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Breadth in Problem Scoping: a Comparison of Freshman and Senior Engineering Students*

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In this paper we characterize breadth of problem scoping in an engineering design problem. Specifically, we present several measures that quantify the number and variety of factors an individual problem-solver considers during the engineering design process. We apply these measures to data collected from freshman and senior engineering students who solved a short design problem. The results of our study indicate that graduating seniors do consider a broader array of factors than freshmen as they undertake the problem-scoping stage of the design process.

Keywords: design; problem scoping; breadth; context; engineering design task; undergraduate; engineering education research

INTRODUCTION

AS A PROFESSIONAL PRACTICE, engineering is pervasively situated in society. Engineering is in the plastic cup that holds your hot coffee or cold soda, the vehicle that transported you to and from your place of work, the technology that allows you to speak in real time with someone else on the other side of the world. Every day we experience ways in which engineering improves our lives; we also encounter situations in which failing to consider the broad impact of a project can lead to tragic results. For example, this can manifest itself whenever a product must be recalled due to unintended adverse affects. In our lives as global citizens it manifests itself as we experience the unintended impact of the use of fossil fuels on the global environment. Considerations of impact are also closely aligned with such ideas as sustainability in which the goals include both minimizing negative impacts of technology (e.g. pollutants and waste products) as well as maximizing positive impacts (e.g. environmentally friendly fuels and agricultural systems). As such, engineers must design their solutions within societal, cultural and environmental contexts.

Today's engineers must have many skills to succeed in the increasingly complex world of engineering work. These skills include, among others, an ability to define problems as well as to solve them, a tolerance for ambiguity, design judgment, an understanding of uncertainty and an appreciation of the impact of designed solutions on the people and environment they interact with [1–3]. Because engineering is situated in real contexts, an ability to consider broad impacts (encompassing technical, social, economic, political, cultural and environmental considerations) is a particularly important aspect of being a successful engineer. Evidence of this need is indicated in reports that describe the future needs of engineering (e.g. [4–9]), studies that illustrate the nature of engineering practice [10], and accreditation criteria for engineering programmes. For example, the Accreditation Board for Engineering and Technology's (ABET) Criterion 3 Program Outcomes and Assessment specifically states: 'Engineering programs must demonstrate that their students attain: . . . the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental and societal

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context' [11]. Graduating engineers who possess these kinds of skills will be better able to contribute effectively to the global situation described by Friedman [12] and to participate in the kinds of policy discussions that are the basis for a democratic society.

A number of learning experiences have been designed to increase students' ability to design in a global and societal context. The breadth of these types of experiences are demonstrated in the following sampling: problem-based learning (PBL) workshops on the social consequences of design at the University of Maryland [13]; inclusion of socially relevant design projects in an introductory engineering course at Smith College [14]; 'Engineering in Context', a capstone design sequence incorporating organizational and cultural contexts, at University of Virginia [15]; 'Product Design and Innovation' (PDI), a programme that combines engineering design education with a social and cultural context of technologies at Rensselaer Polytechnic Institute [16]; the Institute for Design Engineering and Applications (IDEA), with its emphasis on interdisciplinarity and community, at Northwestern University [17]; and 'EPICS, Engineering Projects in Community Service', a programme started at Purdue University that fosters solutions to technology-based projects for local community service organizations [18, 19]. The existence of these programmes and their integration within engineering education provide strong evidence that engineering educators are concerned whether students consider global and societal issues in their design projects. It also points to a need within the community to find ways to gauge the effectiveness of curriculum in teaching engineering students to think broadly. An added benefit would be tools that could be used to provide formative feedback to students while they are working on their design projects.

One way that broad consideration of the impacts of a project can play a crucial role in engineering work is in the early problem scoping stage of engineering design. Problem scoping is defined as the stage of the design process during which designers explore the relevant issues and set the boundaries of the problem they will continue to solve [20–22]. During this process, they gather the information they need to clarify or better define a problem, as well as identify the information necessary to formulate a design solution. A number of studies illustrate the significant role of problem-scoping activities as they relate to expertise and effective practice (e.g. [22–27]). Consideration of broad issues is evident in early problem structuring activities (e.g. [20, 28, 29]), has been shown to influence concept generation (e.g. [30]), and is often a cause of design iterations [31]. As an example, in a summary of research on design, Restreppo and Christiaans [28] note that information accessed during early problem structuring phases (e.g. information related to users, environments of use, etc.) is fundamentally different from the kinds of information accessed during problem solution phases (e.g. information related to materials, manufacturing conditions, etc.). These and other studies illustrate how broad problem scoping is key to creating a robust design solution that fulfils the design purpose, works within the constraints of the problem and accounts for broader issues such as ethics, and the impact on society and the environment.

While this research indicates the importance of structuring design problems with an attention to broader impact, there is still an overarching question that needs to be addressed: how can breadth of design problem scoping be quantified and represented? What are measures to characterize breadth of problem scoping and how can they be used to describe change in scoping behavior for engineering students? We have been exploring these questions in a variety of studies that help frame our approach to describing breadth of design problem scoping [32–36].

METHODOLOGY

In the research described here we asked participants to consider a design problem that encompasses a broad range of factors. Referred to as the Midwest floods problem, it was presented to the participants as follows: 'In the past, the Midwest has experienced massive flooding of the Mississippi River. What factors would you take into account in designing a retaining wall system for the Mississippi?'

Data were collected from 74 students attending a large, Midwestern research university in the mid-1990s. Of the 74, only one failed to contribute suitable data. The complete dataset consisted of 29 freshman responses and 61 senior responses, with an overlap of 17 freshmen who participated three years later as seniors. This enabled us to perform two kinds of longitudinal analyses: (a) within-subjects, with the 17 pairs of freshman–senior data and (b) across-subjects, with the full freshman and senior data sets.

This 'Midwest Floods' problem was the third in a series of three problems that were administered to students in one experimental session. The three problems were designed to be increasingly less structured, with the 'Midwest Floods' problem being the least structured of the three. The first problem asked participants to design a structure to launch a ping-pong ball to hit a target with specified dimensions. The second problem asked participants to design a way to cross a busy street on campus. Analysis of participant responses from the first two problems is presented elsewhere [37, 38].

Participants were prompted to think aloud while answering the questions. This methodology is called verbal protocol analysis [39]. Participants were audio-taped, and the recordings were later transcribed into verbal protocols. Next, the protocols were segmented or divided into short passages, sometimes as short as one or two words but averaging about 10 words per segment. Finally, each segment was coded for breadth of problem scoping as described in the following section.

Coding and representing breadth

A two-dimensional coding scheme was developed to characterize breadth of design problem scoping demonstrated in the protocols [32–35, 40]. Each segment was coded for physical location and frame of reference. Physical location codes record the physical area of focus of the participant's segment and consist of four codes: WALL, WATER, BANK and SURROUNDINGS. These codes are ordered to approximate a progression from focus on details of the designed artifact (i.e. the wall) to the context of the problem. For example, WALL and WATER represent locations that are in close proximity to the retaining wall. These may be considered detail issues in the sense that they are typical of bounded engineering problems that focus only on core engineering science issues. The codes BANK and SHORE represent locations further away from the retaining wall. These may be considered context issues in the sense that they describe interactions between the designed solution and the broader system (e.g. environment, urban, social).

Frame of reference codes represent perspective of focus for the participant and consist of four codes: TECHNICAL, LOGISTICAL, NATURAL, and SOCIAL. These codes also approximate a progression of increasing breadth, with TECHNICAL and LOGISTICAL factors (e.g. water pressure, construction costs) emphasizing detail and NATURAL and SOCIAL factors (e.g. flood damage, safety) emphasizing context.

Due in part to the verbal nature of the data, not all transcribed utterances were responses to the original question, 'What factors would you take into account in designing a retaining wall system for the Mississippi?' As participants thought aloud, they sometimes made conversational comments about the problem or repeated parts of the problem statement for clarification. Such segments were assigned NO CODE on both coding dimensions. On average, each participant had about 10 such (NO CODE, NO CODE) segments, all of which were excluded from the analysis. A small number of segments were general or ambiguous enough to warrant coding on only one dimension. For instance, the following segment was coded (NO CODE, SOCIAL): 'We have politics'. In this case, the participant mentioned politics as a factor relevant to the design, but in the absence of specifics, the physical location code could not be determined.

Table 1 provides the working definitions for the physical location and frame of reference codes used during the coding process.

Two coders independently coded each protocol with an inter-rater reliability goal of 80 per cent.

Table 1. Summary of the two coding dimensions and the four codes in each

Physical Location	Description
WALL	The wall itself, things that interact with the wall, alternatives for having a wall, where to put the wall.
WATER	Length of the river, fish, flood without effects, pressure issues without mention of the wall.
BANK	Interface of the wall, edge of the river, width of the river.
SURROUNDINGS	Anything away from the water, living areas, things along the water, specific effects of the wall or flood to the shore.
Frame of Reference	**Description**
TECHNICAL	Technical or engineering vocabulary, design issues, decisions about having the wall.
LOGISTICAL	Cost, funding, construction process, maintainability issues, resources needed.
NATURAL	Volume of water, damage, effects of flood, topography, animals, plants, weather and weather predictions.
SOCIAL	People, safety concerning people, towns, living areas, fields of engineering and education.

Table 2. Sequence of segments with physical location and frame of reference codes

Segment	Text	Physical Location	Frame of Reference
5	There are a lot of factors as far as what type of land is around the Mississippi as far as farmland maybe national park or urban development.	SURROUNDINGS	SOCIAL
6	And where it is actually, designing a retaining wall for the Mississippi, I think there is some sort of structure all ready there, so maybe it will be a redesign of a retaining wall system, and	WALL	TECHNICAL
7	I can remember part of the problem was a lot of the dams or the retaining walls were old and worn away over time and needed replaced but did not get to it.	WALL	TECHNICAL

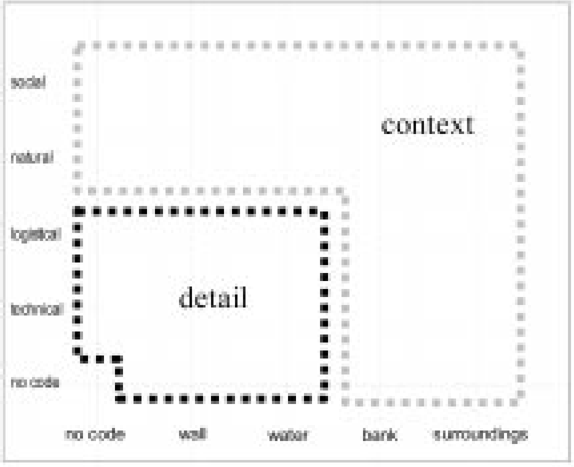


Fig. 1. Two-dimensional coding space represented graphically, with physical location codes on the horizontal axis and frame of reference codes on the vertical axis. The 25 unique pairs of code combinations or *nodes* correspond to the grid intersections. Except for (NO CODE, NO CODE), the nodes are divided into 8 detail-focused nodes and 16 context-focused nodes.

For coded protocols that met the reliability goal, disagreements were arbitrated to consensus. Coded protocols that did not meet the reliability goal were set aside and recoded until the reliability goal was achieved. After reaching the 80 per cent agreement goal, all disagreements were arbitrated to consensus.

Table 2 shows three coded segments from a protocol. The columns represent the following (from left to right, respectively): the line number in the protocol, transcribed text from the participant, the physical location code assigned, and the frame of reference code assigned. All protocols were coded in this manner. As such, the coded protocols provide information on the number of segments coded for each of the frame of reference and physical location codes as well as the number of segments coded of the combination of frame of reference and physical location codes (e.g. SHORE and SOCIAL).

Figure 1 shows how the two coding dimensions (physical location and frame of reference) can be represented graphically to facilitate interpretation of the codings of breadth of problem scoping. Physical location codes are on the horizontal axis, and frame of reference codes are on the vertical axis. Intersections on the grids, called nodes, represent an aspect of the design problem in terms of both physical location and frame of reference. For example, a segment with a WALL physical location code and a TECHNICAL frame of reference code would be located at the node on the problem-scoping grid at the intersection of WALL and TECHNICAL. As such, this intersection refers to the designer discussing a technical aspect of the wall in the protocol. As shown in the figure, the inner nodes are more focused on the details of the designed artifact and are referred to as detail nodes. The outer nodes represent the broader problem scoping that focuses more on context and are referred to as context nodes.

Comparing Freshmen and Seniors on a series of measures

Several measures for characterizing breadth of problem scoping were created as part of this analysis. Based on the coded segments, each of

Table 3. Summary of measures used to characterize breadth of problem scoping represented in Midwest floods responses

Measure	Description	Interpretation
total coded segments	total number of segments, excluding those coded (NO CODE, NO CODE); always equal to sum of number of detail segments and number of context segments	how substantial the participant's response was; approximate measure of how many factors the participant mentioned
detail segments	number of segments coded as focused on detail	approximate measure of how much the participant's response focused on design details
context segments	number of segments coded as focused on context	approximate measure of how much the participant's response focused on the context of the design problem
total node coverage	number of nodes with one or more segments, ranging from 0 to 24; always equal to sum of detail node coverage and number of context node coverage	how varied the participant's response was; approximate measure of the number of kinds of factors the participant mentioned
detail node coverage	number of detail nodes with one or more segments, ranging from 0 to 8	approximate measure of how varied the participant's discussion of detail-focused factors was
context node coverage	number of context nodes with one or more segments, ranging from 0 to 16	approximate measure of how varied the participant's discussion of context-focused factors was

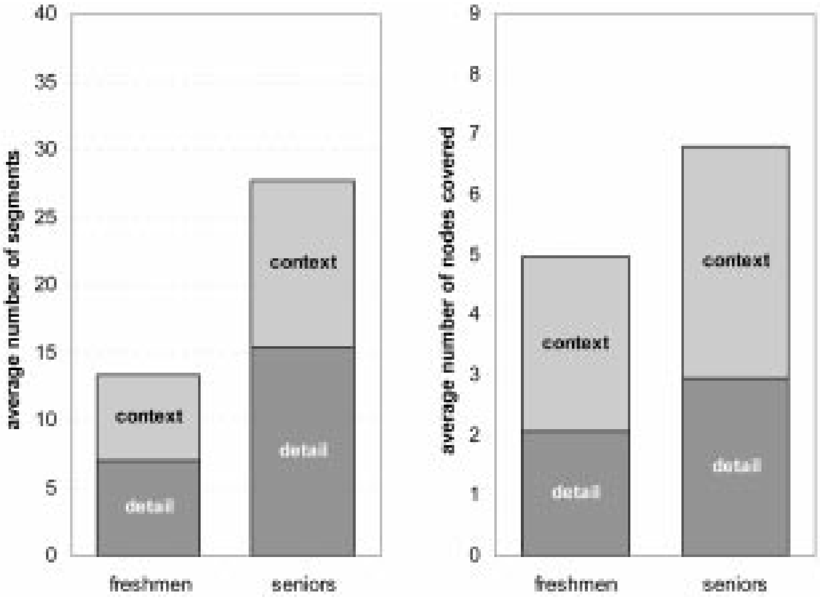


Fig. 2. (left) Average number of coded segments by class standing for across-subjects comparison ($N = 73$, 29 freshmen + 44 seniors). Bar divisions show average number of detail- and context-focused segments. (right) Average number of nodes covered by class standing for across-subjects comparison. Bar divisions show average number of detail and context nodes covered. Differences are statistically significant for both detail- and context-focused segment counts and node coverage.

the measures below was computed for each participant and facilitated the longitudinal comparisons.

Number of coded segments (total and detail vs. *context)*

This is a measure of the number of segments representing discussion of factors relevant to the design problem. More precisely, this is a count of the segments that were coded on one or both dimensions, i.e. all segments except those coded (NO CODE, NO CODE). To measure focus on detail and context, we also counted detail segments and context segments separately.

Number of nodes covered (total and detail vs. *context)*

Recall that there are 24 *nodes* in the coding space, one for each unique code pair, excluding the (NO CODE, NO CODE) pair. We say that a node is covered for a given participant if it provided one or more segments coded with the node's corresponding code pair. Based on this notion of node coverage, we also computed the number of nodes covered by each participant's response. As with the coded segment counts, we also measured coverage of detail and context nodes separately.

Intuitively, while the segment counts give an approximate measure of how substantial the participant's response was, node coverage measures how varied the response was. For example, a participant with a low coded segment count but high node coverage responded succinctly but discussed a wide variety of factors with respect to physical location and/or frame of reference.

RESULTS

Across-subjects comparative analysis

Recall that we collected data from 29 freshmen and 61 seniors, but of the 61 seniors, 17 were students who had participated in the study as freshmen and are included in the former sample of 29. For the across-subjects statistical comparison of freshman and senior responses, we were concerned that inclusion of data from the 17 repeat-measure seniors would no longer satisfy the assumption of independence between the freshman and senior samples. Conservatively, we

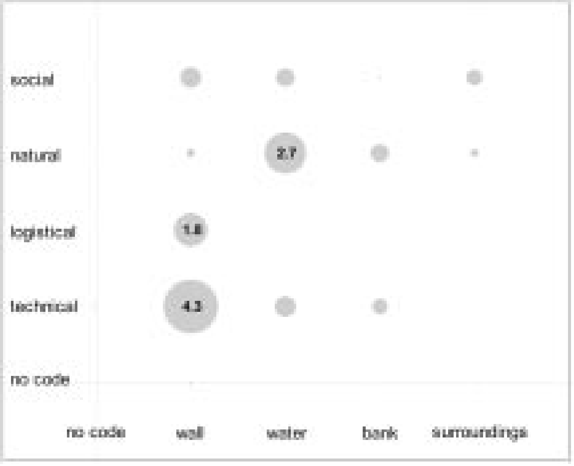


Fig. 3. Average number of segments by code pair for 29 freshmen in across-subjects comparison. Disk area is proportional to the average number of segments with the code pair corresponding to the disk's location. The average number of segments is shown at the center of each disk. Disks are shown at the same scale as in the corresponding senior chart for accurate freshman–senior comparison.

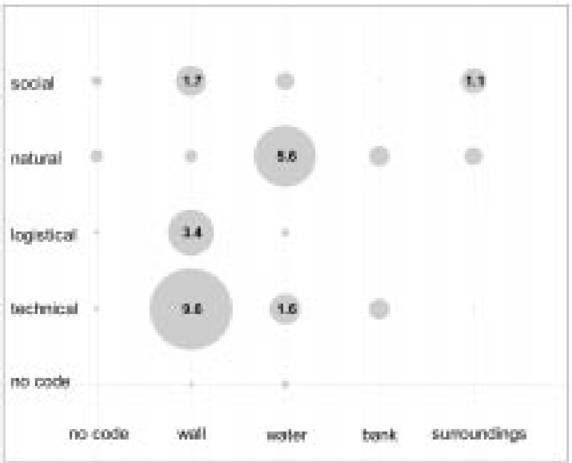


Fig. 4. Average number of segments by code pair for 44 seniors in across-subjects comparison. Disks are shown at the same scale as in the corresponding freshman chart for accurate freshman–senior comparison.

limited analysis to all 29 freshmen and only the 44 seniors who did not participate in the study as freshmen.

As shown in the left chart in Fig. 2, freshman responses contained an average of 13.3 coded segments, statistically significantly fewer than in senior responses, which contained an average of 27.7 segments ($p < 0.001$, Mann- Whitney). Considering detail- and context-focused segments separately, we found the same result, with freshman responses containing 7.0 and 6.3 detail- and context-focused segments, respectively, compared with 15.5 and 12.3 for seniors ($p < 0.001$, Mann-Whitney). In other words, on average, seniors had more substantial responses, due to more discussion of both design details and design context.

Seniors' responses were not only more substantial but were also more varied than the freshmen's, as shown in the right chart in Fig. 2. Both within the detail and context categories, senior responses covered more nodes than the freshman responses did ($p < 0.01$, Mann-Whitney).

Figures 3 and 4 provide a more detailed comparison of the coded freshman and senior responses, showing what kinds of factors were discussed. As expected, the distribution of segments across the coding space was non-uniform. Both freshmen and seniors tended to discuss factors related to the wall itself and the water. Discussions of the wall tended toward technical details (e.g. wall dimensions) and logistical considerations (e.g. construction procedure). Discussions of water included topics such as flooding and aquatic wildlife. Comparing the two figures, we see that seniors discussed certain kinds of factors more, with about twice as many segments coded (WALL, TECHNICAL or LOGISTICAL) and (WATER, NATURAL). In addition, seniors more frequently discussed water in a technical frame, with examples including rainfall statistics and considerations of force on the wall due to flow and water pressure.

Within-subjects comparative analysis

The within-subjects analysis focused on the 17 participants for whom we had linked freshman and senior data, allowing us to compare paired responses, rather than only in aggregate, as in the previous section. As such, this comparison allows an analysis that can more accurately account for individual differences. Judging from the average freshman segment codings shown in Fig. 6 and comparing with those shown in Fig. 3, the 17 freshmen appear to be representative of the super-

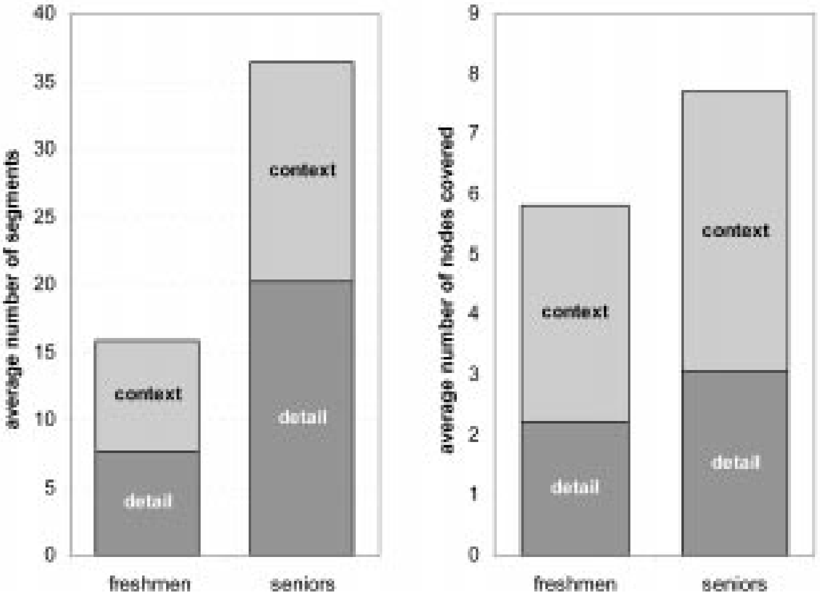


Fig. 5. (left) Average number of coded segments by class standing for within-subjects comparison ($N = 17$). Bar divisions show average number of detail- and context-focused segments. (right) Average number of nodes covered by class standing for within-subjects comparison. Bar divisions show average number of detail and context nodes covered. Differences are statistically significant for both detail- and context-focused segment counts and detail-focused node coverage.

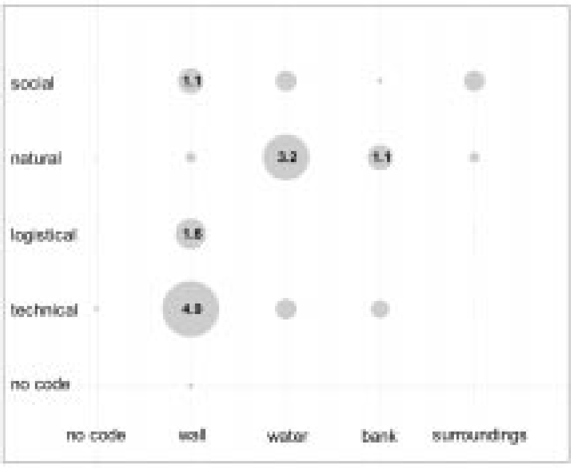


Fig. 6. Average number of segments by code pair for 17 freshmen in within-subjects comparison. Disks are shown at the same scale as in corresponding senior chart for accurate freshman–senior comparison.

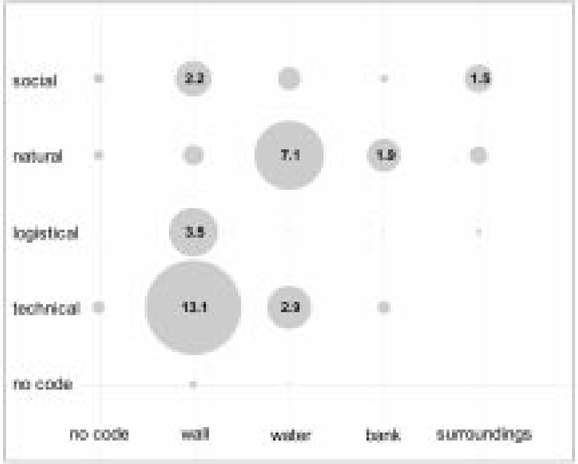


Fig. 7. Average number of segments by code pair for 17 seniors in within-subjects comparison. Disks are shown at the same scale as in corresponding freshman chart for accurate freshman–senior comparison.

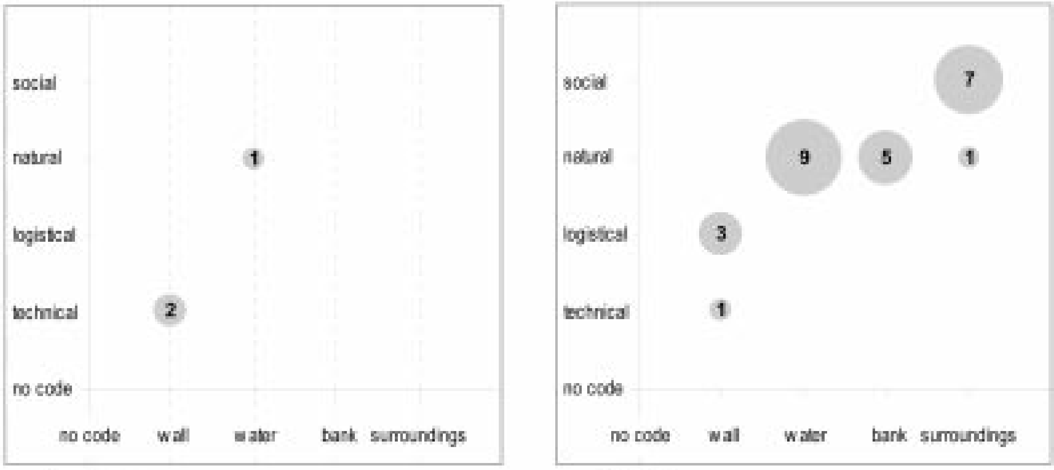
set of 29. (Although the disks in these figures are shown at slightly differing scales, the similarity in segment distribution across code pairs is apparent.)

The freshman–senior differences shown in Fig. 5 are statistically significant. Mirroring results reported in the previous section, seniors exhibited more segments and greater node coverage ($p < 0.01$, Wilcoxon signed rank). Examining the segment count difference more closely, we again found that seniors had more detail segments and context segments ($p < 0.05$, Wilcoxon signed rank). With respect to node coverage, seniors covered more detail nodes ($p < 0.05$, Wilcoxon signed rank). However, the difference in context node coverage did not test as significant at the $p < 0.05$ level.

Figures 6 and 7 show the average segment codings of the same 17 participants as freshmen and seniors, exhibiting the same changes observed in the larger, across-subjects comparison discussed earlier. Among the 17 pairs of freshmen and seniors, we observed a variety of different patterns in the ways in which their responses changed after freshman year. As one would hope, many of the students' senior-year responses were more substantial and discussed a wider variety of factors. However, this was not uniformly the case, and we discuss the differences by providing three contrasting cases, starting with the pair shown in Fig. 8. The segment count and node coverage measures summarized above prove particularly useful for concisely and precisely expressing patterns of change.

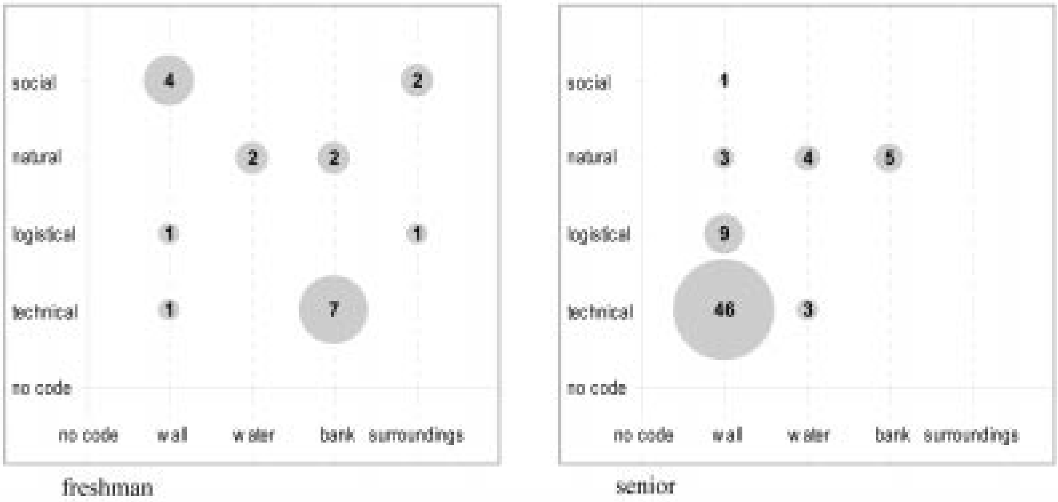
Figure 8 illustrates the most commonly observed pattern of change, where the participant's senior-year response was more substantial and discussed a wider variety of factors than their freshman-year response. In terms of the quantitative measures defined earlier, their response consisted of more segments and covered more nodes, respectively. About half of the 17 paired responses exhibited this kind of change.

For contrast, the next case is of a student whose



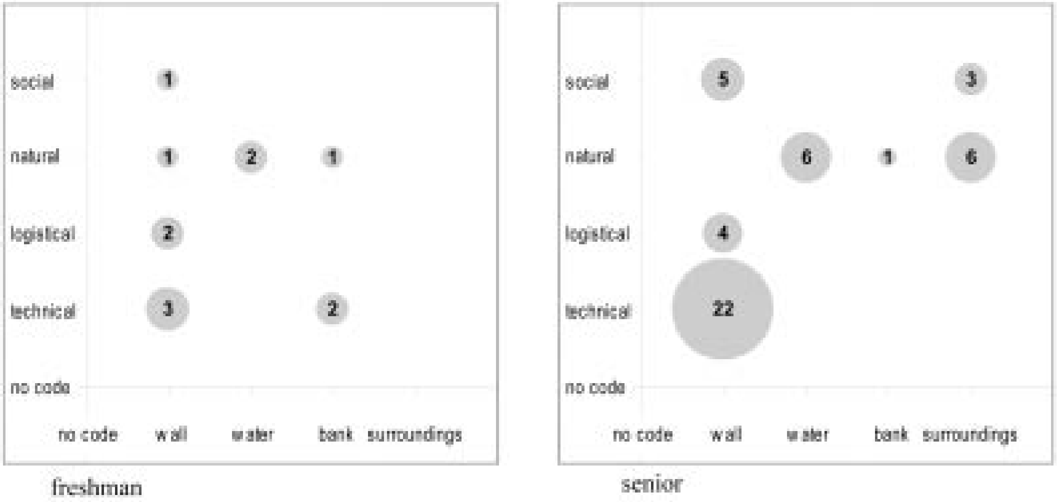
freshman **senior**

Fig. 8. Case of a student whose Midwest floods response as a senior was more substantial and discussed a wider variety of factors.



freshman senior

Fig. 9. Case where the primary difference between the freshman and senior responses results from a shift in focus—in this case, a shift towards focus on detail.



freshman senior

Fig. 10. Case where senior-year response was more substantial, but neither overall node coverage nor detail or context focus changed much.

senior year problem scoping was narrower and focused less on context. In Fig. 9, the total segment count increased substantially between freshman and senior year, but total node coverage is largely unchanged. However, a separate examination of detail and context nodes reveals a substantial difference. In the senior-year response, although total node coverage did not change much, detail node coverage increased by one and context node coverage decreased by two. These measures suggest a shift in focus toward more detail-focused factors. This shift is confirmed by the changes in detail and context segment counts, with 56 more detail segments and five fewer context segments in the senior response. While only a few participant pairs exhibited comparable shifts in focus, we did observe examples of shifts in both directions—toward detail (as above) and toward context. (A student whose shift was toward context was shown as an example in an earlier publication [35].)

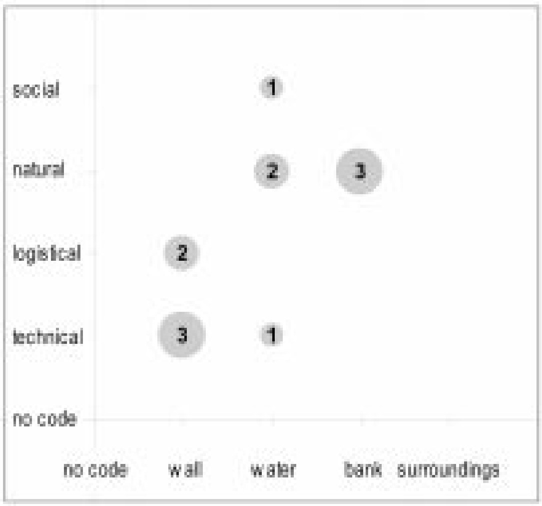


Fig. 11. Typical example University of West State freshman response.

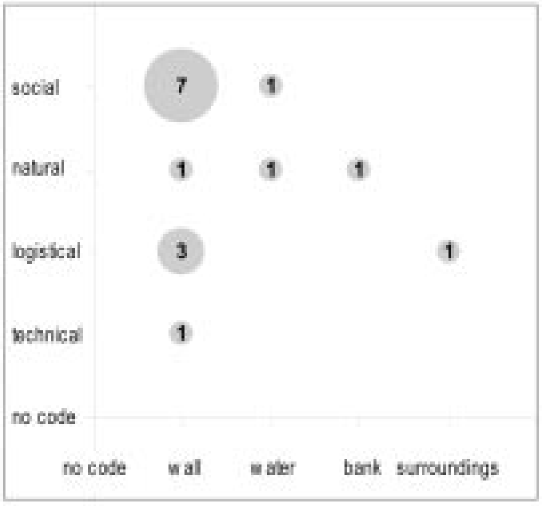


Fig. 12. Less typical University of West State freshman response. Note substantial node coverage, especially among context nodes.

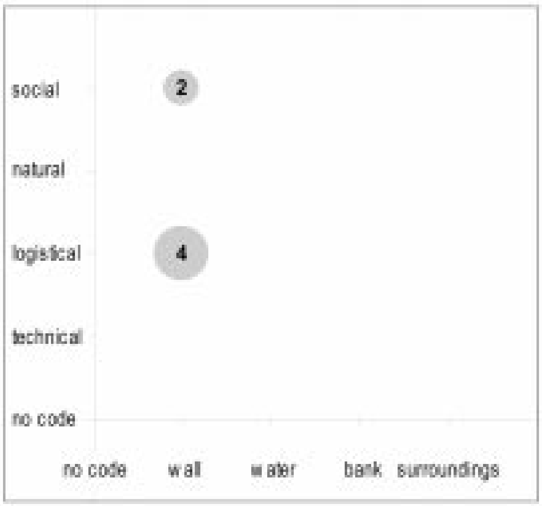


Fig. 13. Less typical University of West State freshman response. Note low node coverage and segment count.

The final case discussed here is illustrated in Fig. 10 and is one where the student's response remains largely unchanged with respect to node coverage and detail/context focus but increases in segment count. In this case, the number of segments quadrupled, but node coverage changed little, even considering detail and context coverage individually.

DISCUSSION: RELATED WORK

Recognizing the resource-intensive nature of the data collection and analysis methods described above, we conclude this paper by briefly discussing an ongoing, related research effort that promises similar views into problem scoping but with more efficient methods. Working with the same engineering problem (retaining wall design), the current study involves collecting the participants' responses in written form (*vs.* audio/video recordings) and limits each participant's time on task to ten minutes (*vs.* no limit). Transcription of these shorter, written responses is significantly easier than dealing with audio/video recordings. Subsequent segmenting and coding procedures were essentially the same as in the original study. We collected data from freshmen from four institutions in the spring of 2003 as part of a larger longitudinal study [41]. Analyses of these new data yield results similar to the results from the dataset described in this paper, suggesting a successful streamlining of the research methods [42]. Figures 11 through 13 present three cases from this new dataset from one of the participating institutions, University of West State, a large public university in the Northwest US.

Similarities between the newer freshman data and the 1990s-era freshman data suggest that the findings reported in this paper remain relevant today, in spite of being based on data from several years ago. They also suggest some generalizability of the findings, because the data were collected at different times from different institutions with a different method of data collection. Overall, the freshmen in the newer data set focused on the same kinds of factors as in the 1990s set. Both sets of freshman responses frequently included detail-focused discussions of the retaining wall's design and construction (i.e. code pairs (WALL, TECHNICAL) and (WALL, LOGISTICAL)), as well as factors related to the river, rainfall, and aquatic wildlife (i.e. (WATER, NATURAL)). In addition, as illustrated in the above figures, freshman responses in the newer data set exhibit variation in segment count and node coverage that is similar to the variation in problem scoping in the freshman responses of the cases shown earlier (see Figs 8–10). Analysis of new freshman data—collected on paper rather than verbally—also indicates that the broad context factors are still readily differentiated from of the more narrowly-focused technical/local design considerations.

The character of this new freshman data appears analogous to our earlier freshman data in several ways. We take this as evidence that the research method remains useful and relevant today. Analysis of the new freshman data suggests that current, incoming engineering students have not changed much with regard to the factors they consider when designing solutions to engineering problems. With increasing emphasis on teaching students to take into account the broader global and social context of engineering, we hope that engineering seniors of today will be even better prepared than the seniors we studied in the 1990s.

DISCUSSION: IMPLICATIONS

As stated earlier, in this research, we sought to develop measures to characterize breadth of problem scoping and to then use those measures to describe the scoping behaviour of engineering students. Initially using a verbal protocol analysis, we developed measures that helped us to not only characterize breadth of problem scoping quantitatively, but to also develop representations that concisely illustrate what aspects of the problem and context their problem scoping focused on. We believe these measures and representations will be useful to colleagues who are interested in research or assessment tools to measure contextual breadth in students' problem scoping. We also think these measures will be useful for determining the kinds of design problems to use and how best to pose design problems that will foster the development of broad thinking skills we want engineering graduates to possess.

In this study we used those measures to address the research questions:

(a) Do students consider broad contextual issues when formulating a design problem?
(b) Does breadth of student consideration of contextual issues change from the freshman to the senior year?

We found that both freshman and senior students do consider broad, contextual issues when formulating a design problem. As one might expect with freshmen, there was wide variation in the amount and kinds of contextual factors they considered. This indicates for us that engineering programmes should carefully consider the ways in which the mission, goals and importance of the engineering professions are communicated in recruitment materials and introductory courses. If the importance of global and social concerns of engineering are made clear to prospective and beginning engineering students, those who might otherwise assume engineering to be narrowly, technically focused might be more likely to enroll and remain in engineering. If nothing else, this would help beginning students develop a more accurate and complete understanding of the engineering disciplines and professions.

Our across- and within-subjects analyses show changes in problem scoping from the freshman to the senior year, both in quantity (how many factors they consider) and breadth (the variety of detail- and context-focused factors). This development in number and scope of issues considered is what we expected to find. While we do see growth on average, we also see variation in the data that demonstrate that not all students grow in terms of breadth of issues considered. To what extent does this represent cause for concern?

One way to answer this question is to take the problem-scoping behaviours of experts as a point of comparison. We are currently analysing data analogous to those discussed in this paper that were collected from practicing, professional engineers. Other analyses describe the process (and not just the product) of experts' problem scoping [29]. These analyses suggest that experts' problem scoping is somewhat concentrated in intensity at the beginning of the design process and is then revisited throughout the design process. As implied throughout this paper, we believe that high-quality solutions require both consideration of detail and context. However, we also realistically acknowledge design to be a social, team process that integrates the contributions of multiple individuals with varying expertise. Considering this, perhaps we should be less worried by variation in senior engineering students' ability to consider contextual factors. In either case, analysis of data from expert engineers will further illuminate these issues.

To answer the call from ABET and other engineering stakeholders, engineering educators have developed a variety of courses, curricula and programmes to better prepare students to engage in broad, contextualized problem scoping in design. In addition to example efforts highlighted in the introduction, there are international study programmes and other opportunities that, while resource-intensive, have the potential to expose students to an even broader range of problem-solving contexts and experiences. (See Sheppard & Jenison [43] for a structured review of a sample of freshman design courses.) By continuing to refine and adapt data collection and analysis methods, we are exploring how they can be transformed into instructional activities, contributing to efforts towards more research-informed approaches to design education [44]. The Midwest floods problem might be useful as a tool for assessing the impact of efforts to improve design education. In hopes of further streamlining the methods, we are investigating the feasibility of a web-based administration of the Midwest floods or similar engineering design tasks and questions. With the possibility of some automated analysis, we imagine a web tool that returns the student their individual responses in the context of other students' or experts' responses. By giving the student the opportunity to reflect on and compare their responses with others', such a tool might also be valuable as a facilitator of self-assessment and metacognition.

The results of this study indicate that, on average, graduating seniors consider more and a broader array of factors than freshmen as they undertake the problem-scoping stage of the design process. While this is encouraging news, we also see that there is room for improvement for all students to be prepared for success in an increasingly complex, global environment.

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