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# Assessment of 21st Century skills in a computing programme during the Covid-19 pandemic

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ABSTRACT: Within higher education, the suspension of face-to-face instruction due to the Covid-19 pandemic has created numerous challenges, one of which is the assessment of student learning. In this article, the author examines the effectiveness of an existing assessment method, the computing professional skills assessment (CPSA) within a fully on-line environment in a computing programme at a university in the United Arab Emirates. The purpose of the CPSA is to measure students' proficiency in the 21st Century or professional skills - skills that are essential to life and workplace success, such as teamwork, communication and problem solving. The CPSA is designed as a small group assessment, where through an on-line asynchronous discussion students attempt to develop solutions to a computing-related problem that crosses disciplinary boundaries and to which there is no single correct answer. Results indicate that students performed consistently at or near the desired proficiency level. Based on these findings, it appears that the CPSA is an effective assessment for the 21st Century skills in a fully on-line environment.

Keywords: Learning outcomes, professional skills, computing, measurement

## INTRODUCTION

The suspension of face-to-face instruction due to the Covid-19 pandemic has created challenges and opportunities as they pertain to teaching, learning and assessment. The need to rapidly launch on-line learning has strained education systems worldwide. This has occurred while concerns towards teacher preparedness, technological readiness, pedagogical quality and student capacity existed. The long-term consequences of the move are yet to be learnt. Of particular concern has been the assessment of student learning with the elimination of the more traditional methods, such as face-to-face examinations or laboratory-based tasks. It is now thought to be more difficult to implement authentic tasks into an on-line assessment regime, especially for learning outcomes that are transferable, cross-disciplinary, generic, and thought to be lifelong that is, the 21st Century or professional skills.

In this article, the author examines the effectiveness of a previously established assessment method, the computing professional skills assessment (CPSA) that had earlier been conducted mostly on-line, but always as part of a face-to-face learning environment. The face-to-face component was thought to be very important to the successful implementation of the CPSA, but with Covid-19 and the transition to fully on-line learning, this had to be eliminated. The CPSA has been designed to assess the 21st Century skills as defined in a computing programme at a university in the United Arab Emirates. The specific research question that allows to examine the effectiveness of this assessment method is:

1. Given the recent transition to a fully on-line environment, to what degree have students achieved the desired target level of performance for the CPSA professional skills learning outcomes?

## LITERATURE

The literature framing this research concerns 1) learning outcomes, and specifically, the 21st Century or professional skills learning outcomes as they pertain to the computing discipline; 2) what constitutes an effective assessment; and 3) investigations into assessing the professional skills within the fields of engineering and computing.

Learning outcomes are statements of the knowledge or skills students are expected to have achieved as part of an educational experience. Meaningful learning outcomes are ones that should be sustained and built on over time. Over the past number of years, the importance of learning outcomes to guide student learning, student assessment,

course design and programme development, as well as for accreditation purposes has been well established [1][2]. The learning outcomes movement has been at the centre of the ongoing transition towards a learning perspective rather than a teaching perspective [3]. This in turn has been reflected in pedagogies that promote active learning, authentic tasks and other skills that are necessary for meaningful engagement in a knowledge economy where one knows numerous career changes are now the norm [4]. These changes have naturally increased the importance of learning outcomes aligned to this way of thinking and beyond traditional discipline-specific learning outcomes. Though every course and programme have different learning outcomes, learning outcomes known as generic, general education, soft skills, 21st Century or professional skills are consistently recognised as an essential element to a well-rounded, sustainable education, that is aligned with the needs of employment [5]. These learning outcomes include amongst others, concepts such as communication, problem-solving, ethics, critical thinking and teamwork.

Though at its core, the effectiveness of an assessment has to focus on the degree to which an assessment fairly evaluates student knowledge or performance on a particular learning outcome, there are multiple lenses to apply to the construct of assessment effectiveness. The most appropriate for this study are sustainable assessment and learning-oriented assessment as they are closely related and are actualised within the CPSA. The concept of sustainable assessment has seen a massive increase in interest over the past few years. According to Google Scholar as of 8 February 2022, there have been 2,119 citations to Boud's seminal sustainable assessment paper from 2000, when there were only 779 citations as of 1 January 2015 [6]. In this paper, Boud stated that …*sustainable assessment can be defined as assessment that meets the needs of the present and prepares students to meet their own future learning needs* [7].

Preparing students for their future learning needs means that an assessment needs to be authentic, provide meaningful feedback, and promote self-assessment and reflective practice [8]. Boud later argued that rather than assessing students' ability to memorise and regurgitate, assessments should force students to think critically and solve contextualised problems [9]. In a similar manner, learning-oriented assessment tries to focus assessment towards student learning, not just memorisation or regurgitation of facts. Learning-oriented assessment should promote deep learning and a high level of cognitive engagement [10]. One of the key principles behind learning-oriented assessment is that it is well-aligned with curricular learning outcomes, so that it targets worthwhile and appropriate learning [11]. This concept is manifested within the CPSA since the CPSA aligns to specific ABET learning outcomes. Often, this leads to the development of authentic-style assessments, where students engage with complex, cross-disciplinary problems [3].

The remaining principles behind learning-oriented assessment are concerned with understanding learning outcomes and engagement with feedback [12]. Examining exemplars of other student work is one way to understand learning outcomes - this is done as part of CPSA implementation since it sets the level of expectation towards student performance. Engagement with feedback is accomplished through completing two full rounds of the discussion and receiving feedback at the end of the first round.

Within the engineering and computing disciplines in the US, as early as the Engineering Change 2000 document [13], the Accrediting Board for Engineering and Technology (ABET) started to emphasise these professional skills learning outcomes in order to better prepare graduates for professional and lifelong learning. Currently these transferable, cross-disciplinary and sustainable learning outcomes are embedded in curricula and continue to be seen as fundamental to life and successful professional employment. Repeatedly, employers stress the importance of these learning outcomes for graduates [4].

Even though the importance of learning outcomes like the professional skills has been established in tertiary education, within computing and engineering they have a reputation for being difficult to teach and assess [14][15]. There are a number of reasons why this is the case. First, these learning outcomes cannot be judged as right or wrong as with some technical skills, and this means that levels of student performance need to be elaborated and described to come to a shared understanding [16]. Second, some faculty in the technical disciplines may lack experience in assessing the professional skills because they did not receive training in how to assess them, or they were not assessed in these skills throughout their university education [17]. A final reason is that there are only a few published assessments geared towards the professional skills.

Within engineering and computing, most of the existing measures to assess the professional skills, assess only one or a few, but certainly not all [18]. One of the issues with this is that it makes the assessments less sustainable because a number of assessments would be required to assess all of the professional skills. Some of the problems with other assessment methods is that they rely on student perceptions of how they are doing on a skill, which is an indirect method of assessment [18]. Though others believed assessment of the professional skills through internships to be a success, there is a lack of control and standardisation if employers conduct evaluations [19]. In fact, universities have been limiting the role of employers in the assessment of interns because of leniency bias [20]. Another issue is that some of these assessments, especially portfolios, can be very labour intensive, cumbersome, and therefore unsustainable. With portfolios, though reflective practice can help develop skills [21], an over-reliance on reflection in assessment can make them indirect measures, while faculty assessment of the contents can again become an overwhelming task. Another way the professional skills have been assessed is through a take-home written examination [22]. While such examinations may be simple to administer and grade, they are more an assessment of a student's theoretical understanding about a professional skill rather than their application of the skills themselves.

Prior to the CPSA, only one assessment in the literature, the engineering professional skills assessment (EPSA), purported to assess all of the professional skills simultaneously as defined by ABET's Engineering Accreditation Commission [18]. With the EPSA, small groups of students were provided with a written scenario of an authentic, real-world, unresolved engineering problem and then asked to propose solutions over a 45-minute time period. Though a discussion facilitator was present, they only got involved if the discussion got off track. The discussions were recorded and then transcribed since discussion transcripts offer examples of student skills which increase the efficacy of the assessment. Using these transcripts, a group of faculty convene, engage in a norming process and rate the transcripts according to the EPSA rubric. At the end of the rating process, each group is given a single score from the rubric on each of the professional skills learning outcomes which is then used to determine the degree to which students were attaining these important and sustainable learning outcomes. Researchers determined that this method was a useful way to assess the professional skills, so this led to numerous follow up studies [23-25]. As a group assessment, it is not burdensome for faculty and the focus on performance of the professional skills means that it is a highly sustainable assessment.

A version of the CPSA has been in use since 2014 [26] but the method, instruments and supporting materials have undergone numerous revisions to increase reliability, validity and efficacy. At this time, more than 1,200 students have used the CPSA as part of their course assessment. Issues surrounding student performance, validity and reliability, and student attitudes towards the instrument have all been used to improve the CPSA. In terms of student performance, a 2019 article, Danaher et al investigated students from years 2, 3, 4, and the Masters level found that students were consistently near the target level of performance for all of the professional skills [27]. In another article, Danaher et al also identified a pattern amongst 3rd year students, where there was across the board improvement from one implementation of the CPSA to the next within the same course/semester, demonstrating that students were learning the professional skills throughout the semester [28]. In the previously mentioned article, Danaher et al examined reliability, these authors relied upon evidence-based rater discussions about the scores given, along with interrater reliability calculations to determine CPSA reliability [27]. Over a three-year period, interrater reliability ranged from 75% to 93%. Validity checks have been consistently undertaken with minor modifications to the instrument and method occurring on a regular basis to make improvements [27]. In many of the implementations of the CPSA, students have been asked to complete an anonymous on-line survey into how they perceived the efficacy of the assessment. A consensus has developed in that the students find the activity quite useful in improving their professional skills though it can pose a consistent and heavy workload [29].

## THE COMPUTING PROFESSIONAL SKILLS ASSESSMENT

The CPSA is both a method and instrument. It is an on-line discussion board task that is designed as a group assessment to measure student proficiency in all of the CPSA learning outcomes. These outcomes were originally written to align with ABET's six professional skills outcomes as detailed by their Computing Accreditation Commission. These types of outcomes are the non-technical or the more generic 21st Century, outcomes that cross interdisciplinary boundaries. Currently, the CPSA outcomes are defined as: 1) students problem solve from a computing perspective; 2) students work together to accomplish shared goals; 3) students consider ethical, legal and security aspects; 4) students communicate professionally in writing; 5) students analyse the local and global impacts of computing; and 6) students interpret, represent and seek information.

The main components of the CPSA are a set of text-based scenarios that include an introduction and a set of guiding questions for the discussion, and the CPSA rubric which contains scoring instructions. A scenario is a brief text (~700 words) meant to stimulate meaningful small group discussion around a computing topic, where students can work towards a set of recommendations as to the next steps that should be taken. While scenarios are referenced and take information from trustworthy scientific, professional, and general news sources, they are not meant to be all-encompassing theses on any topic - they are merely discussion starters. To ensure consistency of application of the scenarios, they include a standardised introduction and guiding questions. Most of these question prompts are aligned with the professional skills learning outcomes, and if a group of students works through the prompts, they will have worked through the task. Only CPSA 2 - students work together as a group and CPSA 4 - students communicate professionally in writing do not have specific prompts attached to them as these concepts are embedded in the tasks and instructions provided to the students.

The next major component of the CPSA is the rubric. The rubric is actually comprised of six separate sub-rubrics, one for each of the six professional skills learning outcomes, and a set of scoring instructions for faculty raters. As the example from CPSA learning outcome 1 shows below (see Figure 1), each sub-rubric uses a 6-point scale from 0 - Missing to 5 - Mastering. The levels, 1 - Emerging to 5 - Mastering, are aligned to year of study, so the target level of attainment for a student in the third year is 3 - Practicing, while a Masters student is expected to score a 5 - Mastering. Also included in the sub-rubrics are an expanded definition of the learning outcome and a single or set of assessment criteria. Within each of the cells, there is a description of the particular level of attainment for the aligned assessment criteria. Faculty raters assign scores for the individual criteria and then assign a composite whole number score for the entire learning outcome.

Until the onset of the pandemic, the CPSA was delivered on-line, but always as part of a face-to-face course environment. Given the onset of Covid-19 and a move to fully on-line teaching, this is the first instance of the CPSA being administered without face-to-face interaction. The face-to-face aspect was thought to be important because

students knew one another on a more personal level, and were therefore able to bypass the initial two stages in Salmon's on-line learning model where developing group cohesion is paramount [30].

CPSA 1. Students problem solve from a computing perspective.
Rater composite score for skill_____

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 convincingly and accurately define the problems and differentiate between them, providing realistic justification. |
| Recommendations for solutions | Students do not make any recomm-endations for potential solutions. | Students may recommend potential solutions that do not fit the identified problems. Students may make recommendations for potential solutions without identifying the problems first. | Students propose reasonably viable recommendations for non-technical and technical potential solutions. | Students propose detailed and viable recommendations for non-technical and technical potential solutions. |
| Stakeholder perspectives | 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. |
| Comments | | | | |

 Rubric Development Funded by Zayed University Research Incentive Fund and the Abu Dhabi Education Council

Figure 1: Learning outcome 1 from the CPSA rubric.

## METHOD

The participants in this study come from a single section of a fourth-year computing security course in an ABET accredited English - medium computing programme located at a gender-segregated public university in the United Arab Emirates. The 24 students in this section of the course were all female native speakers of Arabic who agreed to participate in the study as their contributions have been kept confidential. For the purposes of this research, the students were randomly assigned into four equal discussion groups of six participants. All students were familiar with the discussion board component of Blackboard, the institutional learning management system.

The CPSA follows a step-by-step process with at least two distinct group discussions. Previously, students would be introduced to the CPSA and given the purpose, goals and expectations for the task in a face-to-face classroom environment. Next, with faculty guidance students review the discussion prompts and read through the scenario. As a class they then discuss how each of the prompts might be addressed and then, they examine exemplars of discussion posts from previous iterations. The last step in this initial introduction is a review of the on-line discussion tool that is mechanism to deliver the CPSA.

These same procedures were followed in this implementation, but it was completed fully on-line in a synchronous environment. Following this introduction, students are randomly assigned into discussion groups and then work through one 12-day round of a CPSA discussion that has the same discussion prompts. This round differs from the final upcoming round in that there may be limited faculty intervention to ensure groups are on the right track.

At completion, a short synchronous debrief to answer student questions and to discuss strengths and weaknesses of the group discussions is led by faculty. The final round has no faculty involvement in the discussion because it is formally assessed. Again, in randomly assigned groups, students read another scenario and discuss the prompts for 12 days. At completion of the discussion, a team of at least three faculty raters use the CPSA rubric to score the discussion transcripts and assign scores for each group and all six of the CPSA learning outcomes. Where this procedure differs from all other implementations of the CPSA is that it all occurs on-line, whereas previously, the introduction and debriefs were conducted face-to-face and students knew one another from their usual classroom interactions.

## RESULTS

Each of the four student groups received a score on all six of the CPSA professional skills learning outcomes (see Table 1). These scores were then aggregated to calculate the overall mean score for each group and each learning

outcome. Additionally, the individual scores were then used to calculate the group and mean score % ≥ 4 because 4 is the target for fourth-year students. Overall, student groups performed extremely well since the group mean scores ranged from 3.50 - 3.83, and learning outcome scores ranged from 3.0 - 4.0. The overall mean of these means was 3.75. Only with CPSA 5 - students analyse the local and global impacts of computing did students appear to struggle in that no groups achieved the target. From the perspective of % ≥ 4.0, three groups scored 83.33%, while group 2 achieved only a 50%, and for the learning outcomes, three were calculated to 100%, two 75%, while no group achieved the target for CPSA 5, which came in at 0%.

Table 1: Group scores on CPSA learning outcomes.

| Group | CPSA 1 | CPSA 2 | CPSA 3 | CPSA 4 | CPSA 5 | CPSA 6 | Mean | Group % ≥ 4 |
|---|---|---|---|---|---|---|---|---|
| 1 | 4 | 4 | 4 | 4 | 3 | 4 | 3.83 | 83.33 |
| 2 | 4 | 3 | 3 | 4 | 3 | 4 | 3.50 | 50 |
| 3 | 4 | 4 | 4 | 4 | 3 | 4 | 3.83 | 83.33 |
| 4 | 4 | 4 | 4 | 4 | 3 | 4 | 3.83 | 83.33 |
| Mean | 4.00 | 3.75 | 3.75 | 4.00 | 3.00 | 4.00 | 3.75 | |
| Outcome % ≥ 4 | 100 | 75 | 75 | 100 | 0 | 100 | | |

## DISCUSSION

The results point to the fact that the CPSA remains an effective assessment while conducted completely on-line, a modification that was forced on faculty and students due to the Covid-19 outbreak and the cessation of face-to-face learning. The efficacy of this instrument and method are demonstrated through the quality of the students' performance as it pertains to fairly evaluating targeted learning outcomes, its alignment with learning outcomes and its future orientation.

Most importantly, the CPSA is an effectual assessment because of how students performed in achieving the desired learning outcomes in this new fully on-line implementation of the instrument. Up until this recent implementation of the CPSA, there had always been a face-to-face component to introduce and review the discussion task. If students had not been able to demonstrate the expected level of proficiency in the professional skills during this implementation, it would have called into question the usefulness of the assessment when conducted fully on-line. However, this was not the case. Similar to an earlier study that found students performing very close to the target [27], current results with group mean scores ranging from 3.50 - 3.83 and students having attained the target 75% time, mirrors the previous work. This fully on-line implementation of the CPSA appears to be acting comparably to its predecessor.

The second piece of evidence that demonstrates the effectiveness of the CPSA is its tight alignment with the targeted learning outcomes. Because learning-oriented assessments should promote deep learning and avoid the regurgitation of facts [10], they must be well-aligned to well-written learning outcomes that demand a high level of cognitive engagement. The CPSA alignment to the ABET professional skills learning outcomes achieves this. When this occurs, it often leads to assessments that demand students solve complex, multi-disciplinary problems as members of a group, which is the method employed within the CPSA.

The final reason why the CPSA is an effective assessment is that it is future oriented. Because it measures the professional skills learning outcomes, it has a focus on skills that are needed for career, and often, life success. These are the skills that employers stress as important for success in the workplace [20][23][24]. Boud wrote that an effective assessment needs to *…meet the needs of the present and prepares students to meet their own future learning needs* [7]. Students need to engage in authentic tasks that promote critical thinking and are close to what they might experience in the workplace [9]. Skills, such as working together to accomplish shared goals, communicating professionally and considering ethical implications of actions, are all professional skills within the CPSA and key learning outcomes for work and life. Knapper [8] expanded on Boud's work [7] by stressing the importance of feedback and reflective practice. Because the CPSA involves more than one round of group discussions, the first to learn the process, get feedback, and reflect on how to improve while the second round is formally assessed, it is an example of what Knapper emphasises as essential [8].

## CONCLUSIONS

Since the Covid-19 pandemic led to suspension of much face-to-face learning the world over, many educators and education systems were forced to rapid implementation of on-line learning. In many cases this was a monumental move into the unknown as nothing of this scale had been implemented before. While issues such as technological readiness and student access were important, the most important issue remained the ability to facilitate quality learning experiences which includes the ability to effectively assess student learning. With many traditional forms of assessment no longer viable in the on-line realm, other sustainable and effective forms of assessment needed to be implemented.

By examining the effectiveness of the CPSA through answering the research question into student performance, it was found that students performed to the desired targets and achieved the desired learning outcomes. These results point to

the CPSA having a learning orientation and being sustainable especially for the professional skills learning outcomes - ones that are transferable, cross-disciplinary, thought to be lifelong and paramount for successful employment [4][5].

Though the current fully-on-line results aligned with earlier CPSA results that included a face-to-face component [27][28], more research needs to be done. This was only one study with a relatively small sample size, so further research into the efficacy of the CPSA in a purely on-line environment needs to be conducted. It may be that in larger groups, the initial two stages in Salmon's on-line learning model [30], where developing groups cohesion is paramount is more important, and that without this, student achievement is not to the expected level.

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BIOGRAPHY

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