Engineers' Written Feedback on Design

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***Abstract* — In our continued efforts to characterize feedback on design, we analyzed experienced engineers' feedback on design. This analysis enabled us to characterize and compare experienced engineers' feedback on design to students' and educators' feedback. Participates were 10 experienced systems engineers, with an average of 28 years of industry experience, who attended the ninth International Council on Systems Engineering (INCOSE) Great Lakes Regional Conference in Cleveland, Ohio. A coding scheme consisting of three domains (User-centered design, Substance, and Focus of feedback) was used to analyze the feedback. The experienced engineers' feedback profile was different than both students' and educators' profiles. However, there were some similarities between engineers' and educators' feedback.**

Keywords— Design Education, First-Year Engineering, Feedback on Design, Systems Engineering.

I. INTRODUCTION

Engineering educators are encouraged to provide students with authentic learning experiences that reflect aspects of engineering practice. This can be accomplished through the integration of real world design problems. As design is seen as a central [1] and defining [2, 3] aspect of engineering practice, it is essential that engineering students develop design skills, and become more like experienced engineering practitioners [4]. One way of developing design skills is to provide feedback on students' design work. Feedback is a key catalyst for learning [5] and is positively related to improvements in engineering design skills and professional skills such as communication, teamwork, and critical thinking [6].

One of the most utilized frameworks in studying design and feedback is the expert-novice framework [7]. We used this framework to analyze feedback on design [8]. Based on this framework, the design work or feedback of individuals who are identified as experts (typically based on greater experience and higher education) can be compared to individuals who are identified as novices. The goal of this comparison is to highlight the differences between experts and novices in order to encourage novices to become more like experts.

Expert designers spend more time on the design task than novices [4]. Novice designers perceive the design task as a well-structured problem [9] and immediately engage in problem solving activity [10]. In contrast, expert designers tend to delay design decisions to understand [11] and frame the problem [12] as well as do research and gather information [13] to generate concepts and design ideas [10]. Thus, novice designers work with a few ideas and do not spend time and effort to explore alternatives [14], while expert designers tend to generate different ideas before problem solving [15]. When evaluating different options, novices do not critically evaluate their design decisions [16], while expert designers conduct experiments and use systematic troubleshooting to find and correct flaws in their solution [17].

In our previous studies, we developed a coding scheme for written feedback on design including two domains Substance (Communication, Design Concept, Design Idea) and Focus of feedback (Direct Recommendation, Investigation / Brainstorming, Expression of Confusion, Negative Assessment, Positive Assessment, Details/Example) [18]. We coded and analyzed the feedback of students and educators in a first-year engineering course based on this coding scheme [8, 19]. In summary, students provided more feedback related to the communication aspects of design work (e.g., grammar, quality of images) and educators provided more feedback on the design ideas specific to the design problem. Both groups gave feedback on design concepts related to the design process (e.g., identifying users, defining criteria and goals). In addition, students gave mostly negative feedback and direct recommendations on how to improve the design work. In addition to these two categories, educators also provided more detailed comments with examples and asked thought-provoking and brainstorming questions to guide the students to think about their design work more deeply and correct their own mistakes [8].

These comparisons between students and educators highlight the similarities and differences between both groups and helps to develop educational content for the students. To help engineering students becomes more like practicing engineers and acquire feedback skills, we also need to characterize engineers' feedback on design, and highlight the similarities and differences between engineers, engineering students, and engineering educators.

The aim of this paper is to investigate how experienced engineers provide feedback on design. This can help engineering educators understands the differences between the feedback provided by engineering students, educators, and experienced engineers. This comparison could enable the development of more effective pedagogies for instructing students on how to provide feedback on design work and how to design professional development materials for educators.

II. Research Question

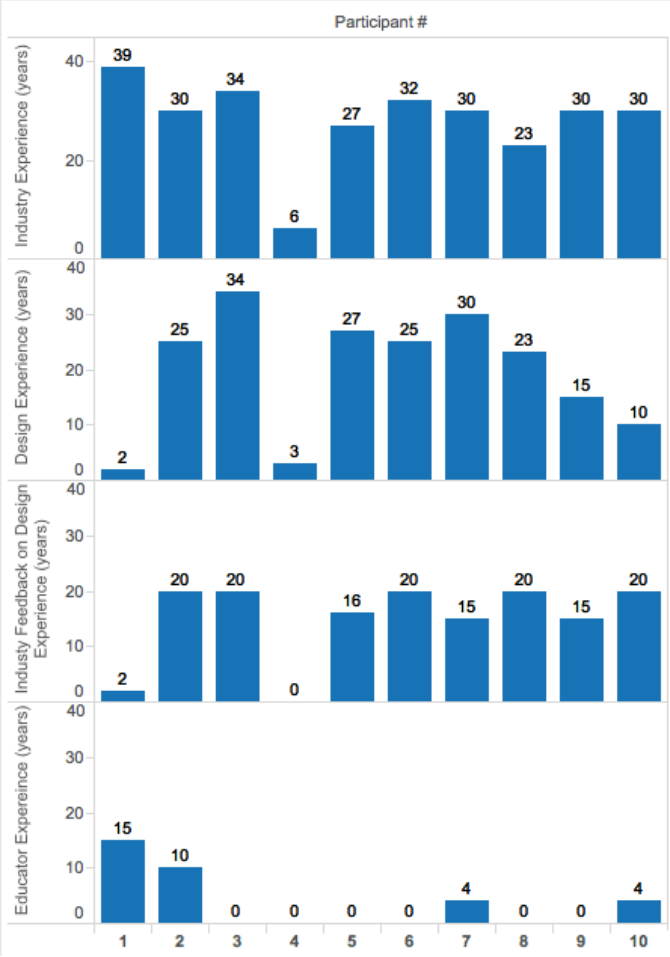
In this paper, to understand the characteristics of written feedback on design provided by experienced engineers, we investigate the following research question: *What are the characteristics of engineers' written feedback on design?*

III. Methods

A. Participants and Settings

In total, 10 systems engineers participated in this study. This sample consisted of systems engineers who attended a feedback on design workshop at the ninth International Council on Systems Engineering (INCOSE) Great Lakes Regional Conference (GLRC) in Cleveland, Ohio in October 2015. The systems engineers are members of one of the five INCOSE chapters located in Midwest United States. They are mainly systems engineers practicing in different industries such as healthcare, chemical, and security. All participants (with one exception) have more than 20 years of industry experience. (Fig. 1); their average industry experience was 28 years. Four of the participants were also involved in teaching systems engineering.

Fig. 1. Participants' experience



Systems engineers typically work at the interface between management, customers, suppliers, and specialty engineers in the systems development process. They are familiar with constraints, system requirements, and end users' needs and how to map these to develop the system architectures. More than 20 years of experience as system engineers in industry and being challenged with a variety of real world problems make them eligible to be classified as expert designers.

B. Design Problem

As part of the feedback on design workshop participants were asked to provide written feedback on a sample student solution to a systems engineering problem. Both the problem and the sample solution were provided for the participants. The problem was a public transportation network development plan for the Abu Dhabi region in UAE. As was mentioned in the design problem statement, the region expects rapid and high growth in transportation demand, while the current transportation system is not satisfactory for the current demand. Different modes of public transportation such as the tram, metro, and bus lines should work as an integrated system to be able to manage the demand. The integrated public transportation system must compete against private transportation to keep the region sustainable and reduce the traffic. Such an open-ended problem can be seen as a complex system design problem due to the interacting social and technical sub-systems. To approach the problem, a systems dynamic method was picked, due to its ability to capture interactions in social systems. The workshop participants were asked to evaluate the following components of the solution: problem scoping, modeling, outcomes, and discussion. The participant had a three-page document in which the system dynamics model was illustrated (Fig. 2) and explained. It was expected that systems engineers would be familiar with the systems dynamic concept and could evaluate its outputs.

C. Analysis

Based on the nature of engineers' feedback on the design work and building on our previous analysis of students' and instructors' feedback on design, we developed a coding scheme for feedback on design with three domains: User-centered design, Substance of feedback, and Focus of feedback. The User-centered design domain was constructed based on user-center design concepts [20]. The goal of this domain is to highlight how much the reviewers had the users in mind when providing feedback. The Substance and Focus domains were taken from our previous analysis of students' and instructors' feedback [18]. The User-centered design domain includes two subcategories, the Substance domain includes four, and the Focus domain includes seven (Table I). Each feedback response was broken into smaller discrete comments and coded based on the coding scheme.

Figure 2. Sample solution, proposed system dynamics

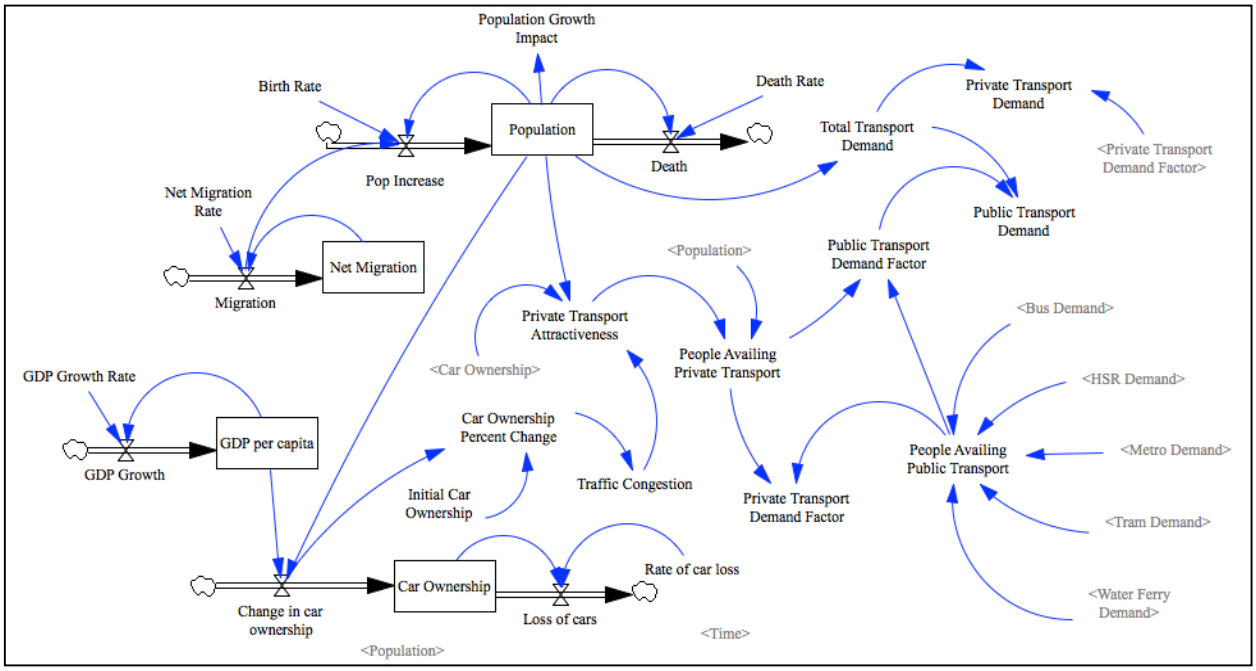


TABLE I. CODING SCHEME FOR ENGINEERS' FEEDBACK ON DESIGN

Domain	Category	Description	Example
User-Centered	Yes	Explicitly refers to design users or any of the stakeholders, or their needs.	Identify stakeholders
	No	Do not mention user-center design concepts	Need to start thinking about Risk.
Substance	Communication	Refers to writing or presentation of the design work.	There is no reference provided.
	Design Concepts	Explicitly refers to one of the design concepts taught in class by using terminology taught in class.	While the problem attempted to frame a more holistic qualitative and quantitative challenge, the stated scoping and modeling failed to capture the holistic dimensions.
	Design Ideas	Refers to design ideas specific to this team's project work, using terminology that is specific to the problem this team chose to work on.	In the model, it is not apparent how the affect of highways and the regional train are taken into account.
	No code	Does not fit in any of the above codes.	The student completed the initial tasks.
Focus	Direct Recommendation	Gives specific advice of what to do.	Please describe how the results of this model will be used to drive the design of the system.
	Investigation/ Brainstorming	Requests specific information or asks thought provoking questions. May suggest new ideas, typically in form of questions.	How do you quantify attractiveness?
	Expression of Confusion	Comments on having difficulty understanding the design work, implying something is wrong, does not provide a new idea.	"Not clean", what does this mean?
	Provide Detail/Example	Explains a previous comment (with the same goal) or provide an example to make sure the students will understand it.	… such as service to the downtown, developed islands, and open spaces; flexibility for growth and regional transport.
	Positive Assessment	Explicit positive assessment of the quality of the design.	The systems dynamics model appears reasonable. It is focused on transportation demand overall.
	Negative Assessment	Explicit negative assessment of the quality of the design or missing information.	Requirements were not defined.
	Short/ Un-interpretable Phrases	Typically short phrases (not full sentences) that cannot be interpreted by the coder.	Expandability

IV. RESULTS

Overall, the 10 engineers who participated in this study provided 61 comments. The majority of the engineers' comments were not user-centered; only 10% of the engineers' comments were user-centered (Fig. 3).

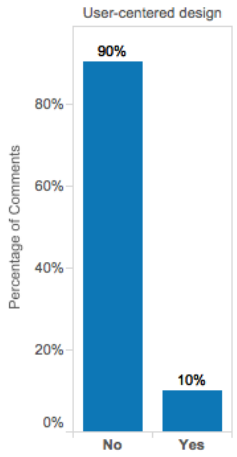


Figure 3 – Engineers' feedback coded by User-centered design.

The engineers' comments were mostly focused on Design Ideas specific to the design problem. More than half (56%) of the comments were related to Design Ideas, 21% were related to design concepts, and 20% were related to Communication (Fig. 4).

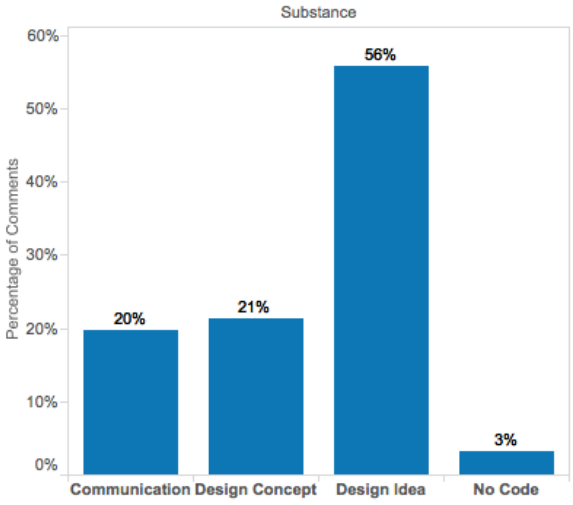


Figure 4 – Engineers' feedback coded by Substance.

The engineers' comments were focused on multiple categories of Focus of feedback. Seventy-seven percent of the engineers' feedback were equally distributed among Direct Recommendation, Negative Assessment, and Investigation / Brainstorming (Fig. 5). Detail / Examples, Expression of Confusion, and Positive Assessment together were 20% of the feedback comments.

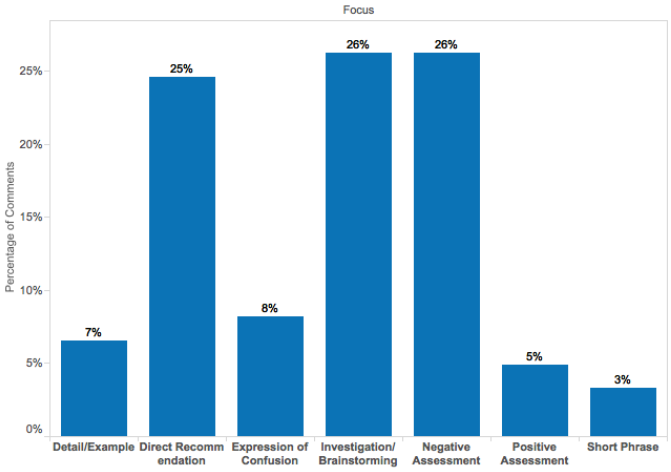


Figure 5 – Engineers' feedback coded by Focus of feedback.

V. DISCUSSION

The engineers' feedback was not highly focused on the user, rather it provided design ideas specific to the design problem, focused on direct recommendations (how to change, fix, or improve the design), contained negative assessments (pointed out the flaws) in the design work, and included investigation or brainstorming comments (tried to give the designers new ideas).

Overall, the engineers' feedback profile was different from both engineering students' and engineering educators' profiles observed in our previous studies. However, there were some similarities between engineers' and educators' feedback (the design problem in this study and our previous studies were different).

The engineers' Substance of feedback was different from both students' and educators'. While engineers' feedback was mostly related to design ideas specific to the problem, educators' comments were related almost equally to design ideas and design concepts (i.e., design process). Interestingly, the engineers did not comment as much as educators on the design process; rather the engineers focused on the design ideas and the design solution. This result is not surprising as educators and engineering have different goals. Educators see feedback as an educational opportunity for the students, thus they provided comments to help students improve their approach to a design problem. In contrast, engineers mostly care about the outcome, thus they commented on the ideas on how to improve the design product.

Students' Substance of feedback was very different from the engineers'; students' Substance of feedback was mostly related to communication and design concepts. Unlike students, whose lack of experience may have prevented them from providing many comments on design ideas, engineers with considerable experience paid attention to the technical details of the solution and concentrated their feedback on design ideas. This is similar to expert-novice differences in design context where experts try to generate new ideas more than novices [10].

The engineers' Focus of feedback was similar to engineering educators'. Both groups provided more direct recommendations, negative assessments, and investigation brainstorming comments. The main difference between students' and these two groups' (engineers and educators) feedback lies in investigation/brainstorming. While engineers and educators focused almost 25% of their comments on brainstorming, students brainstorming comments was only at about 5%. This difference is similar to experts-novice differences in design projects. Similar to experts who delay decision making to understand [11] and frame the problem [12], gather information [13], and generate [10], and evaluate difference design ideas [17], engineers focused on Investigation/Brainstorming comments and asked thought provoking questions to help designers explore different alternatives and delay decision making. In contrast, students, similar to novices in design processes who perceive the design task as a well structure task [9] and immediately start problem solving without exploring alternatives [10], gave Direct Recommendation comments and specific instructions on how to improve the design work.

In addition, both engineers and educators provided between 5% to 10% of their comments on details / examples and expression of confusion. Students had even fewer comments in these two categories. Expression of confusion indicates something is possibly wrong with the design decisions and encourages the designers to reevaluate their design choices. It seems engineers see the feedback as a dialogue to express their confusion and hope the designers will respond by improving their work. However, students perceive this as an assessment task. One reason for this difference may be engineers have more confidence to express their confusion while students' lack of confidence may prevent them from admitting they do not understand a part of the design work and asking for clarification.

The only category in which students provided more comments than engineers and educators was positive assessment. One reason might be that students in pre-college education are taught to provide both positive and negative feedback to their peers and do not only focus on negative feedback.

VI. Limitations and Future Work

The design task that was assigned to the engineers was different than the students and educators. This may have some influence on the feedback the engineers provided. To be able to directly compare engineers' feedback to students' and educators' feedback, we are collecting engineer's feedback on the same sample design work. This will allows us to more directly compare and characterize the feedback of the three groups.

VII. Conclusion

In this paper, we characterized experienced engineers' feedback on design. Overall, engineers' feedback was not user-centered focused but rather focused on the solution and design ideas specific to the design problem. The engineers' feedback also focused on pointing out what is wrong with the design, making direct recommendation on how to fix it, and giving some brainstorming ideas on how the designers might improve their design. The substance of feedback provided by the engineers was different from both the engineering educators and the students. In focus of feedback domain, engineers' feedback was similar to educators' but different from students' feedback.

Acknowledgment

This work was made possible by a grant from the National Science Foundation (EEC-1329304). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

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