of Engineering Education*, 94(1), 2005, pp. 41–55.

[13] K.J. Reid and E.M. Cooney, Implementing rubrics as part of an assessment plan. *International Journal of Engineering Education*, 24(5), 2008, pp. 893-900.

[14] R. M. Felder, *Engineering education: A tale of two paradigms, in Shaking the Foundations of Geo-engineering Education*, B. McCabe, M. Pantazidou and D. Phillips, Eds., CRC Press, New York: 2012, pp. 9-14.

[15] A. Ater Kranov, M. Zhang, S.W. Beyerlein, J. McCormack, P. D. Pedro, and E.R. Schmeckpeper, *A direct method for teaching and measuring engineering professional skills: A validity study*. 2011 American Society for Engineering Education Annual Conference, Vancouver, Canada, http://www.asee.org/public/conferences/1/papers/775/view, Accessed 3 November 2015.

[16] A.D. Christy, *Student portfolios for assessing ABET a-k outcomes*. Proceedings of the 2013 ASEE North Central Section Conference, https://www.researchgate.net/publication/259972436_Student_portfolios_for_assessing_ABET_a-k_outcomes, Accessed 15 January 2017.

[17] S. Richerson, K. McAteer, M. Spencer, and S. Scheibler, *A portfolio approach to learning professional skills*. In Frontiers In Education Conference-Global Engineering: Knowledge Without Borders, Opportunities Without Passports, 2007, IEEE.
[18] D. Lopez, J. L. Cruz, F. Sanchez, and A. Fernandez, *A take-home exam to assess professional skills*, 2011 Frontiers in Education Conference (FIE), 2011.
[19] A. Al-Bahi, M. Taha, and N. Turkmen, Teaching and assessing engineering professional skills, *International Journal of Engineering Pedagogy*, 3(3), 2013, pp. 13-20.
[20] D. Carless, Exploring learning-oriented assessment processes, *Higher Education*, 69(6), 2014, pp. 963–976.
[21] J. B. Biggs and C. S. Tang, Teaching for quality learning at university: what the student does. McGraw-Hill/Society for Research into Higher Education/Open University Press, Maidenhead, England, 2011.
[22] D. Carless, *Learning-oriented assessment: Principles, practice and a project*, in L. H. Meyer, S. Davidson, H. Anderson, R. Fletcher, P.M. Johnston, & M. Rees, Eds. Tertiary Assessment & Higher Education Student Outcomes: Policy, Practice & Research, Wellington, New Zealand: Ako Aotearoa. 2009, pp.79-90.
[23] D. Carless, Learning-oriented assessment: conceptual bases and practical implications, *Innovations in Education and Teaching International*, 44(1), 2007, pp. 57–66.
[24] M. Danaher, K. Schoepp, and A. Ater Kranov, A new approach for assessing ABET's professional skills, *World Transactions on Engineering and Technology Education*, 14(3), 2016, pp. 355-360, http://www.wiete.com.au/journals/WTE&TE/Pages/Vol.14,%20No.3%20(2016)/04-Danaher-M.pdf , Accessed 3 January 2017.
[25] M. Danaher, K. Schoepp, and A. Ater Kranov, *The Computing Professional Skills Assessment: An Innovative Method for Assessing ABET's Student Outcomes*. IEEE EDUCON 2016, April 10-13, Abu Dhabi, UAE. http://ieeexplore.ieee.org/document/7474529/
[26] A. Azmy, A. and H. Mokhtar, A Project-Based Framework for Teaching and Assessment of Design Modules, *International Journal of Engineering Education*, 33(2), 2017, pp.629-638.
[27] O.C. Chaim, and E.W. Cazarini, Peer and Self-grading: Comparisons between Analytical and Holistic Rubrics in an Engineering Classroom, *International Journal of Engineering Education*, 33(6A), 2017, pp.1798-1802.
[28] Australian Graduate Survey, Graduate Careers Australia, http://www.graduatecareers.com.au/research/surveys/australiangraduatesurvey/, Accessed 24 January 2018.
[29] K. Schoepp, M. Danaher, and A. Ater Kranov, An Effective Rubric Norming Process, *Practical Assessment, Research & Evaluation*, 23(11), 2018, http://pareonline.net/getvn.asp?v=23&n=11, Accessed 27 September 2018.
[30] K. Schoepp, M. Danaher, and A. Ater Kranov, *The computing professional skills assessment utilized with graduate students*, 2017 IEEE Global Engineering Education Conference (EDUCON), 2017.
[31] M. Danaher, K. Schoepp, and A. Ater Kranov, A new approach for assessing ABET's professional skills, *World Transactions on Engineering and Technology Education*, 14(3), 2016, pp. 355-360, http://www.wiete.com.au/journals/WTE&TE/Pages/Vol.14,%20No.3%20(2016)/04-Danaher-M.pdf , Accessed 3 January 2017.

Appendix

The Computing Professional Skills Assessment (CPSA) Rubric

CPSA 1. Students will be able to problem-solve from a computing perspective.

0 - Missing	1 - Emerging	2 - Developing	3 - Practicing	4 - Maturing	5 - Mastering
Students do not identify the problem(s) in the scenario.	Students begin to define the problem(s). Potential solutions may be general and/or naive.		Students are generally successful in defining primary and secondary problems with reasonable accuracy and with justification. There is evidence that they have begun to formulate potential solutions from a computing perspective.		Students convincingly and accurately define the primary and secondary problems, providing justification. They suggest detailed and viable potential solutions from a computing perspective.
Students do not identify stakeholders.	Students identify the most obvious stakeholders. Students may state stakeholder perspectives in an inaccurate or limited way.		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.

CPSA 2. Students will be able to work together to perform a specific task.

0 - Missing	1 - Emerging	2 - Developing	3 - Practicing	4 - Maturing	5 - Mastering
Student discussion is not guided by the prompts.	Students use only a portion of the prompts to guide their discussion. Students get off task. They may be unaware that they have gotten off task or may work to get back on task but unsuccessfully.		Students use the entire set of prompts to guide their discussion. Students recognize when they get off task and work to get back on task.		Student discussion is closely aligned to the entire set of prompts. Students plan their discussion according to the prompts in order to ensure completion and thorough consideration.
Students do not acknowledge or encourage participation of others.	Students may pose individual opinions without linking to what others say. Students acknowledge the ideas of others, but may too hastily defer to an opinion.		Students acknowledge, build on, clarify and/or critique and others ideas with some success. Students encourage participation of others to come to consensus.		Students clearly encourage participation from all group members, generate ideas together, actively help each other, and clarify and/or critique each other's ideas.

CPSA 3. Students will be able to evaluate ethical, legal, and security considerations when solving a problem.

0 - Missing	1 - Emerging	2 - Developing	3 - Practicing	4 - Maturing	5 - Mastering
Students do not identify ethical, legal, and security considerations.	Students give passing attention to related ethical considerations and/or may describe only the most obvious ethical considerations.		Students identify relevant ethical, legal, and security considerations in context of the problem(s).		Students clearly articulate relevant ethical, legal, and security considerations and evaluate them in the context of the problem(s).

CPSA 4. Students will be able to communicate professionally in writing.

0 - Missing	1 - Emerging	2 - Developing	3 - Practicing	4 - Maturing	5 - Mastering
Students are unable to write in an accurate manner.	Student errors in grammar, punctuation, and spelling at times impedes the effectiveness of communication.		Students have few errors in grammar, punctuation, and spelling, so effective communication is seldomly impeded.		Students write clearly and have no discernable grammar, punctuation, or spelling errors.
Students do not demonstrate a professional vocabulary.	Students inconsistently demonstrate a professional vocabulary.		At times students demonstrate the vocabulary expected of a computing professional.		Students consistently demonstrate the vocabulary expected of a computing professional.

CPSA 5. Students will be able to analyze the local and global impacts of computing.

0 - Missing	1 - Emerging	2 - Developing	3 - Practicing	4 - Maturing	5 - Mastering
Students do not consider either the local or global impacts of computing on individuals, organizations and society.	Students analyse local and/or global impacts of computing on individuals, organizations and society. Student analysis may be superficial.		Students analyse local and global impacts of computing on individuals, organizations and society. Students begin to recognize the associated complexities and interdependencies.		Students judiciously analyze local and global impacts of computing on individuals, organizations and society. Students recognize the associated complexities and interdependencies.

CPSA 6. Students will be able to recognize when they need to seek further information to extend their knowledge.

0 - Missing	1 - Emerging	2 - Developing	3 - Practicing	4 - Maturing	5 - Mastering
Students do not refer to or evaluate information presented.	Students refer to the information presented in the scenario. Students refer to the sources of information presented during the discussion.		Students evaluate the information presented in the scenario. Students evaluate the sources of information presented during the discussion.		Students critically evaluate information presented in the scenario and presented during the discussion. Examples include, but are not limited to: discussing potential and probable biases of the information sources, distinguishing fact from opinion in order to determine levels of information validity, analyzing implied information.
Students do not differentiate between what they do and do not know. Students do not demonstrate an awareness of the need to seek additional information.	Students begin to identify what they do and do not know. Students may acknowledge the need to seek additional information.		Students identify what they do and do not know. Students provide additional sources to support the discussion and extend their knowledge.		Students accurately identify the specific limits of their knowledge and how those limitations affect their analysis. Students actively seek relevant additional information and bring forth a variety of reliable sources to support the discussion and extend their knowledge.

Biographies

Maurice Danaher received his PhD in Information Systems in 2003 from Swinburne Institute of Technology, Melbourne, Australia. He received a Masters degree in Engineering Science from the National University of Ireland, Cork, Ireland in 1981. He was awarded a Bachelor degree in Civil Engineering with Honours by the National University of Ireland, Cork, Ireland in 1977. Currently he holds the position of Associate Professor in the College of Technological Innovation, at Zayed University, Abu Dhabi, United Arab Emirates. He commenced his career as a Civil Engineer in Ireland and subsequently worked as an Engineer with the Boeing Company in the USA and Canada. He later taught Civil Engineering at Singapore Polytechnic, Singapore for three years and then for many years lectured and conducted research in Information Technology at Edith Cowan University in Perth Australia. In 2006 he moved to the United Arab Emirates and worked as an Assistant Professor in Information Technology at Abu Dhabi university and from 2008 at Zayed University and was later promoted to his current position of Associate Professor. 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. Dr. Danaher is a speaker for the Society of Engineers, UAE and is on the list of speakers for IEEE UAE. He promotes the IEEE student branch at Zayed University. He has won a number of grants in the UAE totaling over US$250,000 for research into quality assurance of IT education.

Kevin Schoepp received a B.Ed. in secondary education and an M.Ed. in teaching English as a second language from the University of Alberta, Edmonton, in 1993 and 1999 respectively. He received a M.A. in educational technology and an Ed.D. in higher education leadership from the University of Calgary, Calgary, in 2004 and 2010 respectively. He taught grade six in Canada and taught English as a second language in Canada, Costa Rica, Turkey, and the UAE. From 2003 until 2016 he worked at Zayed University, Abu Dhabi as an English instructor, educational technologist, campus administrator, and then as the Director of the Office of Educational Effectiveness. He last worked as the Director of Academic Excellence at Jumeira University, Dubai, and is now an independent researcher located in Tulum, Mexico. He has published more than 33 articles and book chapters and delivered more than 40 conference presentations. His current research interests include assessment and learning outcomes in higher education. Dr. Schoepp's was awarded as Zayed University's Outstanding Faculty member in 2005. Other awards include leading Zayed University's assessment program to be one of ten colleges and universities named in the inaugural 2016 class of the Excellence in Assessment program- a program sponsored by the Voluntary System of Accountability, the Association of Public and Land-grant Universities, the American Association of State Colleges and Universities, and in partnership with the Association of American Colleges and Universities and the National Institute for Learning Outcomes Assessment.

Ashley Ater Kranov received her PhD in adult and organizational learning from the University of Idaho in 2006. She has been an adjunct associate professor in the School of Electrical Engineering and Computer Science at Washington State University in the USA since 2009 and is President of the consulting firm Global Professional Skills Assessment based in Baltimore, MD. From 2011 to 2013, Dr. Ater Kranov served as Managing Director of Professional Services at ABET. Dr. Ater Kranov serves as a reviewer for the National Science Foundation, American Society for Engineering Education conference proceedings, and journals such as the Journal of Engineering Education, the Journal of Sustainability in Higher Education and IEEE Transactions on Engineering Education. Her research areas of interest are direct methods to teach and measure professional skills necessary for 21st century engineering and computing workplace success and how to increase gender equity in the technical fields.