Are students in graduate programmes adequately attaining professional skills?

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ABSTRACT: A method known as the computing professional skills assessment (CPSA), developed by this team, assesses the professional skills identified by ABET as essential for computing graduates. The method allows simultaneous evaluation of six skills: problem solving, teamwork, professional and ethical considerations, communication, local and global impacts, engagement in further research and learning. The range of the measurement scale is from a skill level of zero up to entry career. The instrument has been tested and validated with undergraduate students. As the top end of the scale corresponds to the attainment level for professionals in entry level positions, here the authors trialled it with a class of 16 postgraduate students who were expected to achieve at that level. The authors found that the students performed near to the target level. As the method is also well suited to teaching the skills, they conducted a survey of the students' perceptions of its benefits. The results showed the students were very positive about the method and felt it was very beneficial for developing their professional skills.

INTRODUCTION

To be desirable and successful in the global knowledge economy, a graduate requires not only disciplinary skills and knowledge, but a mastery of the professional skills and, therefore, the ability to responsibly contribute both locally and globally to society, and towards sustainable development. Also known as transferable or soft skills, these non-technical skills are applicable across all disciplines, and include communication, teamwork, critical thinking, problem solving and the ability to consider ethical and social implications [1]. Employers place high importance on these skills, with some valuing them even higher than disciplinary knowledge [2]. Many university programmes are incorporating these skills as measurable learning outcomes in an effort to address the skills gap perceived by employers globally, particularly creative and critical thinking, problem solving and leadership skills [3][4]. This incorporation has inherent hurdles as effective teaching strategies and assessment of the associated learning outcomes of the professional skills remain under development in many computing programmes at undergraduate and graduate levels [5].

The computing professional skills assessment (CPSA) [6][7] is the first and only method in the literature to assess the six ABET (formerly known as the Accreditation Board for Engineering and Technology Education) Computing Accreditation Commission (CAC) professional skills learning outcomes simultaneously. The CPSA learning outcomes have evolved with different wording from the ABET outcomes. They are shown in Table 1 alongside their ABET counterparts.

Table 1: CPSA and ABET CAC learning outcomes alignment.

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

The CPSA consists essentially of a performance task, student responses to the task and a rubric. For the performance task, students participate in an on-line discussion of a scenario, which describes a real-world situation. Scenarios are created according to checklist criteria, which stipulate, for example, that the content is true, multi-faceted, able to be related to other disciplines, relevant locally and globally, contains technical information, has a range of sources and is written at a suitable language level. The scenario creation criteria ensure standardisation and effectiveness through equal consideration of the targeted outcomes. By working in teams to analyse the scenario and discussing the issues on-line, students demonstrate their abilities in the professional skills simultaneously. Some current topics, which have been utilised are: cybersecurity, sharing and privacy in social media and issues surrounding Google dominance of Web search. The CPSA rubric is used to evaluate student performance in the form of a discussion transcript generated by the discussion board. The rubric is a six-dimension, task-specific, analytic tool, which is used to measure demonstration of the skills.

The CPSA has been developed over the past four years and has undergone continuous improvement and refinement. It has been trialed a number of times with undergraduate students. In the research presented here the authors trialed it with postgraduate students. They wished to test the top end of the scale and see how postgraduates performed on the authors' scale. Additionally, as the method is ideal for teaching and practice of the skills, the authors wished to get feedback from the students on the benefits they perceived from a learning viewpoint.

METHOD

The CPSA has been developed with funding provided by Zayed University's Research Incentive Fund and by the Abu Dhabi Education Council's Award for Research Excellence. It addresses the following six skills: problem solving, teamwork, professional and ethical considerations, communication, local and global impacts, and engaging in further research and learning. The method aligns with the design of a performance assessment, by eliciting and measuring a set of outcomes or skills produced interdependently when students analyse real-world issues [8]. By addressing inter-related skills and measuring their production simultaneously the validity of the assessment of the skills is increased [9].

Performance assessments are constructed of three parts; namely, a task to elicit performance, the performance itself or product of the performance and a criterion-referenced measurement tool, such as a rubric to measure the quality of the output. The CPSA features a scenario and prompts as the task, a team-based on-line discussion as the performance generating a transcript as the product, and a rubric as the criterion-based measurement tool to ascertain the extent of production of the professional skills. In groups of about five, students respond to prompts to discuss and analyse aspects of a 1½ page scenario outlining a current computing issue. The scenario is carefully crafted in compliance with strict criteria and at a language level that is suitable for non-native speakers of English. The six prompts as below are standardised across each scenario:

1. What are the primary and secondary problems?
2. Who are the major stakeholders and what are their perspectives?
3. What are some of the major professional, ethical, legal, security and social issues?
4. What are the local and global implications of both the problem/s and possible solutions?
5. What are the next steps that would lead to possible future solutions?
6. What, if any, additional information would you need to effectively address the problem/s?

These prompts have been designed to elicit the skills that the students should demonstrate, and additionally, they are typically the questions one should consider in problem solving. Concrete examples of student attainment in the professional skills are produced and performance is directly assessed, improving the efficacy of the assessment [10].

The CPSA rubric, a task-specific analytic rubric, has evolved over a number of cycles of usage and revision establishing validity and reliability. Each outcome or dimension is scored on an individualised set of performance indicators and descriptors on a common integer scale from 0 - 5, categorised progressively as *0 - missing*, *1 - emerging*, *2 - developing*, *3 - practicing*, *4 - maturing*, and lastly *5 - mastering*. These terms were chosen due to their ability to highlight the nature of achieving mastery in a skill or skills set, and are a better fit for a skills-based performance task than measurement terms of poor to excellent for example.

To ensure inter-rater reliability when using the rubric, a consensus estimate approach to calibration has been adopted [11]. Individual raters participate in a norming process to reach a consensus on work, which evidences each given descriptor and score to within a range of one point on the scale. The norming process also contributes to improvement of the rubric as there is much discussion on any area of alignment difficulty, and notes are made for improving the next iteration of the rubric. Once calibrated, the raters use the rubric to score the discussion transcripts produced during the performance task, assessing the group discussion performance rather than individual students.

It was decided that the target outcome for graduate students was the highest level of mastery on the CPSA rubric, so *5 - mastering* was set as the benchmark. This would be the optimal skill level for graduates entering the workplace, or for postgraduate students. Given below in Table 2 are three of the CPSA learning outcomes with corresponding level *5 - mastering* descriptors. This decision was informed by earlier cycles of the CPSA with students in the third year of

an undergraduate programme with a benchmark level of *3 - practicing*, which proved accurate according to performance attainment.

Table 2: Three CPSA learning outcomes and rubric descriptors at level *5 - mastering*.

CPSA learning outcome	CPSA rubric *5 - mastering* descriptor
1. Students will be able to problem solve 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 thoughtfully consider perspectives of diverse relevant stakeholders and articulate these with clarity and accuracy.
5. Students will be able to analyse the local and global impacts of computing.	Students judiciously analyse local and global impacts of computing on individuals, organisations and society. Students recognise the associated complexities and interdependencies.
6. Students will be able to recognise when they need to seek further information to extend their knowledge.	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, analysing implied information. 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.

RESULTS

The CPSA was administered to a class of postgraduate students in Spring 2017. The students were pursuing a Master's degree in cybersecurity and the activity was embedded as an assignment in a course on information security management. The class consisted of 16 students of which 10 were men and 6 were women. The ages ranged from early to late 20s. All except one student were working full time in computing positions. The class was divided into three groups and the discussion was run on one occasion for a 12-day period. Ideally, the discussion activity should be run twice as the first run familiarises the students with the method. However, as this course was run in a condensed mode, there was insufficient time to run the discussion activity twice. The students were coached in the method in advance with a short trial before embarking on the main discussion activity.

The topic for the discussion was cryptography. The activity was given as a graded course assignment to ensure that students would make their best efforts in the task. Instructions given to the students started as follows:

> *Assume that you have been appointed by the UAE government to a task force of 5 or 6 computing professionals. You have been asked to examine the current issue outlined in the article below. Your team has not been asked to make specific recommendations to solve the problem. Rather, you have been asked to make recommendations that will help the Government decide what next steps they should take. This task is discussion-based, meaning you will participate through a collaborative exchange and critique of each other's ideas and work. Your team needs to think carefully about the issue and discuss it amongst yourselves in the on-line discussion board. You need to look at the issue from various perspectives. The goal is to challenge and support one another as a team to tap your collective resources and experiences to dig more deeply into the issue/s raised in the article. As each team member will refine his/her ideas through the dialogue that develops, and, as you are working together, it is very important to make your posts in a timely manner.*

The cryptography scenario was about 750 words in length and presented snippets of information on a current complex issue in cryptography - the conflict between privacy and security. The scenario was carefully crafted following the set of guidelines for scenario creation and approved by the three research team members before use. The students researched, examined and analysed the issue, and were required to make between four and six posts of around 350 words each over the 12-day period. While the CPSA rubric assesses team performance (as it is designed for programme level assessment), the students were graded individually for the purposes of the course.

The evaluation of the students' performance is done by examining the discussion transcripts using the rubric. This process starts with norming sessions for the rating team. During norming, the team members calibrate or align their scoring, so that every member applies the rubric consistently across student groups. It is critically important that raters score consistently with one another. Following norming, the team rate the student transcripts giving scores in the range of 0 to 5 for each outcome.

For this trial of the CPSA, the rating team scores for each outcome and student group is shown in Table 3. The mean score was calculated for each outcome to give overall performance on the outcome. The mean scores show that *Outcome 1 - students will be able to problem solve from a computing perspective, Outcome 4 - students will be able to communicate*

professionally in writing, and *Outcome 5 - students will be able to analyse the local and global impacts of computing* were the highest rated at 4.7. The outcome where the students were the weakest was *Outcome 6 - students will be able to recognise when they need to seek further information to extend their knowledge* in that the mean score was the lowest at 4 and only one group achieved the desired level of 5. *Outcome 2 - students will be able to work together to perform a specific task* and *Outcome 3 - students will be able to evaluate professional, ethical, legal, security and social issues when solving a problem* had mean scores of 4.3.

Table 3: Attainment of CPSA learning outcomes.

Group	Outcome					
	1	2	3	4	5	6
A	5	4	4	5	5	4
B	4	4	4	4	4	3
C	5	5	5	5	5	5
Mean	4.7	4.3	4.3	4.7	4.7	4

Student Survey

The method, while designed originally for programme level assessment, is ideal for teaching and learning. Typically, the students undertake the activity twice for 12-day periods. During the first run, which is for the purpose of familiarising the students with the activity, the students receive a lot of coaching and feedback. In the trial presented here, the students participated just once in the activity due to time limitation, however, they received coaching in advance.

To gain input from students about the efficacy of the CPSA method and its impact on their learning of the professional skills learning outcomes, at task completion the authors asked that they voluntarily complete an anonymous 11-item survey that was embedded into the learning management system. The survey is comprised of 8 Likert-scale items that are adapted from the Australian Course Experience Questionnaire (CEQ) [12] in order to enhance reliability and validity, and three open-ended items asking their likes, dislikes and suggested improvements.

Likert-scale Items

Though voluntary, the response rate to the survey and all of its items was nearly perfect with all 16 students completing the survey. In only one case was an item not completed by all of the students. The Likert-scale items allow the students to give their perceptions as to the degree that the discussion activity helped them in achieving the professional skills learning outcomes. Students rated each of the items either *5 - strongly agree (SA), 4 - agree (A), 3 - neither agree nor disagree (NA), 2 - disagree (D)* or *1 - strongly disagree (SD)*. Table 4 shows the responses from highest to lowest mean score and also includes the standard deviation and the dichotomous percentage, which combines the ratings of SA and A to give a quick snapshot of where strengths and weaknesses lie. The joint highest rated items were *The activity helped to develop my ability to analyse problems* and *The activity helped me to develop my understanding of ethical, legal and social issues*. The lowest rated item had to do with teamwork. Overall, all of the items were rated quite high given that a mean of 4.47 was the lowest and a mean of 4.81 was the highest, and that the lowest dichotomous percentage was 93.75%. This means that students strongly believe in the efficacy of the CPSA method to help them learn.

Table 4: Survey item responses.

Items	Mean	Standard deviation	Dichotomous %
The activity helped to develop my ability to analyse problems.	4.81	0.40	100
The activity helped me to develop my understanding of ethical, legal and social issues.	4.81	0.40	100
The activity helped me to develop the ability to analyse the impact of computing on the world.	4.75	0.45	100
The activity helped me to recognise the limits of my knowledge and the need to continue to learn more.	4.69	0.48	100
The activity helped to improve my skills in written communication.	4.69	0.60	93.75
As a result of the activity, I feel more confident about tackling unfamiliar problems.	4.63	0.50	100
The activity helped to develop my problem-solving skills.	4.63	0.62	93.75
The activity helped me develop my ability to work as a team member.	4.47	0.70	93.3

Open-ended Item Responses

In addition to the Likert-scale items, students provided feedback on their likes, dislikes and suggested improvements through the three open-ended items. As with the Likert scale, the results were very positive, but some interesting suggestions for improvements emerged, which demonstrates the benefits of the CPSA with graduate students.

In terms of what students liked, three themes emerged out of the iterative process of reading and re-reading the responses. Three students mentioned the topic itself, cryptography, others being able to understand a topic from different perspectives, and finally, learning and interacting with peers. Given the comments regarding the topic, it will need to remain one of the scenarios, as long as it is a good curricular fit. When it came to understanding the topic from different perspectives, one student noted they *…liked out of the box thinking* as a result of hearing different interpretations. Finally, the interaction and learning from peers brought forth the comment that the CPSA was *…one of the best activities ever*, because it helped them *…learn from each other, from different posts, and different perspectives*. The interaction component of the CPSA has consistently been identified as a strength by students [7][13].

The positive results from the open-ended items meant that there was not an overabundance of dislikes to report. In fact, four students commented directly that there was no aspect of the CPSA that they disliked. Some students felt that the discussion period itself was too short, because it limited the depth of the discussion. Specifically, a student stated *…we need more time to explore the topic in more depth*. The most common issue that emerged was that some students did not follow the discussion guidelines and wrote far more than the requested ten lines per post. Finally, one student noted they *…just wanted to politely say that some group members were drifting away from the main topic and not really acknowledging some of the good points by all members*. Though students appreciated working together and hearing diverse perspectives, this student did feel some problems with this emerged.

To find areas to improve the CPSA method, the authors ask students for how they would like the activity changed. Though five students said no changes were needed, a number of others did provide some meaningful feedback. One student thought the faculty member should monitor and participate in the discussion by *…posing a question or giving an idea to stimulate our thinking*. In a similar manner, another student felt that students needed prompt feedback in order to *…know if they are going on the correct track or not*. Finally, as a culmination activity, a student suggested that *…each group have to submit a paper based on the submitted recommendation*. Such a task would provide a concise way for students to summarise their discussion and their recommendations.

CONCLUSIONS

Professional skills are recognised as being of paramount importance to employers, but these skills are difficult to teach and assess. The CPSA assesses the level of these skills and additionally can be used to teach the skills. In the work presented here the authors trialed the CPSA with postgraduate students. The class of Master's students performed near to the targeted level of performance of *5 - mastering* on the CPSA. This indicates that the rubric score level of *5 - mastering* is an accurate target level for students in a Master's programme or entry level professional employees in computing. Further, the findings add to the validity of our scale at the *mastering* level. Additionally, the results of a survey of the students showed that they felt that the activity was beneficial to them and that it helped in the development of their professional skills.

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