Assessing teamwork in a computing programme

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ABSTRACT: The computing professional skills assessment (CPSA) is a scenario-based on-line discussion in which small groups of students are assessed after they discuss and attempt to solve a computing-related problem. The CPSA assesses the six professional skills learning outcomes prescribed by the Accreditation Board for Engineering and Technology (ABET). One of the key professional skills is teamwork. Reporting on research conducted within a computing programme located at a UAE university, this article describes how the CPSA is able to successfully assess teamwork through its specific rubric criteria, and to demonstrate the language of effective teamwork as it emerges through an analysis of the discussion transcripts. Examples of language from the transcripts that serve to question, clarify, summarise, agree, disagree, synthesise, thank and conclude, are shared and discussed. The analysis of the transcripts indicated that while polite and courteous teamwork is a strength of this student population, they often struggle to challenge one another, seek clarification or come to a decisive conclusion.

INTRODUCTION

Teamwork, the ability to effectively work together to perform a specific task, is universally recognised as one of the key professional skills required by graduates to be effectual in the global knowledge economy [1][2]. Given the project driven nature of the computing industry, computing graduates who can work well with others are much coveted by employers and have a better chance of workplace success in this technical field [3][4].

Because of the importance of teamwork for employment and the corresponding emphasis placed upon it by the Accrediting Board for Engineering and Technology (ABET) [5], most computing programmes have embedded this skill as a measurable programme learning outcome. This means that teamwork needs to be well taught and assessed if one is to effectively meet the immediate needs of students and the long term needs of employers and society. To accomplish this task, the computing professional skills assessment (CPSA) has been developed and deployed over the last number of years [6].

The CPSA is a scenario-based on-line discussion where small groups of students work together and discuss a computing-focused issue, and then attempt to solve the associated problem. The CPSA is comprised of a scenario, a set of prompts, a rubric and the method itself. It is appropriate for both course and programme level assessment of ABET's six professional skills. The professional skills are the non-technical or general education learning outcomes that are essential to successful employment, much coveted by employers, and often a challenge to teach and assess within technical programmes [7]. Teamwork is one of the most prominent professional skills, because it is transferable across disciplines, and because employers want universities to increase their emphasis on it when compared to science, technology and mathematical skills [1].

In this article, the authors report on research conducted within a computing programme located at a public UAE university. The purpose of this article is to demonstrate how the CPSA is able to successfully assess teamwork through its specific rubric criteria, and to demonstrate the language of effective teamwork as it emerges through an analysis of the discussion transcripts. Implications of these findings are discussed from a programmatic perspective.

Research questions:

1. What examples of teamwork are present within the discussions?
2. How much teamwork is present within the discussions?
3. Are there differences in the presence of teamwork based on programme year?
4. What are the strengths and weaknesses of teamwork as present within the discussions?

THE CPSA

The CPSA is the only method in the literature to assess the six ABET Computing Accreditation Commission's (CAC) professional skills learning outcomes concurrently. Delivered through an asynchronous on-line discussion, the CPSA is made up of a 1.5-page scenario, a standardised set of prompts, an analytic rubric and the method itself. After reading the real-world situation presented in the scenario, small groups of approximately four to five students use the prompts to guide their 12-day discussion as they work towards a solution. At completion of the discussion, the rubric is used by a team of faculty (academic staff) to evaluate student performance based on the discussion transcripts. The CPSA has undergone continuous modification and advancement over the past five years [8]. It has been used with undergraduates and graduates and has proven to be a reliable and valid method of assessment [9].

Teamwork via the CPSA

Over time, the CPSA learning outcomes have evolved to have slightly different wording than the CAC's version, so that the outcome is a better fit with the CPSA method itself. In some cases, the modification is quite minimal as is the case with teamwork (see Table 1). The CPSA version of teamwork allows for a gradation of performance and is aligned to a particular task.

Table 1: CPSA and ABET CAC learning outcomes alignment.

CPSA	ABET CAC
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.

The teamwork learning outcome in the CPSA rubric is shown in Table 2. The definition of teamwork is expanded upon to state that: *student discussion is guided by the prompts. Students interact in a group setting to address the problems raised in the scenario by acknowledging, building on, clarifying and/or critiquing each other's ideas.* The outcome is broken into two criteria named prompts and discussion. The prompts criterion examines how well the student team follows the complete set of prompts to accomplish the task. The discussion criterion examines how well the students interact with one another acknowledging, encouraging and critiquing each other. The rubric has four main bands of performance and is scored from 0 to 5. The five levels are: 0 - Missing; 1 - Emerging; 2 - Developing; 3 - Practicing; 4 - Maturing; 5 - Mastering. Levels 1 and 2, and levels 3 and 4 share the same descriptors. The rubric definition and rubric descriptors formed the framework to assess the teamwork manifested in the student transcripts.

Table 2: The teamwork skill in the CPSA rubric.

CPSA 2. Students will be able to work together to accomplish shared goals.
Rater composite score for skill_____

Definition: student discussion is guided by the prompts. Students interact in a group setting to address the problems raised in the scenario by acknowledging, building on, clarifying and/or critiquing each other's ideas.

	0 - Missing	1 - Emerging	2 - Developing	3 - Practicing	4 - Maturing	5 - Mastering
Prompts	Student discussion is not guided by the prompts.	Students use only a portion of the prompts to guide their discussion.		Students use the entire set of prompts to guide their discussion.		Students plan their discussion according to the prompts in order to ensure completion and thorough consideration.
Discussion	Students do not acknowledge or encourage participation of others.	Students notice other students' ideas. Students may make attempts to bring others into the discussion. Students may pose individual opinions without linking to what others say.		Students acknowledge, build on, clarify and/or critique other's ideas with some success. Students make some successful attempts at realising shared goals.		Students encourage participation from all group members, generate ideas together, actively help each other, and clarify and/or critique each other's ideas. Students accomplish shared goals.

METHOD

From the more than 400 students who have been assessed by the CPSA, three groups of five students were randomly selected to serve as the sample for the analysis. One group was chosen from each of a 3rd year, 4th year and graduate level course in order to ensure that a range of exemplars would be present in the analysis. Though the groups participated in the on-line discussion, all of the courses are delivered in a face-to-face environment, so issues that often surround on-line collaborative learning, such as a lack of connection were not a concern [10].

A form of transcript analysis was the method used for this study as it is very suitable as a way to study asynchronous on-line discussions [11]. Transcript analysis *refers to a system for making replicable and valid inferences from texts to the contexts of their use* [12]. To begin the process, a number of types of teamwork were identified, and then used to categorise each of the discussion posts. In reading and re-reading the discussion posts, the authors were able to develop a coding mechanism, which could place each of the posts into one of eight categories. They created this coding structure through an iterative process, whereby coding was tried and tried again until the eight categories were confirmed. The categories that were identified were: *build upon; agree; thank/commend; disagree; transition; question; conclude* and *clarify*. A definition of each category and an exemplar post has been provided below (Table 3). In each case, student names have been changed to maintain confidentiality, and any grammatical or spelling errors have been corrected to ease the readability, while ensuring that the meaning has not been altered.

Table 3: Categories of discussion posts.

Category	Definition	Exemplar
Build upon	A post that takes what has been written before in an earlier post from a colleague and adds to it.	*In addition to the definition of cryptography mentioned by my colleague Asma, cryptography is a science to keep information secure from unintended audiences by encrypting…*
Agree	A post which indicates simple agreement or endorsement of an earlier post.	*I agree with Lateefa about the fundamentalist libertarians…*
Thank/ commend	A post using words like thanks, great job, well done in response to a colleague's post.	*Great job Mohamed and Suhail of listing the stakeholders for encryption. For the most part, stakeholders' views…*
Disagree	A post which indicates disagreement with an earlier post, and it may be done subtly to not offend a colleague.	*I do not agree with you, Fatima, on the point you made that the argument that strong cryptography will weaken law enforcement is a vague construct.*
Transition	A post that demonstrates an understanding of what has been written before it, and is able to move the discussion onto another area in need of discussion.	*Since my colleagues Ali, Nora and Iman have identified the major professional, ethical, legal and security issues that will affect the stakeholders of cryptography, I will focus on the social issue. A social issue is…*
Question	A post that poses a question for colleagues to respond to, and is an attempt to engage others.	*So, what would be the way to keep people's privacy as well as report to the government if there is any inappropriate action?*
Conclude	A post that attempts to wrap up the discussion since it is to come to a conclusion at the end of the 12 days.	*Since this discussion is coming to a conclusion, I would like to propose an idea that would keep both factors of privacy and security. Personally…*
Clarify	A post where some level of misunderstanding has occurred, so a student attempts to clear up the misunderstanding.	*As I tried to point out on a previous post, the major issue of this case is the level of understanding about the encryption. So, I suggest people should always keep…*

After the coding mechanism was developed, each discussion post was labelled with the appropriate teamwork category. However, with the coding of the discussion posts built around the categories identified in Table 3, through the labelling process, it became apparent that some of the posts could be characterised with more than one category. Where this was appropriate, coding was done so multiple categories could be represented. An example of such a post, is *Thank you Badr for sharing your ideas regarding legal, security, professional and ethical issues related to cryptography. However, I don't agree on the use of key escrow by the government as you suggested for many reasons….* This post is an example of one that was labelled both *thank/commend* and *disagree*. By the end of the labelling of the discussion posts, the authors were able to perform basic descriptive statistics that allowed us to answer the research questions in a meaningful manner. Though a number of other coding schemes exist for on-line discussion boards [13]14], it was felt that because of the unique task and set of prompts involved in using the CPSA, none of these were appropriate.

RESULTS

For this investigation, the quantitative analysis contains results related to the number and lengths of posts, instances of teamwork by level, the number of orphan posts, prevalence of teamwork types, and then prevalence of teamwork types disaggregated by programme year.

Prior to the specific examination into the prevalence of, and the way in which teamwork is manifested in the CPSA transcripts, it is important to be aware of the overall composition of the discussions themselves, especially since the participants were different 3rd year, 4th year and Master's students. As shown in Table 4, the number of posts per group were quite similar in that it ranged from 23 to 27, with the 3rd year students actually producing the most posts. For total words in each set of transcripts, 3rd year students produced more and averaged more words per post with 215 than did the 4th year students. The massive difference in this regard was with the Master's students as they compare to the

undergraduate students. The graduate students produced nearly 13,000 words in their discussion and more than doubled the average length of post than the two groups of undergraduate students with a mean of 516 words.

Table 4: General data about discussion posts.

	Posts	Words	Post-mean length
3rd year	27	5817	215
4th year	23	4712	205
Master's	25	12,898	516

Given the large discrepancy between the Master's students and the undergraduate students, it is not surprising that these differences are reflected in other measures as well. Firstly, when it comes to specific instances of teamwork, there was practically a doubling from level to level. For example, Figure 1 demonstrates graphically how, of the 106 instances of teamwork, the 4th year students with 31 instances of teamwork almost doubled the output of the 3rd year students, and the Master's students with 59 instances of teamwork virtually doubled the output of the 3rd year students. There was considerable growth in instances of teamwork from level to level. The second way in which differences between the levels is apparent is through a count of orphan discussion posts. Orphan posts are posts where the author has not acknowledged or attempted to engage with any other posts from colleagues. It is as if the post has been created in a vacuum with no concern of what has been written before it. These posts are a clear indication of a lack of teamwork. Figure 2 shows an obvious pattern in that the percentage of orphan posts decreases substantially from 3rd year students to 4th year students to the Master's students. The 3rd year students are approaching 50% orphan posts, while the Master's students only had a single post classified as an orphan.

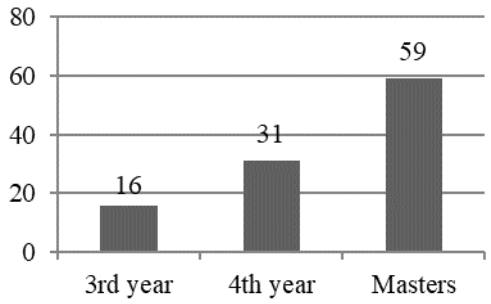

Figure 1: Instances of teamwork.

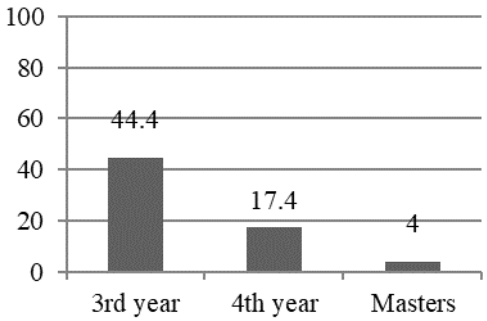

Figure 2: Percentage of orphan posts.

The final quantitative analyses, looks at the overall prevalence of the different types of teamwork that have been identified within the discussion posts. There are a total of 126 types of teamwork identified, which is more than the 106 instances noted earlier, but this is because some of the instances of teamwork were classified as more than one type of teamwork. For example, a post may have both *thanked* the contribution of another group member, while then going on to *transition* the discussion to another one of the prompts that needed to be addressed. Hence, this was then counted as one instance of teamwork, but classified as containing two types of teamwork. Figure 3 represents the dominance of *build upon* and *agree* as the types of teamwork most prevalent in the discussions in that they are almost 2/3rds of all types found. At the other end of the spectrum, posing a *question*, *concluding* a section or the discussion and *clarifying* something that was written earlier only occurred 14 times total. *Thanking/commending* the work of others, *disagreement* and *transitioning* the discussion to another area happened 12, 10 and 10 times, respectively. The data clearly demonstrates that the less critical and more consensus focused aspects of teamwork dominated the discussions.

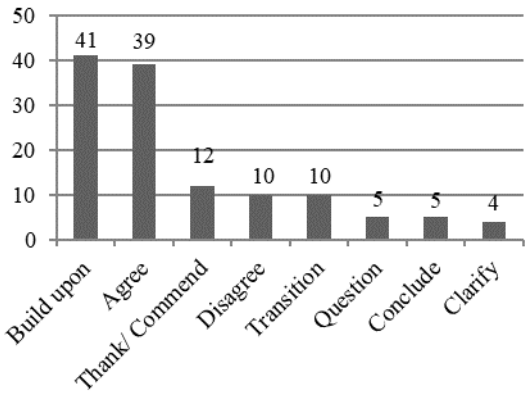

Figure 3: Number of teamwork types.

The overall investigation into the types of teamwork has also been broken down to programme year as is shown in Table 5. Given that types of teamwork were far more numerous at the Master's level when compared to the undergraduates, in all but one case, *question*, was this not true. In this specific occurrence, the 4th year students questioned one another five times, while no questions were posed by either the 3rd year or Master's students. One of the areas where the Master's students differed greatly from the undergraduate students was with *thank/commend* as the graduate students did this 11 times, but the others only did it once. Generally, the Master's students utilised more of the discussion techniques than the undergraduates. Another of the more striking differences were that there were a number of types of teamwork that the 3rd year students did not engage in or only engaged in once. In fact, only *transition* with two instances and *build upon* with 13 occurred more than one time.

Table 5: Types of teamwork by year.

	3rd year	4th year	Master's
Build upon	13	10	18
Agree	1	11	27
Thank/commend	0	1	11
Disagree	0	3	7
Transition	2	2	6
Question	0	5	0
Conclude	1	1	3
Clarify	1	1	2

DISCUSSION AND CONCLUSIONS

This section is built around the findings that emerged through the results section as they directly pertain to the research questions. In response to the first research question - what examples of teamwork are present within the discussions - it is through the iterative coding process embedded into the transcript analysis that the eight types of teamwork were established as *build upon; agree; thank/commend; disagree; transition; question; conclude* and *clarify*. The CPSA rubric descriptors have these types of teamwork embedded into them, especially at the levels 3, 4 and 5.

Regarding the second research question - how much teamwork is present within the discussions - it has been answered three different ways. The first way it was answered, was by counting the instances of teamwork present in the discussions, and then disaggregating this according to the 3rd year, 4th year and graduate students. Of the instances of teamwork, it was very obvious that there was a marked increase from year to year. As teamwork is a learning outcome for ABET accredited programmes, such as this one, this is a positive, because students seem to demonstrate an increased ability for teamwork as they progress through the computing programme. Moreover, there also seems to be a significant difference in performance between undergraduate and graduate programmes as would be desired and expected.

The second way research question 2 was answered, was by counting orphan posts. In this regard, there was an inverse relationship between the number of orphan posts and instances of teamwork. It seemed as though a great deal of the 3rd year discussion lacked any attempt at teamwork given that almost half of their posts were classified as orphan. With the Master's students the exact opposite occurred since only one of their posts was labelled as an orphan. Again, there appears to be far more teamwork as students' progress through the programme than exists at the beginning of the programme. The final way that research question 2 has been addressed is by looking at the overall prevalence of the different types of teamwork that have been identified within the discussion posts. From this one sees that *build upon* and *agree* are by far the most prevalent forms of teamwork that exist. The other six forms of teamwork only account for just over 1/3 of the total. Skills, such as disagreement, questioning and clarifying are quite conspicuous by their absence. These are key skills to be able to work well with others, so perhaps more needs to be done to address these and other areas.

Specific to programme year, the third research question - are there differences in the presence of teamwork based on programme year - it is clear that differences exist. Masters students exhibited far more teamwork overall compared to the undergraduates, and 92% of examples of compliments i.e. *thank/commend* were from them. Perhaps their work experience (as many had jobs) played a role in their being able to recognise how compliments feel good and are motivating. They also seem far more skilled overall because they use, to a much greater degree, the skills that were often lacking in the earlier analysis. For example, they disagree, transition, conclude and clarify much more than the undergraduates, and because of this, their discussion was richer and had more depth.

The fourth research question asked what are the strengths and weaknesses of teamwork present in the discussions. The best way to respond to this question is to analyse the results overall. In terms of strengths, it is clear that there is more evidence of teamwork as students advance through the programme. This is exactly what would be expected.

Another strength is that all levels of students seem willing and able to build upon what others have written before them, while the 4th year and Master's students overtly agree with their peers on a regular basis. The most glaring weakness in the discussions is that the 3rd year students have such a large number of orphan posts. This demonstrates a lack of understanding of what it means to work with others, because the discussion is almost a series one off posts rather than a meaningful discussion.

The other areas that are weak pertain to when there is possible division between the perspectives put forth by students. The discussion skills to disagree, question and clarify are not very prevalent, especially at the undergraduate level. These skills are important, because there are often diverse perspectives and alternate solutions to problems put forth in a team environment. Disagreeing, questioning and clarifying can help bring issues and concerns to the forefront, so that they can be successfully worked out by the team. Without these skills, an acquiescence might emerge that does not facilitate high quality teamwork. From the perspective of the computing programme, it is these skills that need to be taught, practiced and reinforced to enhance the ability of students to effectively work in teams. The CPSA provides a means of tracking this data over time to identify how a programme is meeting the needs of students.

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