Students' Perceptions of Best and Worst Aspects of Design Courses: A Qualitative Analysis of 87 Courses and 5591 Students

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***Abstract*—This Full Paper presents the results of qualitative analysis of students' perceptions of the best and worst aspects of 87 courses related to design such as engineering design, product design, biomedical engineering innovation and design, and Mechanics-Based Design. The total enrollment in the courses was 5591 students at a Research-Intensive University in the US. Iterative close readings of the comments and open and axial coding were applied to the comments to generate codes that represent students' comments. Codes were grouped in categories that represent students' opinions about teaching. Students reported the best and worst aspects of design courses related to the following categories: course planning and logistics, teaching strategies, learning experiences, assessment and evaluation, mentoring and modeling, and encouragement and motivation. This work suggests that careful design of all aspects of teaching is important. Special attention should be given to aspects of design courses such as project-based learning, teamwork, and hands-on applied learning.**

Keywords—design courses, student evaluation of teaching, student rating of instruction, qualitative metbods

I. INTRODUCTION

Students' perceptions of the quality of the courses that they take in undergraduate education can help teachers improve their courses and quality of teaching [1], and help administrations provide better guidelines and policies to improve the students' learning experience. Students' perceptions of the courses and teaching can also be used to measure teaching performance [2] and assess the effectiveness of changes or improvements made to courses [3, 4]. Students' Evaluations of Teaching (SET) or Students' Rating of Instruction (SRI) is a large area of research in applied psychology [5]. SET encompasses students' evaluation of different aspects of their experiences in the courses they take and not just limited to "teaching." For example, SET includes student's perceptions about assessment, learning, and course planning. A recent literature review conducted citation analysis that revealed three main topics in the SET literature: (i) the use of SET, (ii) validity issues concerning SET, and (iii) the construction and validation of SET instruments.

First, regarding the construction and validation of SET instruments, several studies investigated the dimensions of students' perceptions of teaching effectiveness or quality and showed that SET could be composed of several dimensions. For example, based on confirmatory factor analysis (CFA) with two samples of more than 7,000 and more than 2,000 students in various university classes who rated items in the Student's Perceptions of Teaching Effectiveness (SPTE) questionnaire, results showed six first-order dimensions of instructional quality that are useful across a broad range of university courses. These six dimensions were: (i) rapport with students (attitude twoard students), (ii) course value, (iii) course organization and design, (iv) fairness of grading, (v) difficulty of course, and (vi) workload [6, 7]. Another CFA with a sample of 7,632 students in various university classes who rated items in the Student Course Experience Questionnaire (SCEQ) questionnaire, results showed five first-order dimensions. These five dimensions were: (i) teaching, (ii) goals and standards, (iii) assessment, (iv) workload, and (v) generic skills (related to learning) [5]. Another study [8] showed four dimensions of teaching quality, for students' rating of instruction, that are grounded in current instructional design principles: (i) organization and structure, (ii) assessment and feedback, (iii) personal interactions, and (iv) academic rigor. Simpler dimensionalization of students' perceptions can lead to the following factors: (i) course design, (ii) lecturing (class) performance, and (iii) overall satisfaction [9]. Another simplification of students' perceptions can reduce students' perceptions to overall view about teaching and overall view about the teacher [10]. Another study [11] showed that students identified nine teaching effectiveness competencies: communication, availability, creativity, individual consideration, social awareness, feedback, professionalism, conscientiousness and problem-solving. All these aspects are part of what the students may perceive as good or bad aspects of a course. One meta-analysis of the literature pointed out that although effective instruction may be multidimensional, student ratings of instruction measure general instructional skill, which is a composite of three subskills: (i) delivering instruction, (ii) facilitating interactions, and (iii) evaluating student learning [12].

Second, regarding validity issues in SET, they address whether the evaluations accurately (i) reflect students' opinions about the quality of instruction, regardless of whether ratings reflect what they learn and (ii) reflect instructional effectiveness [13]. The validity challenge for SET is to develop short SET-instruments that consist of questions on important dimensions of instruction [2]. One recommendation is to use Rasch Analysis, based on Item Response Theory (IRT) which provides a better alternative for examining the psychometric quality of rating scales and informing scale improvements [14]. Issues of reliability are also important to consider [15].

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Third, regarding the use of SET, some guidelines include (i) using multiple methods to achieve high survey response rates, especially in-class time [16], (ii) considering the effects survey design and method might have on the respondents, and (iii) using multiple methods of evaluation [2]. The interpretation of SRI is also an important topic [17] to be able to use the feedback from students meaningfully to make decisions about making changes to teaching. These guidelines are useful in assuring the quality of research studies that involve SET.

Research on SET is predominantly quantitative in nature. Some research on SET included using interview or focus groups [18]. This full paper presents the results of qualitative analysis of students' perceptions of the best and worst aspects of 87 courses related to design such as engineering design, product design, biomedical engineering innovation and design, and Mechanics-Based Design.

II. METHOD

A. Context

The current study took place at Johns Hopkins University, and resulted from a commission's work that aimed at interpreting the mission of undergraduate education in the 21st century and developing a new model that would serve for the next decade or more. The commission was asked to think broadly and creatively about (i) how to support and encourage students to define their own education by allowing them to explore and pursue their own interests, (ii) how to create a holistic curricular, co-curricular, and extracurricular experience, and (iii) how to develop the pedagogy and infrastructure needed to support these objectives.

The commission was divided into working groups that identified areas of interest to investigate based on data available from multiple sources including students' evaluations of teaching. Design courses were of special interest and were investigated thoroughly to provide insights on how to improve them. Other special interest courses included lab courses and community-based learning courses. The current analysis focused on design courses only.

B. Participants

A total of 5591 students were enrolled in 87 design courses in the three years: 2015, 2016, and 2017. A sample of the courses and enrollment data is given in Table I

TABLE I. DESIGN COURSE DATA

Course*	***Enrollment***
Advanced Electronic Lab Design	50
Advanced Systems Engineering: Concept, Design, Development and Integration	4
Bioengineering Innovation and Design - Global Health	49
Biomaterials Senior Design II	5
Chemical Engineering Product & Process Design	182
Electronics Design Lab	113
Engineering Design Project	130

[a.] Sample of courses

C. Measures

A standard course evaluation is used for all the courses at the university including design courses. The course evaluation included both Likert-scale type rating questions for different aspects of teaching as well as open-ended questions.

The rating questions included the following:

1. Overall quality of the course
2. Instructors' teaching effectiveness
3. Intellectual challenge of the course
4. Teaching assistant for the course
5. Feedback provided for work
6. Workload (compared to other courses taken at the university)

The open-ended questions included the following:

1. What are the best aspects of this course?
2. What are the worst aspects of this course?
3. What would most improve this class?
4. What should prospective students know about this course before enrolling? (You may comment on any aspect of this course such as assumed background, readings, grading systems, and so on.)
5. Describe one thing you learned in this class that you didn't previously know or fully understand.
6. If this course was expanded to a three-credit course, what additional topics would you like to explore or what existing topics should be studied in more detail?
7. How could the final project - either the activity or instructions - be improved for future students, if at all?

The analysis reported in this full paper focused only on the first two open-ended questions related to the best and worst aspects of the course.

D. Procedure

A request was sent to the office of the registrar to obtain all students' feedback and ratings in course evaluations in all courses designated as "Design courses" for three years: 2015, 2016, and 2017. Data for all design courses were combined and divided by the question. Data were imported in the MaxQDA software for qualitative data analysis.

E. Analysis

In the first stage of analysis, iterative close readings by three readers (A, B, C) were undertaken to immerse the readers in the comments in order to understand the intricacies of the students' feedback. Following an analytical grounded-theory-guided process, each reader independently read 10% of the statements, which were sampled randomly, "deconstructing" the students' comments in response to the question at hand. The three readers coded the statements independently using open-coding [19] and then met to discuss the codes and consistency of coding. The readers compared their codes and achieved consensus regarding the codes that emerged.

In the second stage of analysis, one of the authors of this paper conducted axial coding and assembled the codes into larger or overarching categories based on the inductive generation of codes [20].

III. Results

In this section, we discuss the categories and underlying codes that emerged from the analysis of students' comments about the best and worst aspects of design courses. Students' comments on the best and worst aspects of the design courses were organized according to the following categories: (1) course planning and logistics, (2) teaching strategies, (3) learning experiences, (4) assessment and evaluation, (5) mentoring and modeling, and (6) encouragement and motivation. Both mentoring and modeling, and encouragement and motivation are related to teachers' roles. One category emerged in the best aspects and did not appear in the worst aspects and is related to non-traditional learning opportunities. Details of all categories are presented below.

A. Best Aspects of Design Courses

1) Course planning and logistics: The following codes related to course planning and logistics emerged from the analysis of students' comments.

a) Field visit was beneficial: Students highlighted that the field visits to companies, plants, or labs were useful and beneficial. One student stated, "Also, the field trip was very beneficial. A trip like that helps to put in perspective how important the work we are doing is, and also starts the conversation on what could be improved both by the individual and as a group."

b) Organization and schedule are convenient and flexible: Students appreciated the flexibility of schedules and the organization of the course and mentioned that good organziation and flexible schedules help them lear better. Students mentioned, "Lots of flexibility as long as you're doing an amount of work that can be justified," "the times for which you can work in the lab are very flexible, which is nice and unlike other classes," "It allowed us flexibility in coming up with and executing our own design project," "learn from one of the top professors organization wise picking up habits that will be incredibly useful throughout graduate school," "The lectures were fantastic and well organized.

c) Workload: A few number of students thought that the workload is not heavy or reasonable. Some found that the workload was light. Some students found the workload to be heavy but enjoyable. One student mentioned "There are only six assignments and then the final presentation and report - so the workload is not bad." Some other comments by students include: "The workload was very appropriate for a chemical engineering class," "She is a wonderful professor and is very thoughtful when assigning deadlines and conscious about our workload," "She is a wonderful professor and is very thoughtful when assigning deadlines and conscious about our workload."

2) Teaching strategies: The following codes related to teaching emerged from the analysis of students' comments.

a) Lectures are useful and interesting: Students gave the following qualifications to lectures: "informational," "thoughtful," "entertaining," "useful," "detailed," "excellent," "interesting," "helpful," "amazing," "engaging," "valuable" "good quality" "a lot of more applicable information from lecture." One student mentioned "She lectures in a very understandable way so students gain a lot from her teachings." Another student mentioned, "I would say that the best aspect were the lectures, they were very well done."

b) Guest speakers are insightful: Students expressed that one of the best aspects of design courses is guest speakers who come from the industry and provide useful insights. "You hear lectures from people in the industry who actually have meaningful things to say about the material we are learning," "The speakers are interesting to hear from because they understand where we are in our careers right now and provide a useful perspective into the working world," "I really enjoyed listening to the different guest lecturers. I have a lot better idea of what being a consultant means which is really helpful." "It's helpful to hear guest lectures from people who have succeeded in industry and can offer an alternative perspective to what we usually hear."

c) Discussions: Students mentioned that different formats of discussions helped them in learning. Discussion were "open," "insightful," and "helpful." Some comments included: "I enjoyed the journal club discussions, and they provided good insights about the industry," "We got to have a lot of discussion about interesting topics in thermal design of space systems," "This class provided a lot of interesting discussions and readings. The professor was really involved and active in the discussions, without completely controlling the conversation at all times," "The best aspects are the engagement and course discussion which helps put in to context our projects," "you could have more live discussions with others and have your ideas challenged in real time," "In-class discussions are very helpful to develop ideas of structural engineering that can be beneficial for students who have not had significant exposure to design."

3) Learning experiences: The following codes related to learning experiences emerged from the analysis of students' comments.

a) Applied hands-on learning experience: Students mentioned hands-on and practical learning as one of the best aspects of the design courses. Some examples of students' comments include: "Very hands on, loved making the prototype and addressing the issues," "Real world, hands on design experience and collaboration with outside sponsors. Hands on machining experience. It really prepares us for industry," "The best aspects of this course is that it is a hands-on course in which you are actually building a final product. All the concepts that are learned in other classes all come together to a real world application, which is extremely fun to see," "Compared to traditional materials science courses, design team covers more applied engineering problems in a wider range of topics from programming to electrical engineering," "The best aspect of this course was the opportunity to work on a real-world problem and gain hands-on experience along a great set of professionals

and experts from a wide variety of disciplines," "Best class by far in terms of preparing students for the real world. [University name is masked for blind review] is a very research heavy campus which leads to many classes focusing on theory with very little regard for introducing students to real world applications or how to turn this knowledge into marketable skills in the job hunt. This class does a great job of trying to balance that out."

b) Lab experience is practical and useful: Students expressed the value of lab experiences and mentioned that the time they spend in the lab is useful and practical. The labs help in the design projects and are interesting. One student stated, "All of the labs teach you useful, hands-on skills, which you can then apply on the final crane design project."

c) Project is challenging, practical, and interesting: Comments included "We have a very amazing project that is very challenging but very rewarding." "The project is driven by self-motivation, valuable contacts within [the university] or abroad who gave feedback, ample research and time devotion, and a pinch of luck," "The projects are challenging but rewarding."

d) Client interactions (Learning social, communication, and problem-solving skills): Students mentioned that they learned communication and problem-solving skills throught their interactions with clients. Comments included: "The course gives you the opportunity to work with industry clients, providing the potential for a significant amount of real world experience," "gettting real world experience working on an industry problem for a client," "Getting to experience making a device for a client to solve a real problem, rather than building smaller scale "toys" that don't solve any need," "I like the fact that you get to meet with an actual client and have a big budget," "Working with a client and seeing real world applications of engineering." "I feel that we are learning a ton about real world engineering as we work with real clients on real projects.

e) Assignments and readings are relevant and thought-provoking: Some students reported that they liked the assignments and found them to be useful and helpful in learning. Other students found that the fact that assignments were few helped them focus more on working on their projects. Some comments included: "Readings are informative and though provoking," "I like CAD so I enjoyed the assignments and exploring the software," "Good open ended project where you can really shape your assignment," "I think that the block parts at the end of the assignments, while annoying at the time, were very helpful in better understanding how to visualize 2D to 3D," "Very few assignments, gave lots of time to work on the project without worrying about frequent presentations or reports," "When you finish an assignment, you feel great and you get to see a physical representation of what you've done." "Reading relevant papers in the field and analyzing them also helps prepare students for graduate/work life where the ability to sift through vast amounts of information, and summarize it efficiently is extremely important," "I feel i learned more by reading research papers than cramming for a normal test."

f) Background knowledge is empowering: Some comments included: "We could use our previous ChemBE knowledge to come up with a product that could actually change the world around us," "We can utilize our skills and knowledge from previous ChemBE courses to design a new product," "It is a great opportunity to apply our knowledge," "Combining the ChemBE knowledge that we learned so far," "It was a great chance to use the knowledge I've accrued over the last four years," "Integrating knowledge from all previous courses to apply to the human body."

g) Creativity and freedom: Students highlighted their appreciation of being able to be creative and have freedom to work independently in design courses. Comments included: "The best aspects of this course are you get to create a project that you are really passionate about, and you really get to do what you want." "Total creative freedom to do the project however you would like," "Encourages creativity, lets students have their own project with minimal constraints, exposes students to entrepreneurship, and almost always ends up with the student being a cofounder or recipient of significant grant money," "Creating a video game from scratch was a lot of fun. It's even better that I was able to learn python along the way," "makes you realize how important team work is and how much creativity and ingeniousness can flow out of our young minds when everyone is a contributing member," "It's very do it yourself, very independent and creative, and you are free to create whatever project you like." "It's great doing real world problems and feeling as if we are just as good and creative as people who do this for a living," "It gives us an opportunity to use our creativity in engineering."

h) Learning content knowledge and skills: Learning domain-specific content knowledge and skills was one of the best aspects of the design courses for many students. Comments included: "Learn good technical drawing techniques," "The best aspect of this course was being able to learn about how to use AspenTech, which is useful for prospective chemical engineers if they are going into chemical plant designs," "t was a great opportunity learning how to go from the diagram of a schematic to layout and seeing how all the different little parts come together," "This course is not only effective at teaching students how to design and analyze foundations and retaining structures, but also at exposing students to other aspects of construction. We learned about different methods to instal piles, different considerations concerning labor, and we also briefly touched upon geotechnical materials," "Great intro course to CAD that goes from basic part design to complicated mechanisms and optimization processes," "You get to learn about the actual process of designing a product."

i) Presentation skills: Students mentioned presentation skills as one of the best aspects of design courses, especially that these skills help them learning and mastering the content knowledge. Some comments included: "I think that having to present every week has made me much more competent with the material," "Giving an hour long presentation is good experience for grad school and research presentations. So that is definitely a plus," "Your presentation skills will also be

dramatically improved because the professor will force you to be better," "lots of opportunities to present our work," "The various presentations are great learning experiences," "While preparing for presentations, we search through various materials including websites, journals, books which allows us to broaden our perspective on the subject.

j) Writing skills: Some students mentioned that learning writing skills was one of the best aspects of design courses. Some comments included: "it was so helpful since we'll have to write these kinds of reports in our professional careers as well," "learning how to write and present professionally," "[This course] is useful for learning about modeling and writing lab reports," "We got a lot of experience writing in depth lab reports and received feedback for each one, which was a good experience," "The lab write ups really help get the full idea of each project."

k) Resources facilitate learning: The availability of resources for learning and studying was considered one of the best aspects of the design courses by some students. Comments included: "Professor regularly provided us with access to cutting edge research published in recent journal articles," "Plenty of handouts to aid in learning and reduce the amount of notes," "Access to resources/instruction whenever needed," "We have access to so many resources on campus (machine shops, large budget)," "I think this simulates the real world better than closed-book tests, because when one is doing engineering in real life, one has access to many resources," "Professor [Name masked for peer review] does an excellent job making resources available to you to reinforce the material."

l) Teamwork and collaborative learning: Teamwork and collaborative learning were considered as some of the best aspects of design courses. Comments included: "You learn to work together and together you create something," "Group work was encouraged and helped learning, especially on design problems," "Working so closely with a small group of BMEs on a single project.. makes you realize how important team work is," "Being in design team has taught me to think in an engineering perspective and to learn how to use the tools at my disposal," "Working in teams/small groups with regular, small meetings with an AWESOME TA were my favorite part."

4) Assessment and evaluation: The following codes related to assessment and evaluation emerged from the analysis of students' comments.

a) Assessment: An example of comments included: "I liked the structures of the exams, and I liked how we were assessed on if we could solve the problem versus if we solved it a certain way.

b) Evaluation: Comments included: "I liked the structures of the exams, and I liked how we were assessed on if we could solve the problem versus if we solved it a certain way," "Homework is like the exams and he gives you all the material you need to do well," "it's nice that the exams are take-home rather than in-class," "It's much more motivating to create the deliverables for this course than it is to hand in problem sets and take exams."

5) Mentoring and modeling: The following codes related to mentoring and modeling emerged from the analysis of students' comments.

a) Guidance, direction, and modeling: Examples of coded segments included: "The class was formatted to give us good direction on the project/design process," "The committee meeting was a really great way to get input from people on the direction and progress of the project," "We are given a lot of flexibility and guidance to choose any product direction that we would like," "Professor showed us a new way to thinking when approaching designing products."

b) Feedback: Examples of coded segments included: "The peer review system allowed us to provide feedback on our group members, so that the group grade was not put a risk by the actions of an errant member," "The homework was generally reasonable and we received feedback for everything," "It was really essential to have someone outside of the team to provide feedback on prototypes," "I like the opportunity to get feedback from fellow leaders about problems you're facing during team snapshots. Loved Catch Phrase!"

6) Encouragement and motivation: The following codes related to encouragement and motivation emerged from the analysis of students' comments.

a) Encouragement: Examples of coded segments included: "Professor was very encouraging," "The instructor encourages you to stop him with questions," "The course is interesting and participation is encouraged, making the course engaging," "Professor was encouraging and helpful throughout the whole process of developing a product," "The professor encourages students to ask questions so they can get feedback on their designs."

b) Motivation: Example coded segment mentioned: "It's much more motivating to create the deliverables for this course than it is to hand in problem sets and take exams. The professors are more helpful than most, and truly know us -- They always greet me by name, and that honestly makes me way more willing to be around and work on things, as insignificant as that may seem. [Professor name masked for peer review] in particular has really seemed like she has gotten to know us and that makes everything a little more enjoyable."

7) Other aspects: Other aspects that appealed to students included: (i) professional identity building, (ii) immersive learning experience, (iii) exploration, experimentation, and discovery, and (iv) critical thinking and reflection.

B. Worst Aspects of Design Courses

1) Course planning and logistics: The following codes related to course planning and logistics emerged from the analysis of students' comments.

a) Field visit or trip was not productuve: One student stated, "The on-campus visit to the FDA was not as productive as it could have been. The discussion was not well organized and the reviewers did not have a great understanding of how best to provide feedback." Another student mentioned, "Students need more guidance after the trips in turning all the

trip insights into actionable items. I feel like a lot was lost in the transition from in-country to lab."

b) Organization and schedule are not well planned: Organization and scheduling were among the worst aspects of the design courses for some students. Comments included: "Poor scheduling and organization (lecture room is often double-booked, lectures are often cancelled due to poor scheduling, teams sometimes not notified of room change for presentations, etc.)," "Assessment, deadlines, presentations, and reports should be better organized and better communicated to students."

c) Workload: Many students thought that the workload was too heavy or unreasonable. One student mentioned "The demands on the students are insane, although this can vary between projects. Even though it is only 4 credits, each person in my group often needed to work 20+ hours per week, sometimes double that. It could easily be 10+ credits." Another student mentioned, "excessive workload, especially towards the end of the semester; unrealistic expectations to complete the project given the time constraint."

2) Teaching strategies: The following codes related to teaching emerged from the analysis of students' comments.

a) Lectures were not useful or interesting: Some coded segments included: "lectures didn't correspond to information that team needed to assist them in their design phase," "While it is understandable to present extra material, the disconnect between class and the provided text inhibited learning and prevent people who missed class for legitimate reasons from making up the material," "I feel that 75-minute lectures are too long to the point that they are inefficient. The length discourages people from attending and no one can really hold their attention for that long. This is a gripe about all classes in general - I feel that the 75 minute model should be reconsidered."

b) Guest speakers were not inspiring: Examples of coded segments included: "Many of the speakers were boring and not always positive about their experiences as an engineer," "some of the lecturers from industry seemed to not really like the industry which is giving me second thoughts about continuing with environmental engineering," "Guest speakers are poorly informed and bring little to the table in terms of helpful information with regards to the senior design aspect of the course."

c) Discussions: Examples of coded segments included: "Poor class participation in some of the discussions. Why don't people like to talk?" "while it's supposed to be an outlet to discuss challenges, I feel it doesn't actually happen as much as would be useful or is hoped for as people are more guarded," "too heavy of a focus on non-design aspects with regards to discussions with the instructor."

3) Learning experiences: The following codes related to learning experiences emerged from the analysis of students' comments.

a) Applied hands-on learning experience: Students mentioned that hands-on learning was not applied as they had hoped. Some comments included "we don't actually do very much hands on modeling. It feels like this is a requirement purely to tell prospective students and families that BMEs get hands on experience freshman year, not for freshmen to actually learn anything," "disappointed that it was all theoretical," "Nothing seriously hands on."

b) Lab experience was not practical or useful: Some comments included "The lab lectures didn't really gage too much interest, and students were able to perform the labs without going to the lectures. Therefore, even though lectures were made mandatory, attendance wasn't part of the grade so students still didn't go," "The lab handouts seemed very formulaic, not much thinking had to be done to get them done."

c) Project is not interesting: Comments included "We are often given projects that we don't really understand and not given enough time and information to understand them," "The projects were somewhat ambiguous and the due dates seemed to go undiscussed until a few days before each project was due," "The challenge of the design project was produced mostly by arbitrary and artificial restrictions on the materials we were allowed to use."

d) Client interactions: Students mentioned that they were frustrated when the clients were not involved or when there are contradictions between the professor's and client's expectations. "a lot of your experience is dependent on how communicative your client is," "the professors and clients often have different things they want and its a struggle to figure out whos voice is more important," "We are building a part for a client and yet the professor is the one grading. Oftentimes, this creates issues when the client is satisfied with the design, but the professor is not."

e) Assignments and readings: Some comments included: "Too many assignments that do not add to student's knowledge and are a waste of time," "The weekly homework assignments would take up to 20 hours to complete, and sometimes you'd try the same thing over and over until it randomly worked. This was frustrating and took way too much time, and my grades in other classes suffered as a result."

f) Background knowledge is missing: Some comments included: "We are supposed to do our final project working with a material and code we haven't seen before despite spending the last three years working with steel and concrete," "Not having much of a physics background made the arm model lab and circuits part of the cardiovascular lab hard to understand at first," "Not having a good background for the labs and basically having to make up the stuff on the spot."

g) Creativity and freedom are non-existent: Some comments included: "We are all doing the same topic. We are not actually designing anything. We are not solving any problems because the consultant has already done the work. We all have practice presentations (that are the same) and then present again on things that we have already presented 5 times before," "The design project is too restrictive. Everyone did basically the same thing. I wanted more creativity. Overall it was neat, but it was just annoying when you try to do something creative and everyone else ends up doing the same thing

basically," "A bit of creative liberty could encourage more use of the program."

h) Learning content knowledge and skills: Learning domain-specific content knowledge and skills was lacking for some students. Comments included: "You do not actually gain an intuition on dynamical systems, just another class you have to take," "The two most unique aspects of the course which were exposure to Cadence, and an introduction to Verilog were buried so deep in the amount material taught in other courses that students learned essentially nothing about how to use them."

i) Presentations: Students did not gain from the presentations and presentations took too much time. Some comments included: "We all have practice presentations (that are the same) and then present again on things that we have already presented 5 times before," "We are all pretty skilled at presenting, so the extra time taken to showcase our ideas really wasn't that beneficial," "There were a lot of updates and presentations required that hindered work toward the project." "The worse part is having to do the presentations. They are useful for your client but they take so much time when you could working on a prototype."

j) Writing: Some students mentioned that writing was tedious and not useful. Some comments included, "Very tedious lab reports that require an unnecessary amount of work," "Writing so many long reports in a very short lapse of time." "The worst aspects are the sometimes burdensome amount of writing and reports, which take away from time that could be spent perfecting the design."

k) Resources: Comments included: Students expressed the lack of training and resources needed to learn software that is required in the class. Some comments included:" Most assignments took upwards of 8 hours to complete with one taking 20. This was because no additional guidance was given on how to use Cadence, the primary design software used in this course," "Solidworks is a NECESSITY to build a successful crane, and it is pure luck if someone in the group knows solid works. It is nearly impossible to build a successful crane without it, and without taking CAD before this class, that makes it very risky."

l) Teamwork and collaborative learning: When teams did not function well, this was considered one of the worst aspects of the courses. Comments included: "Working with an unmotivated group; unequal distribution of group work," "getting stuck with a bad group member. Members who don't communicate are frustrating," "The worst aspects of this course is the fact that giving one grade for the entire project is not always fair because with all team projects, some people do significantly more work than others."

4) Assessment and evaluation: The following codes related to assessment and evaluation emerged from the analysis of students' comments.

a) Assessment: Examples of comments included: "Assignments don't have clear guidelines, so we end up losing points because we were not told what to include," "the judges for our presentations give conflicting advice and grade harshly considering they don't often seem to fully understand the projects"

b) Evaluation: Comments included: "The exams were very poorly structured," "he questions on the final did not seem to be consistent with other problems we had received on homework assignments and midterms," "I have no idea what my grade is in the class at the moment."

5) Mentoring and modeling: The following codes related to mentoring and modeling emerged from the analysis of students' comments.

a) Guidance, direction, and modeling: Examples of coded segments included: "The feedback and guidance during the course as particularly frustrating," "Wished we had more guidance on the process design class," "A serious lack of direction and guidance is provided in the first half of the course when teams are choosing projects and formulating needs," "This class was very frustrating since we received little guidance."

b) Feedback: Examples of coded segments included: "We did not receive consistent feedback to help us and guide us through the process," "There is zero guidance and feedback from the primary professor in regards to the individual projects," "Lack of feedback on assignments."

6) Encouragement and motivation: The following codes related to encouragement and motivation emerged from the analysis of students' comments.

a) Discouragement: Examples of coded segments included: "Almost negative involvement and discouragement," "During every one of our progress meetings, which occurred every two weeks, we were berated for being bad at drawing, which was reasonable, but NO ONE in our group responds positively to extremely negative criticism. This was true most of the time in this course, where we would receive extremely harsh criticism for virtually no reason."

b) Motivation is lacking: When the professor does not show care or interest, students feel that they are not motivated. Example coded segment mentioned: "The teacher is kinda arrogant," "The professor clearly does not have time for this class," "The worst aspects of was that the professor was very unclear and unreachable at times."

IV. CONCLUSION

Students in design classes provided rich data on what they thought to be the best and worst aspects in their classess. Students expressed their thoughts on similar topics such teaching, assessment, learning opportunities, and course prepartion. Students found that the same aspects of the course can be considered the best or worst aspect of the course. For example, students consider course planning and organization to be the best aspect of design courses when the courses are well designed to include planned site visits, well designed course syllabus, and appropriate workload. In the meantime, students consider the course planning and organization to be the worst aspect of design courses when courses are not designed well and not planned with care and thoughtfulness.

The qualitative comments of the students are very important and invite for reflection on course evaluations. Students' comments about all aspects of teaching and course design should be considered carefully to improve learning. Students value all aspects of teaching includnig challenging assignments and homeworks, exams, and workload when they develop interest and find an encouraging and supporting professor and class climate. Students also like to work in teams when they are functioning, but hate to be part of teams that are not in harmony. Students like presentations and like guest speakers when they are inspiring and insightful, but do not like guest speakers when they do not provide valuable knowledge or inspiration. Students like to be creative and innovative. Students also get frustrated when they are restricted in their imagination and creativity. Students appreciate mentorship and guidance and always look for feedback on their assignments and work. When feedback is not timely and guidance is lacking, students feel that this aspect is the worst in their design courses.

Design courses, in particular, are applied and hands-on and students consider this to be one of the best aspects when the hands-on experiences are genuine. Students like to learn software to accomplish design tasks and build on their previous knowledge. When students do not have the necessary resources to learn the tools they need to accomplish their work, they feel disappointed.

In summary, design courses have some particular aspects such as project-based learning, teamwork and collaboration, applied hands-on learning, and field visits that need special attention to make these courses useful and help students learn and apply the knowledge and skills they gain after they graduate.

REFERENCES

[1] K. Pavlina, et al., "Student perception of teaching quality in higher education," *Proc. Procedia - Social and Behavioral Sciences,* 2011, pp. 2288-2292.

[2] P. Spooren, et al., "Exploring high impact scholarship in research on student's evaluation of teaching (SET)," *Educational Research Review,* vol. 22, 2017, pp. 129-141; DOI:10.1016/j.edurev.2017.09.001..

[3] F. Jones, "Impact assessment of a department-wide science education initiative using students' perceptions of teaching and learning experiences," *Assessment & Evaluation in Higher Education,* vol. 42, no. 5, 2017, pp. 772-787; DOI:10.1080/02602938.2016.1188057..

[4] J. Bligh, et al., "Early effects of a new problem-based clinically oriented curriculum on students' perceptions of teaching," *Medical Education,* vol. 34, no. 6, 2000, pp. 487-489; DOI:10.1046/j.1365-2923.2000.00447.x.

[5] P. Ginns, et al., "Students' perceptions of teaching quality in higher education: The perspective of currently enrolled students," *Studies in Higher Education,* vol. 32, no. 5, 2007, pp. 603-615; DOI:10.1080/03075070701573773

[6] D.L. Jackson, et al., "The dimensions of students' perceptions of teaching effectiveness," *Educational and Psychological Measurement,* vol. 59, no. 4, 1999, pp. 580-596.

[7] C.A. Burdsal and J.W. Bardo, "Measuring student's perceptions of teaching: Dimensions of evaluation," *Educational and Psychological Measurement,* vol. 46, 1986, pp. 63-79; DOI 10.1177/0013164486461006.

[8] J.P. Meyer, et al., "A criterion-referenced approach to student ratings of instruction," *Research in Higher Education,* vol. 58, 2016, pp. 545-567; DOI 10.1007/s11162-016-9437-8.

[9] K.-f. Ting, "Cross-level effects of class characteristics on students' perceptions of teaching quality," *Journal of Educational Psychology,* vol. 92, no. 4, 2000, pp. 818-825.

[10] R. Forrester-Jones, "Students' perceptions of teaching: The research is alive and well," *Assessment & Evaluation in Higher Education,* vol. 28, no. 1, 2003, pp. 59-69; DOI:10.1080/02602930301688.

[11] V.M. Catano and S. Harvey, "Student perception of teaching effectiveness: Development and validation of the Evaluation of Teaching Competencies Scale (ETCS)," *Assessment & Evaluation in Higher Education*, vol. 36, no. 6, 2011, pp. 701-117; DOI:10.1080/02602938.2010.484879.

[12] S. D'Apollonia and P.C. Abrami, "Navigating student ratings of instruction," *American Psychologist,* vol. 52, 1997, pp. 1198-1208.

[13] P.C. Abrami, et al., "Validity of student ratings of instruction: What we know and what we do not," *Journal of Educational Psychology,* vol. 82, no. 2, 1990, pp. 219-231.

[14] C. Van Zile-Tamsen, "Using Rasch Analysis to Inform Rating Scale Development," *Research in Higher Education,* vol. 58, no. 8, 2017, pp. 922-933; DOI:10.1007/s11162-017-9448-0.

[15] D.E. Clayson, "Student evaluation of teaching and matters of reliability," *Assessment & Evaluation in Higher Education*, vol. 43, no. 4, 2018, pp. 666-681; DOI:10.1080/02602938.2017.1393495.

[16] K. Young, et al., "Student evaluations of teaching: The impact of faculty procedures on response rates," *Assessment & Evaluation in Higher Education*, 2018, pp. 1-13; DOI:10.1080/02602938.2018.1467878.

[17] G.A. Boysen, "Statistical knowledge and the over-interpretation of student evaluations of teaching," *Assessment & Evaluation in Higher Education*, vol. 42, no. 7, 2017, pp. 1095-1102; DOI:10.1080/02602938.2016.1227958.

[18] H. Lempp and C. Seale, "The hidden curriculum in undergraduate medical education: Qualitative study of medical students' perceptions of teaching," *British Medical Journal*, vol. 329, no. 7469, 2004, pp. 770-773.

[19] J.M. Corbin and A.L. Strauss, *Basics of qualitative research: Techniques and procedures for developing grounded theory*, Sage, 2008.

[20] J.W. Creswell and C.N. Poth, *Qualitative inquiry and research design: Choosing among five approaches*, Sage, 2018.