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Student perceptions of oral exams in undergraduate engineering classes and implications for effective oral exam design

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An exploratory study of student perceptions of oral exams in undergraduate engineering courses

Abstract

Effective instruction involves well-designed assessments that provide information to students and instructors about how students progress throughout a course. Such assessments could provide feedback to students and help to guide their learning. Assessment strategies that focus on learning can positively impact students' mastery of the course content. In many undergraduate engineering courses, the primary and dominant assessment format has been written exams, whereas oral exams are not widely used, especially in large undergraduate courses. Because of their dialogic and adaptive nature, oral exams have the potential to generate many unique learning benefits for students [10, 32, 41]. Some of these benefits include providing instructors with an opportunity to deeply understand students' thought processes [10, 33, 34, 62, 70, 91] and to give targeted and immediate feedback to students [9, 41, 43, 46, 66, 88, 91, 92], increasing the interaction between students and the instructional team [33, 45, 46, 54, 69, 93], and helping students to improve technical speaking skills [32, 41, 46, 59, 66, 69]. If well designed and implemented, oral exams could generate positive student engagement and positive perceptions in the class [31, 41, 54, 59, 69, 80], and ultimately improve their motivation toward learning [12, 36, 43, 48, 54, 59, 66, 67, 69, 70, 85]. Despite these potential benefits, many instructors hesitate to implement oral exams, in part because they are relatively uncommon in engineering courses in the U.S., and student perceptions of oral assessments are unknown. Indeed, students' perceptions are important, as studies have shown that their perceptions are likely to affect their attitudes toward learning and, consequently, impact their performance in the class [4, 6, 14, 15].

In this study, we seek to understand students' perceptions toward the implementation of oral exams as an assessment tool in undergraduate engineering classes with a long term goal of identifying features of oral exams that have the greatest potential for positively impacting student engagement and learning. To achieve this goal, oral exams were implemented in six different engineering courses (four unique courses) from two disciplines, Mechanical engineering and Electrical engineering. Student perception data were collected through carefully designed anonymous quantitative and qualitative survey questions. Results from the data analysis of students' perspectives identify benefits and areas for improvement of different oral exam configurations. The results suggest that overall, students consider oral exams to have positively contributed to their learning in many aspects, such as improving technical communication skills, increasing motivation to learn, improving academic integrity, helping with the conceptual understanding of the subject matter, and receiving real-time feedback.

Introduction

Oral exams are commonly used as a component of Ph.D. qualifying exams and have many recognized benefits over written exams. Oral exams allow for real-time feedback and probing to provide for a more authentic assessment of students' conceptual knowledge. Preparation for oral exams also can improve communication skills. However, oral exams are not commonly used in undergraduate engineering courses in the U.S. [10, 33]. One reason for the hesitancy of faculty to

introduce oral exams in undergraduate courses is the workload associated with administering these exams, and the lack of certainty of the benefits that the exams would provide even if the capacity to administer them is available. Another source of hesitancy is uncertainty about how oral exams would be received by undergraduate students. Our initial motivation to try oral exams as an assessment tool stemmed from the constraints imposed by remote instruction due to the COVID-19 pandemic. The pandemic has had many detrimental effects on education, in part due to the suddenness of the shift to remote instruction. One concern that emerged in this sudden shift was how to maintain academic integrity when administering written exams remotely. To address this concern, faculty members who are part of this study implemented oral exams in their courses, and through this experience, realized the potential significant benefit to student learning that oral exams provide. To investigate these potential benefits with a goal toward supporting student learning and helping students achieve conceptual mastery, a collaborative study has been initiated at the University of California, San Diego in which six courses in Mechanical and Electrical engineering were modified to include oral exams. To address the workload associated with administering oral exams, Instructional Assistants (IAs) were trained to help administer them. The instructors of these courses each devised their own approach to implementing oral exams, yet all shared the same set of survey questions asked of students at the end of the course. These surveys explored the potential benefits of the oral exams and the areas of improvement for such exams relevant to undergraduate engineering students. The purpose of this exploratory study is to better understand students' perceptions of oral exams, created with different structures, with the ultimate goal of improving such structures to have a more positive impact on students' engagement and learning.

Literature review

Systems of assessment are well-evidenced to be able to significantly influence student learning [1-7]. The mechanism of such influence is explained with reference to properties of assessment, such as probing power, quality and timeliness of feedback, authenticity, reliability, equity, and resistance to academic misconduct [8-13]. Assessment types that fare well with respect to these attributes are more likely to motivate students and positively shape their approaches to learning [4, 6, 14, 15]. High-quality assessment modalities, fostering learning the most, often are prohibitively costly to implement in terms of time and energy, precluding their adoption in courses. This especially concerns large-enrollment courses, where instructors commonly resort to multiple-choice exams as a recourse in dealing with the large numbers of students. Although such exams can broadly survey areas of students' knowledge by means of numerous questions, the depth of examination is rather limited, and the exam modality generally suffers from a host of other disadvantages, including lack of authenticity and ineffective provision of feedback [12, 16]. In STEM, also common are exams that require students to work out solutions to problems on paper. In comparison to multiple choice questions, such problems demand greater time and labor to be solved by the students and to be graded by the staff, thus limiting the number of problems that can be included on the exam and negatively impacting assessment comprehensiveness [17, 18]. Moreover, written exams of this form are traditionally closed-book, closed notes, and tightly timed, hence rather inauthentic, testing a student's capacity to perform under pressure more so than their understanding of the course content and ability to apply it in realistic circumstances [7, 11, 13, 19]. Exams of this type are argued to encourage memorization and reproduction over conceptual mastery and logical reasoning; they are thus seen as ill-equipping students for their continuing studies and future professional work [6, 15, 16, 20-22].

Various assessment approaches have been proposed and applied, in concert or individually, to promote more effective and equitable learning, such as portfolio assessment, peer review and self-assessment, appraisal of research and design work, evaluation of oral presentations, reflective essays and videos, and interviews [12, 22, 23]; yet multiple choice and traditional written exams persist as the dominant mode of assessment in undergraduate STEM [24-26].

Occupying a distinct position among alternatives to traditional assessment are oral exams. Although strictly speaking traditional themselves, with a history spanning centuries [21, 27], if not millennia [28-30], oral exams have fallen out of favor in the technical subjects, especially in the U.S., so much so that they lost the epithet *traditional* [31]. In Europe, as well as some other parts of the world, oral exams in STEM are not so uncommon, but their usage has been on the decline there as well [10, 27, 32-35]. The relinquishing of oral exams as an assessment tool in undergraduate STEM courses has largely been driven by cost-benefit considerations. Growing literature on assessment in the mid-to-late-twentieth century suggested oral testing was a rather unreliable form of assessment, highly susceptible to examiner bias and prejudices, particularly disadvantageous to ethnic minorities, females, and students from low-income families [33-35]. The assessment mode was further judged inefficacious in comprehensively examining students' knowledge across a broad range of subject domains [33]. The perceived faults and shortcomings of oral exams, coupled with their excessive administrative cost, relegated this form of assessment to the sidelines [10, 33, 35]. New directions in educational practice set out in response to the changing technological, industrial, and socioeconomic landscapes of the modern globalized world have given oral assessment in STEM a renewed chance at impact [10, 16, 22, 32, 36].

With the emergent challenges in higher education brought on by the Fourth Industrial Revolution (aka Industry 4.0), a new set of skills have come into focus, referred to as 21st century skills, essential for students to acquire to be able to succeed in the technologically transformed, vigorously innovative, and rapidly evolving professional ecosystem. Principal among these skills are critical thinking, analytic reasoning, creativity, self-reflection, teamwork, cultural awareness, technical communication, and ethical literacy [37]. The demand for such skills in the modern workplace has been heeded as a calling for the rehabilitation of oral assessments in STEM. This is because such a form of assessment has been argued, above all else, to encourage deep learning—a requisite for the development of the 21st century skillset [38-40]. Of distinct value in the digital era too are other benefits of oral assessment, such as its capacity to promote the development of communication and interpersonal skills in students [10, 32, 41], crucial for success in the interconnected world, and its potential to offset academic misconduct [10, 42-48], which has been exacerbated by increased class enrollments and the rise of contract cheating via the internet [49]. The shining opportunities for oral assessment in the unfolding century should in no way be taken to imply that the concerns about fairness and economy of oral examination, dating from the middle of the last century and earlier, are a matter of the past. Fully addressing these concerns remains a critical challenge [10, 33-35, 50-54], though one we are far better equipped to handle today, having grown significantly more knowledgeable and mindful of our students' diverse learning needs and circumstances, and having accrued many more decades of experience in advancing and employing equitable educational practices and educational technologies for the facilitation and enhancement of learning, fair evaluation, and management of classes of large sizes [26, 55-57].

In exploring the merits of oral exams in the light of contemporary educational trends and professional opportunities, researchers find that this once traditional testing format fits aptly with our present-day notions of active learning, authentic assessment, and student-centric education at large [10, 22, 32, 34, 36, 58]. Joughin points out that oral exams offer the opportunity for complex and stimulating interactions between the student and examiner, necessitating the simultaneous employment of knowledge, reasoning, problem solving, oral communication, and ethics [10]. Oral exams, as such, constitute a mechanism to probe a student's "command of the oral medium" and "command of content," as Joughin puts it, the concurrency of which is critical for success in virtually any professional setting (ibid.). Davids argues that interpersonal competencies, such as those pertaining to effective communication and argumentation, are "not well-developed in today's engineering undergraduates" and that oral exams could help address this deficiency [59]. The ability to interpret, evaluate, and discuss in the present moment is what is often referred to as "thinking on one's feet," a faculty every candidate seeking employment or professional advancement ought to boast, and one which oral exams are particularly suited to assess and develop [60]. Deriving from Barnett [61], who asserts "speech is one way in which individuals help to form their own pedagogical identities," and that "it has an authenticity that writing cannot possess," Huxham concludes that oral exams can be employed "as powerful tools in helping students establish a professional identity" [32]. The claim that oral exams can foster professionalism and identity formation in STEM students is echoed by Theobold, who adds that such positive outcomes are likely to "increase persistence within the discipline" [62]. Contributing to the idea that assessment through dialogue promotes retention of students, Odafe explains that "when students feel that their contributions are valued, they will start to 'own' and value the subject" which "could indicate a turning point in student attitudes towards the subject" [41]. Zhou comments that, with the oral assessment method in hand, it is "easier to reach out to students who would not actively seek help from the instructor," suggesting that oral exams can serve the purposes of early intervention and the prevention of dropout [54]. By way of summary, Iannone describes oral exams as an "assessment for learning," placing its evaluative purpose secondary to its formative function [53].

The utility of oral assessments as an instrument for shaping students' approaches to learning has long been recognized [4, 6, 14, 15]. Citing Boud [63] and Vu & Dall'Alba [64], Villarroel writes "anticipation of assessment has a strong influence on what and how learners study, frames what students do, and drives the learning process" [16]. Well-structured oral exams with clearly laid out expectations can have a particularly strong impact on student learning [12, 33, 34, 65]. Goodman points to evidence suggesting that "students' anticipation of open-ended dialogue on oral exams affects their approaches to learning, leading to deeper learning" [43]. Boedigheimer explains this could be because "students typically do not want to embarrass themselves in a one-on-one discussion with the instructor" and consequently are more likely to "study more thoroughly, emphasizing conceptual understanding over memorization more than they might for a traditional written exam" [66]. Joughin elucidates further, stating that when students view oral assessment "in terms of developing a position to be argued, they are likely to work hard, experience material as having a high degree of personal relevance, accept a high level of ownership of their work, and, perhaps most importantly, develop a deeper understanding of what they are studying" [67]. Such statements are in line with Gent's view that, when it comes to conventional exams, "students often expend more energy on overcoming perceived assessment hurdles than actually developing deeper subject understanding and critical appreciation" [60].

Earlier concerns pertaining to the oral mode of assessment, foremost its reliability and demand on resources, have likewise been revisited in more recent publications [10, 32-34, 46, 53, 59, 68-71]. In defense of oral exams, Pearce and Lee note that it is not the type of assessment, but how it is designed and conducted that determines its reliability [34]. Other practitioners of oral exams concur. Dick [46] proposes the development and adherence to oral assessment guidelines, as well as examiner training to improve reliability, in agreement with earlier recommendations [33, 34]. Rouser advises familiarizing students with the grading rubrics and evaluation criteria ahead of the oral exams to improve preparation and transparency [68]. Recording of exam sessions has also been suggested to enable review for quality control and the handling of regrade requests [46, 59, 68, 70, 71]. Drawing attention to earlier work, Davis informs that reliability can be improved through the process of averaging, i.e., by increasing the frequency of oral exams and the number of evaluators involved [33]. Earlier concerns of the potentially adverse influence of anxiety and stress on students' performance on oral assessment have been similarly discussed in relation to the assessment's validity and reliability [33, 53, 59, 60, 67, 70, 72, 73]. While former studies on the topic produced mixed results, more recent work expresses optimism that measures can be taken to successfully manage the challenge. Offering mock or practice oral exams to acclimate students to the testing modality has been popular among its adopters [36, 42, 44, 51, 60, 74, 75]. Providing tutorial videos to students to acquaint them in advance, and in vivid detail, with expectations and the process of examination has likewise been proposed so as to alleviate students' nervousness [46]. Keeping oral exams as a relatively low-stakes assessment has been advised to this end as well [36]. Finally, to reduce the time and energy cost of oral exams, practitioners have resorted to the employment of multiple assessors, including instructional assistants, as well as peers [31, 42, 45, 75]. Group oral exams, in which several students are evaluated simultaneously, often on a collaborative task, are reported to have reduced administration time by several factors [41, 43, 76-84]. The use of learning management systems and teleconferencing software has also been used to facilitate scheduling and circumvent the hassles associated with coordinating physical meetings [31, 42-44, 62, 75, 85, 86]. Many instructors have in fact testified that the preparation, administration, and grading of oral exams is comparable or even less demanding of their time and effort than conventional written examinations [31, 45, 46, 50, 70, 76, 81, 87, 88].

Recent studies investigating students' perceptions about oral assessment report that overall students find the examinations fair in most, though not all, circumstances [42, 45, 46, 54, 59, 75, 80, 87]. And while students acknowledge that dialogic testing induces stress [32, 34, 41-43, 45, 51, 59, 74, 75, 80, 83, 89], sometimes more and other times less than other types of assessment, they consistently prefer oral over written exams by significant margins (ibid.). This encouraging finding implies that oral exams, as applied nowadays, are not at a disadvantage relative to other assessment methods in terms of fairness and the amount of stress suffered by students. Quite the opposite, students often see oral exams as demanding a greater level of preparation and deeper, more authentic engagement than conventional written assessment, favoring the former approach to testing despite the increased effort involved [31, 36, 59, 66, 69, 70, 80, 83]. Students have also expressed they value the opportunity to practice their communication and interpersonal skills, as they recognize these to be critically important from an employability and professional development point of view [32, 36, 42]. As noted by Joughin, analyzing students' sentiments and opinions about oral exams may help expand our understanding about the dimensions of oral assessment and provide us with valuable insights into opportunities to enhance them [10]—a line

of research that has continued to draw attention and participation from educators and education researchers across the disciplines and around the world.

Methods

To achieve the goal of understanding students' perceptions and gaining insights into oral exams design, instructors designed and implemented oral exams in various engineering courses, and evaluated the impact on student perceptions for each course. Student perceptions of their learning experiences in a course, including those related to how they are being assessed, can influence their learning behavior, and impact their academic performance, thus, are important to evaluate [1-7]. In particular, this research is interested in understanding how oral exams improved student learning toward conceptual mastery, motivation toward learning, engineering communication skills, and academic integrity. This study also seeks to explore the impact on the opportunity students have to demonstrate their knowledge and thought processes in oral exams that more traditional types of exams often lack, such as written exams; as well as the impact on instructors' ability to diagnose students' gaps in learning and provide immediate feedback during an oral exam [90, 94]. Finally, this study is also interested in understanding students' experiences with various oral exam structures, such as increased stress due to the inherent dialogic nature of face-to-face exams that require students to process questions and verbalize answers, or to non-inherent reasons such as lack of experience and familiarity with the format of oral exams.
The course instructors generated a few different oral exam formats that aligned with the course context. All the academic quarters in this study were during remote learning, thus the oral exams were administered remotely via Zoom. The details of each course and oral exam structure are elaborated below:

MAE 30A - Statics and Dynamics, is a sophomore-level class that focuses on fundamental mechanics covering statics and introduction to dynamics mechanics analysis, such as free body diagrams, 2D and 3D equilibrium particle, and rigid body equilibrium and introduction to particle kinematics and kinetics analysis. The data used in this paper were based on the implementation in Summer 2021 during a five-week Summer Session. The lecture was delivered as 80-minute lectures four times per week. The nature of summer courses is fast-paced. There were 32 students in the class with one Instructional Assistant (IA) who worked 15 hours per week. The IA had worked with the professor for three quarters on oral exams prior, thus, can be considered more experienced compared to other IAs and had an appropriate level of technical knowledge and skills. Three oral exams were administered in the course, including a group mock-up and 2 graded ones, which were held between an individual student and an instructional team member. Each oral exam was 15 minutes long. Students were provided an oral exam preparation guide. The oral exam questions were based on a follow-up to the written midterm and final exams, asking students to walk the assessor through their thought process and address follow-up questions that probed the deeper concept behind a problem-solving procedure. Hints were provided to the students whenever students struggled to answer the questions. A portion of the oral exam credit was deducted after providing hints to students. The oral exams were used as extra credit (1% each, a total of 2%) toward the final course grade.

MAE 131A - Solid Mechanics, is a junior-level mechanics class that covers the study of stress and deformation of solid materials under the action of the loads. For the scope of the study discussed in this paper, it was taught twice remotely by the same professor, once in a regular ten-

week quarter in Spring 2021, and once in a five-week quarter in Summer 2021. In the Spring 2021 quarter, 80-minute lectures were delivered twice a week over the ten weeks, while the class met four times a week over five weeks for the Summer 2021 session. There were 130 students in the Spring 2021 quarter with a total of six IAs each working ten hours per week. There were 20 students in the Summer 2021 quarter with one IA working ten hours per week. Both classes were taught by the same professor. All the IAs had an appropriate level of technical knowledge and skills. In Spring 2021, two out of the six IAs had previous oral exam administration experience. The Summer 2021 IA was new to oral exams. In Spring 2021, three graded oral exams were administered in the course, and were held between an individual student and an instructional team member. Each oral exam was 15 minutes. Students were provided an oral exam preparation guide. The oral exam questions were based on a follow-up to the written midterm and final exam, asking students to walk the assessor through their thought process and answer follow-up questions that probe the deeper concept behind a problem-solving procedure. Hints were provided to the students whenever students struggled to answer the questions. A portion of the oral exam credit was deducted after providing hints to students. The oral exams contributed 7% (1.5% for each of the two midterm exams, and 4% for the final exam) toward the final course grade. In Summer 2021, the oral exam structures were exactly the same as MAE 30A Summer 2021, and the course was taught by the same professor.

ECE 65 - Circuits and Components lab is a junior-level circuits course covering nonlinear circuit elements such as diodes, BJT and MOSFET transistors, and operational amplifiers. The Fall 2020 and Winter 2021 offerings of this course are included in the study. Both courses were offered by the same professor remotely during ten weeks with three 50-minute lectures per week. In Fall 2020, 86 students enrolled in the course and two ten-hour IAs participated in administering the oral exams. In Spring 2021, the course had an enrollment of 123 students and two ten-hour IAs, the same IAs from the Fall quarter, along with a ten-hour tutor, helped to administer the oral exams. All IAs had prior experience working as an IA for the course. Fall 2020 and Spring 2021 were the first quarters that the two IAs and the tutor administered the oral exams, respectively. In both Fall 2021 and Spring 2021 academic quarters, three graded oral exams were administered in the course, and were held between an individual student and an instructional team member. Each oral exam was 15 minutes. The oral exam questions had not been asked on any prior assignment or exam. The assessor asked students to walk the assessor through their thought process to solve the problem and answer follow-up questions that probe the deeper concept behind a problem-solving procedure. In every class, students participated in solving practice problems and explaining their solutions and thought processes to their classmates. The oral exams contributed 15% (5% for each oral exam) toward the final course grade.

ECE 144 - LabVIEW Programming Design and Applications is an upper division programming course with hands-on applications. The class was offered remotely during the regular ten-week quarter and 24 students were enrolled. The teaching team consisted of one instructor, one ten-hour IA, two ten-hour tutors, and one five-hour tutor. All IAs had taken the course and had experience assisting in the course before. Instructional Assistants did not have prior experience with administering oral assessments. One graded 10-minute oral exam was administered and was held between an individual student and an instructional team member. The oral exam questions had not been asked on any prior assignment or exam. The questions were presented to the

students at the beginning of the oral exam, and they were asked to create the programming structure for a Virtual Machine. Hints were provided to the students whenever needed. Assessors gave follow-up questions to probe decision-making. The oral exam contributed 7% toward the final course grade.

To understand students' perceptions, the multidisciplinary research team, which includes both course instructors and educational specialists from the Teaching and Learning Center at the University of California, San Diego, designed uniform web-based anonymous surveys that were employed by all participating courses at the end of an academic quarter. For analysis purposes, surveys were sent to each course individually. The student population presents a large group of students with various demographic and academic backgrounds. Each survey included both Likert-scale questions, as well as open-ended questions [90].

Descriptive statistical analysis, statistical inference analysis, and qualitative coding analysis were applied to gauge students' overall perceptions (positive, negative, or neutral). Results from the analysis of these data inform oral exam design and implementation for future studies.

The research results shared in this paper are based on some of the pilot oral exam implementations from Fall 2020 to Summer 2021. The data used are collected from three professors from two disciplines, Mechanical Engineering and Electrical Engineering, who implemented 1-3 oral exams into each of the six courses, four of which are unique courses, as described above. The details of data and analysis are discussed in the next section.

Results and discussion

In all courses under study, end-of-quarter surveys were used to gather students' perceptions on the oral exams. All surveys included the same questions. Of all questions in the surveys, five Likert scale questions with five potential answers ranging from "to a great extent" to "not at all" and two free response questions were utilized in this study. The Likert scale questions used in this study were:

- Did the oral exam(s) contribute positively to your learning in the course?
- Do you feel that the oral exam(s) helped improve your technical speaking skills?
- Did the oral exam(s) increase your motivation to learn?
- Do you feel the oral exam(s) contributed positively to academic integrity in the course?
- Did the oral exams cause you undue stress?

The two free response questions asked about the best aspects of the oral exams and their areas of improvement. To run ANOVA on ranks tests and find the correlation between different factors, scores of 5 to 1 were assigned to multiple choice answers "to a great extent", "significantly", "moderately", "slightly", and "not at all". A score of 5 means the students selected "to a great extent", and a score of 1 means the students selected "not at all" in response to the questions.

Data and analysis of responses to the Likert scale questions

The surveys in the MAE 30A - Summer 2021, MAE 131A - Spring 2021, MAE 131A - Summer 2021, ECE 65 - Fall 2020, ECE 65 - Spring 2021, and ECE 144 - Winter 2021 were completed by 23, 100, 16, 68, 97, and 12 students, respectively, with a corresponding a survey completion

rate of 72%, 77%, 71%, 79%, 50%. Table 1 shows the average ratings of students' responses to the survey questions selected for this study. In the ECE 65 - Fall 2020 survey, the question about undue stress was phrased slightly differently so its average score was not included in the study.

Table 1. The average scores of students' responses to the selected survey questions in the courses under study. An average score of 5 indicates that all students selected "to a great extent", and an average score of 1 indicates that all students selected "not at all" in response to the question.

Course title	MAE 30A - SU21	MAE 131A - SP21	MAE 131A - SU21	ECE 65 - F20	ECE 65 - SP21	ECE 144 - WI21
Number of the survey responses	N = 23	N = 100	N = 16	N = 68	N = 97	N = 12
PC	3.55	3.25	3.55	3.75	3.45	3.5
ITS	3.5	3.5	3.7	3.7	3.6	4
IML	3.25	3.1	3.35	3.35	3.2	3.25
IAI	3.8	3.8	4.2	4.15	3.95	4.25
US	3.35	2.8	3	- *	2.4	2.5

PC: Did the oral exam(s) contribute positively to your learning in the course?
IML: Did the oral exam(s) increase your motivation to learn?
ITS: Do you feel that the oral exam(s) helped improve your technical speaking skills,
IAI: Do you feel the oral exam(s) contributed positively to academic integrity in the course?
US: Did the oral exams cause you undue stress?
* The question about undue stress was phrased differently in the ECE 65 - Fall 2020 survey, so it is not included in the study.

Students' responses to the question about the extent to which they found the oral exams positively contributing to their learning in the six courses under study were compared using Kruskal-Wallis non-parametric (one-way ANOVA on ranks) tests to find out whether there are any statistically significant differences in students' perceptions on the overall positive effect of oral exams to their learning. The distributions of student responses were not normal, hence the Kruskal-Wallis non-parametric test was used for analyzing the data. The average scores for the question about the positive contributions of the oral exams to learning in the courses under study ranged from 3.25 to 3.75. Although the average student ratings of the extent to which they agreed that the oral exams positively contributed to their learning differed in the courses under study, the results of the statistical analysis showed that with a 95% confidence level, there was no statistically significant difference between those ratings. Overall, students reported a positive contribution of the oral exams to their learning in all of the courses under study.

The average scores of students' ratings of the effectiveness of oral exams in improving technical speaking skills, increasing the motivation to learn, and improving academic integrity ranged from 3.5 to 4, 3.1 to 3.35, and 3.8 to 4.25, respectively, in six courses. The results of Kruskal-Wallis tests indicated that with a 95% confidence level, there were no statistically significant differences between how students in the six courses rated the effectiveness of the oral exams on improving their technical speaking skills, increasing their motivation to learn, and maintaining academic integrity. This finding suggests that while instructors used different implementations of oral exams, there was consistency in the perceived effectiveness of oral exams in improving technical speaking skills, increasing the motivation to learn, and improving academic integrity in all courses.

Table 2. The correlation coefficients and their significance in comparing the ratings of the positive contribution of the oral exams to learning and the three proposed benefits

	Spearman's rho value and the corresponding p value		
Course name	PC and IML	PC and ITS	PC and IAI
MAE 30A - Summer 2021	Not statistically significant *	Not statistically significant *	0.507 p = 0.014
MAE 131A - Spring 2021	0.655 p <0.001	0.670 p <0.001	0.515 p <0.001
MAE 131A - Summer 2021	Not statistically significant *	Not statistically significant *	Not statistically significant *
ECE 65 - Fall 2020	0.736 p <0.001	0.649 p <0.001	0.603 p <0.001
ECE 65 - Spring 2021	0.758 p <0.001	0.699 p <0.001	0.575 p <0.001
ECE 144 - Winter 2021	0.734 p = 0.007	0.798 p = 0.002	0.795 p = 0.002

PC: Positive contribution to learning, **IML**: Increasing the Motivation to Learn, **ITS**: Improving Technical Speaking, **IAI**: Improving Academic Integrity. *Only the ones that were statistically significant with a p-value of less than 0.05 were included in the table.

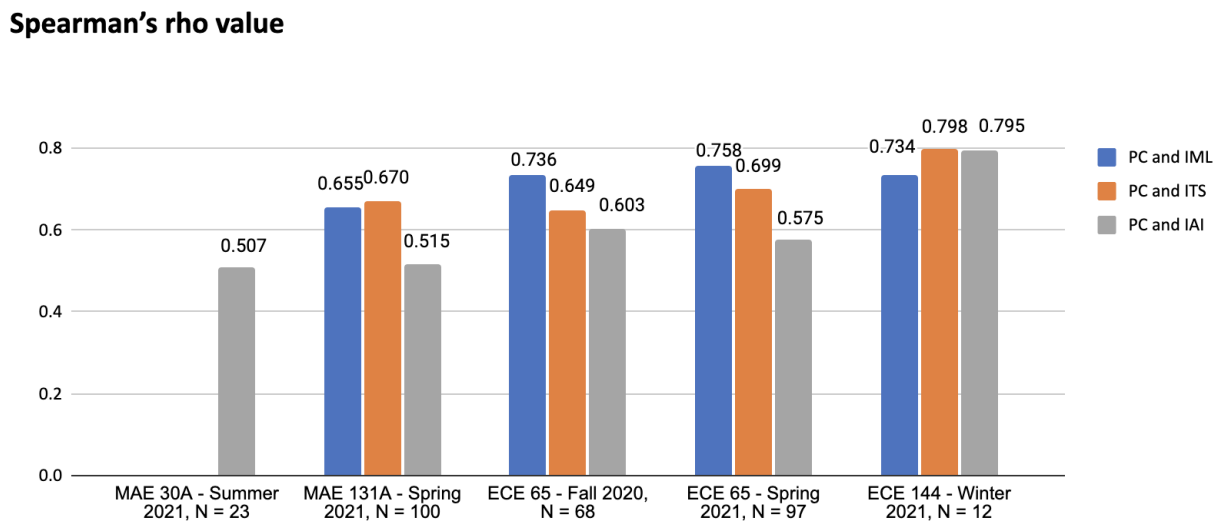


Figure 1. A comparison of the correlation coefficients for positive contribution of oral exam to learning (**PC**) and increasing the motivation to learn (**IML**), improving technical speaking (**ITS**), and improving academic integrity (**IAI**) in the survey responses in the courses under study.

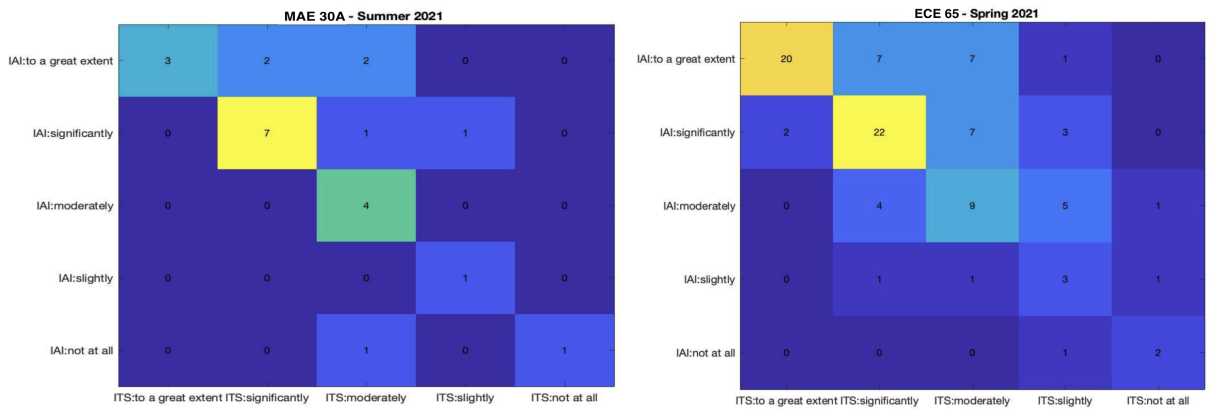
The calculated correlations between students' rankings of the positive contribution of oral exams to learning and three proposed benefits, provided in Figure 1, indicated that in MAE 131A - Spring 2021, ECE 65 Fall 2020, ECE 65 Spring 2021, and ECE 144 - Winter 2021, there were statistically significant association between students' rating of positive contribution of oral exams to learning and their ratings of the proposed benefits. Students in these courses who found the oral exams positively contributing to their learning also agreed with the proposed benefits. In MAE 131A - Summer 2021, none of the correlations were statistically significant. In MAE 30A - Summer 2021, the correlations between positive contributions of the oral exams to learning and improving the technical speaking skills and increasing the motivation to learn were not statistically significant. Since there was no statistically significant difference between students' responses to the survey questions across all six courses, the researchers hypothesize that students in these courses might have had other reasons for finding the oral exams beneficial to their learning. For example, in the free response part of the survey, students in these classes noted that the oral exams promote learning and identified the exams' focus on conceptual mastery of the materials as one of the best aspects of the oral exams.

To investigate whether there was any relation between students' perceptions of the oral exam stress level and the level of positive contribution of oral assessments to student learning, the correlations between these two factors were calculated in the courses under study. The results of a regression analysis showed that there was no statistically significant positive or negative correlation between these two variables. Although in ECE 65 - Spring 2021, MAE 131A - Spring 2021, and MAE 30A - Summer 2021 lower exam stress levels correlated with reports of higher positive contribution of the oral exams on student learning, these correlations were not statistically significant.

To investigate whether students provided uniformly high or low ratings to the survey questions or selected various levels for different hypothesized benefits, the researchers randomly selected the responses to two of the survey questions in two courses and computed the heat maps of the responses to those questions in the selected courses. The heat maps provided a visual comparison

of the responses to the two questions. The numbers in the cells of the heatmap represent the number of students who selected the corresponding answers to the two questions included in these maps. The selected questions were “Do you feel that the oral exam(s) helped improve your technical speaking skills?” and “Do you feel the oral exam(s) contributed positively to academic integrity in the course?”. The responses to those questions in MAE 30A - Summer 2021 and ECE 65 - Spring 2021 were utilized to generate the heat maps provided in Figure 2.

The heatmaps showed that students didn’t uniformly select the same level of agreement for all of the questions. For example, in ECE 65 - Spring 2021, some students selected “significantly” for improving academic integrity (IAI) and “slightly” for improving technical speaking (ITS). As another example, in MAE 30A - Summer 2021, some students selected “to a great extent” for improving academic integrity (IAI) and “moderately” for improving technical speaking (ITS).



(a) (b)

Figure 2. The heatmaps (comparison of student responses to two questions related to effectiveness of oral exams in improving academic integrity and technical speaking for (a) MAE 30A Summer 2021 and (b) ECE 65 Spring 2021.

Data and analysis of responses to the open-ended questions

In the end-of-quarter surveys, students were asked about the best aspects of the oral exams and the areas of improvement for such exams. To analyze the students’ responses to those unprompted questions, their comments were thematically assigned researcher-defined open codes using the ATLAS.ti software. The common phrases that students used in their free responses were then grouped and assigned researcher-defined axial codes and the frequency of such codes were calculated. The frequently used codes and their explanations are provided in Table 3. Figures 3 and 4 provide visual representation of the distribution of those codes in the student free responses in each of the courses under study.

Table 3. The codes assigned to the phrases frequently used in the students' free responses to the best aspect of the oral exams and their areas of improvement

	Axial Codes	Explanation of the code
Best aspects of the oral exams	Conversation with IAs/Professor	Students cited the conversation with the Instructional Assistants or the Professor as a positive aspect of the oral exams
	Promote learning	Students mentioned that the oral exams promote learning as a benefit of the oral exams
	Communication skills	Students mentioned that oral exams were beneficial for improving their communication skills
	Nice IAs	Students cited that the Instructional Assistants (IAs) were nice
	Low pressure exam setting	Students cited the low pressure exam settings as a positive aspect of the oral exams
	Real-time feedback	Students mentioned that the feedback they received from the Instructional assistants or the Professor during the exam with helpful to their learning
	Showing mastery by explaining	Students cited that in the oral exams they were able to show the mastery of the materials by explaining their thought process
	Conceptual understanding	Students noted that the exams focused on the concepts and assessed the conceptual understanding of the course concepts
	All good	Students mentioned that all aspects of the oral exams are good
Areas for improvement	Provide feedback	Students asked the examiner to provide feedback on their performance and notify them of their mistakes and provide the correct answer
	Clarify the questions	Students mentioned that sometimes the questions were not clear and asked for more clarification on the questions
	Offer practice tests	Students asked for practice oral exams
	Increase exam time	Students reported that the oral exam duration was short and asked to increase the exam time
	Oral exam stress	Students cited the undue stress caused by the oral exam and expected the instructors to find a solution for it

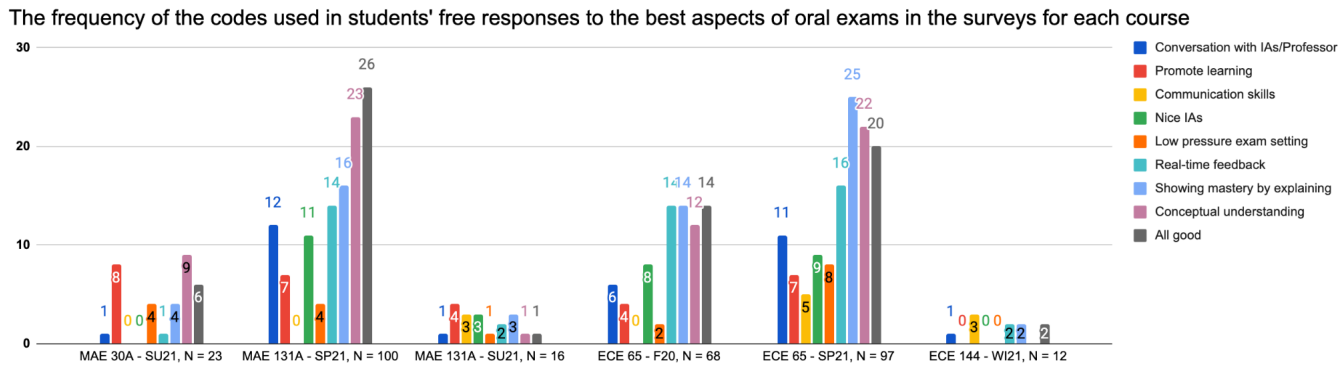


Figure 3. The frequency of the codes related to the best aspects of the oral exams as used in the students' free responses in each of the courses under study.

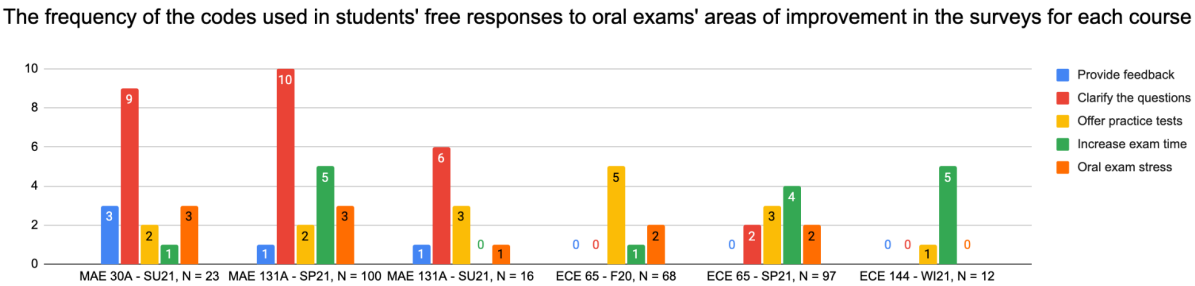


Figure 4. The frequency of the codes related to the areas of improvement for oral exams as they appeared in the students' free responses in each of the courses under study.

The student responses to the open-ended questions about the best aspects of the oral exams and the areas for improvement provided insights into the benefits of the oral exams as perceived by students. Such benefits included "increasing the interaction between the instructional team and students", "receiving real-time feedback and learning from the instructional team", "the ability to show mastery by explaining the thought process", and "oral exams focusing on the concepts and assessing conceptual understanding". For the areas of improvement, students suggested adding more clarifications on the problems, offering practice oral exams, and increasing the exam time. The researchers plan to incorporate the student suggestions in modifying the oral exam logistics for future implementations. Showing students the questions in the written format and utilizing some visual aids such as diagrams in the questions might potentially address the concerns raised by some students. Applying such modifications could also result in utilizing the exam time more efficiently to assess students' understanding of the materials.

Future Work

From analyzing the students' responses to the open-ended survey questions, the researchers identified several oral exam benefits as perceived by the students. In the future, those benefits will be included in the survey questionnaire to receive all participants' ratings of such benefits. Mock oral exam videos will be recorded and shared with students to provide students with examples of interactive technical communications during such exams. The researchers will continue reviewing the oral exam questions to provide more clarity to the students during an oral

exam. Data will be collected to study any potential correlations between the structure of oral exams and the challenges and risks related to administering these exams. Some of the challenges that will be included in the study are the perceived or actual effects of bias in the exam that are not related to the actual exam content, such as biases based on gender, race, ethnicity, fluency in English, etc. [90]. In some of the courses included in this study, there was a negative correlation between the exam stress levels and reports of a higher positive contribution of the oral exams on student learning. The researchers will continue monitoring the stress associated with oral exams and assess potential correlations between the exam stress and students' performance on the oral and written exams and their responses to the survey questions regarding the benefits of the oral exams. Furthermore, the influence of the oral exam grade contribution to the total course grade on students' performance on these exams and their responses to the questions will be studied in the future.

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