Capstone Project Problem Statements

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As the capstone experience is marketed, vetted, and assessed there has been a consistent challenge in developing the capstone student's ability to develop a quality statement of the project problem. This paper provides a summary report of research directed at determining what characteristics are valued in developing a problem statement. The research found that the problem statement and its characteristics vary with programmatic requirements and preferences. Statistics point to alignment of academia and industry on all but two pre-selected problem statement characteristics. Industry was found to have the more rigorous point of view for the two characteristics.

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Introduction

As the capstone experience is marketed, vetted[1], and assessed there has been a consistent challenge in developing the capstone student's ability to develop a quality statement of the project problem. Lectures, handouts, guidebooks and textbooks have modest efficacy in developing student skills. A review of relevant literature has provided little pedagogy or methodologies for developing the required knowledge, skills and abilities within students.

Background

The process of initiating and nurturing the capstone experience within a new engineering program has offered challenges and opportunities. Paramount among these challenges has been the development of industry relations that support industry sponsored projects. After five years, the supply of projects now exceeds the available students taking the two semester course. Sponsor feedback has been overwhelmingly supportive of the capstone curriculum. Generally, sponsor satisfaction with the project results has exceeded faculty assessment of the project quality. This is consistent with the tendency to focus on project success over learning purposes[2]. The capstone process has begun focusing on improving project design quality in order to meet academic goals by focusing on project problem statements.

Sponsored projects are requested using a template that requests potential sponsors to provide project background, summary objectives/requirements, design expectations (deliverables) along with some administrative data including point of contact. Projects are vetted[1] among a capstone committee for selection. Students are assigned project teams and their first assignment is to begin crafting a problem statement for their project. Emphasis is placed on developing the problem statement as an iterative process consistent with Eggert[3]. Lectures are held once a week and the problem statement process is discussed for one full class period and referred to frequently throughout the first semester of the two semester capstone design sequence.

Internal assessments consistently indicate a weakness in the quality of student developed problem statements. Issues of embedded solutions, poorly developed constraints and objectives that are not quantifiable lead to weak measures, or indicators, that the design has met customer requirements. The assessment results reflect what others have found [4,5].

In order to understand the rigors of developing problem statement skills within engineering students, a survey was conducted among academicians and industry sponsors seeking to determine the key points of what is a quality problem statement. The survey was initially developed to gain insights on how to structure both pedagogical materials and assessment rubrics to improve the capstone experiences for senior design students. As the survey was initiated, it became apparent that a broader need for tools to develop quality problem statements may be needed.

Methods

A simple questionnaire was developed and distributed to the capstone community via affiliations with supporting agencies and organizations. Participants included capstone instructors/coordinators (N=41), capstone alumni (N=2; data was included with industry/sponsor data) and capstone sponsors (N=16) as well as other industry representatives. The survey was intentionally kept brief and general. Some comments pointed out that the survey was unclear as to whether questions were dealing with sponsor problem statements or student derived problem statements. This lack of clarity was indicative of the general problem statements

provided to students. Qualitative responses were categorized by subjectively assessing the nature of the responses.

One question asked respondents to rank the value of pre-selected problem statement characteristic components that were adapted from six recognized design textbooks (Table 1). Respondents were also provided the option of adding other components they felt were of value.

As expected, concerns arose about what is meant by the terms used in the survey. This was voiced by a number of respondents and is assumed to reflect a lack of standard terminology within the capstone community as well as the lack of a single design process standard. The latter not being preferred for a number of reasons beyond the scope of this paper. It is also reflective of the issues students face when trying to understand sponsor terminology/jargon when presented with a project proposal. While these issues make communicating challenging, the issues also lead to dialogue. In a paper of this brevity, or even a survey, dialogue is illusive.

Table 1: Problem statement characteristics (coding)

	Respondent Mean (SD)
General statement, definition or description, an overview (GnrlStmt).	3.5 (0.7)
Specific statement, definition; an exact problem statement (SpcfStmt).	3.3 (1.0)
Constraints/criteria (Cnstrnt).	3.2 (0.9)
Solution path, objectives, goals (SlnPthOjb).	2.6 (1.2)
Established (customer) need (CstmrNd).	3.2 (0.9)
Evidence of current art research (PrArtRsch)	2.2 (1.0)
Deliverables (Dlvrbls).	3.3 (1.0)
Practicality (Prctclt).	2.6 (1.0)
Success metrics (ScsMtrcs).	2.8 (1.1)
Identified design methods (IDDsgMth).	2.2 (1.0)

Additional questions addressed additional components or comments, indicators of precision and quality in evaluating capstone problem statements, examples of quality problem statements and explanations of why the problem statements were exemplary. These questions used an open-ended format.

Results

General Statistical Data for the preselected problem statement characteristics is shown in Table 2. Means test and ANOVA data analysis were consistent in identifying that significant difference only occurred between academics and industry respondents for the *problem statement characteristic identified design methods* (IDDsgMth, $p=0.040$) and *evidence of current art research* (PrArtRsch, $p=0.043$). Industry preference was stronger for both of these characteristics as part of

the problem statement than it was for the academic sample. This was somewhat unexpected for prior art as this could be conceived as an academic pursuit and yet, understanding problem context includes understanding what has been done to address a problem or similar problems is a valued design practice common to industry.

The problem statement characteristics question(s) included opportunities for respondents to include additional characteristics ("other"). Additional characteristics offered by respondents are shown in Table 3. From the additional characteristics, it appears a stronger need for "completeness" exists with academic samples than exists for the industry sample. This may be indicative of the daily exposure to, or continued experience with general or vaguely defined issues, constraints and challenges of business.

Table 2. General Statistics for pre-selected problem statement characteristics.

	Role			
	Academic		Industry	
	Mean	SD	Mean	SD
GnrlStmt	3.44	.838	3.61	.979
SpcfcStmt	3.12	1.100	3.56	.705
Cnstrnt	3.17	.972	3.24	.831
SlnPthObj	2.39	1.243	2.94	1.197
CstmrNd	3.20	.954	3.29	.920
PrArtRsch	1.98	1.060	2.59	.939
Dlvrbls	3.29	1.078	3.12	.993
Prctclt	2.54	1.075	2.71	.849
ScsMtrcs	2.83	1.138	2.94	1.029
IDDsgMth	2.00	1.065	2.63	.806

Table 3: Additional Problem statement characteristics

Academic	Appropriate codes (2); schedule (2); available resources; stakeholder description; terms/conditions of submission; optional scope for extra credit; budget constraints; needs statement
Industry	Risks to success

The qualitative questions were well received and are summarized below. Responses are grouped by sample.

Comments/Characteristics/Components

Comments largely reflected definitions of terms and perspectives, i.e., what is a "problem statement (or definition or scope or brief)." Some comments provided insights that are worthy of note as they give further clarification and challenges to capstone instructors and coordinators. Some noteworthy examples from the academic sample:

"As a career design and development specialist for a large international corporation, I always try

to establish a professional problem statement. I insist on a project planning exercise with for example a Gant chart. Regular meetings with the design teams, ensures that they recognize the need for adherence to their project plan, and take unforeseen problems in stride. I strongly believe that lectures are not design, and few academics have the background and experience to appreciate the niceties of professional design."

"Capstone design would be a better experience if students had to struggle finding a compelling opportunity space and within that a valuable problem to solve, then worry about the simpler parts of solution, design, etc.'

"In my view the 'problem statement' is just one part of the problem definition that also should include a background/context statement, target specifications (preferably quanitified), design constraints, and timeline for deliverables. A summary of project learning and functional breakdown may be part of the problem definition but more often would appear under 'concept development activities'."

"In my view the "problem statement" is a complete and separate element of the process. The problem statement is independent of objectives, constraints, etc. Including those in a "problem statement" only serves to contaminate the problem statement, leading students to think about solutions before truly understanding the problem, and leading, in some cases, to actually addressing the wrong problem by moving ahead too quickly."

These responses reflect various points of view. In context they are representative of a seemingly large diversity in what constitutes a problem statement. It seems that problems, their definitions, and their scopes are programmatically defined. This may well parallel intra-industry approaches where problems/projects dealing with design are initiated/developed from various states of generalization. This could imply that related assessment processes will be, of necessity, program specific.

Responses were categorized, based on the respondents struggle with the vague question, by whether the respondents were considering the project proposal (received from the sponsor) or the student (re)definition of the design. Generally speaking, proposals were preferred to be vague/general with exceptions only for proprietary interests, e.g., a specific PLC manufacturer. The term "open-ended" was frequently used or implied. Additionally, sponsor proposals were considered to be problem statements with the inclusion of some or all of schedule, budget, resource, constraints and deliverables identified. Two

comments reflected some rather poignant points of view:

"Must be important to the sponsoring company, should be a "cool" project, best if it requires the use [of] *new technologies, should leave room for students to innovate."*

"Requirement flowdown from goals, to objectives, to performance requirements, to performance metrics with identified margins is a particularly important part of the process. When done well, this flowdown enables the reverse process of verifying and validating performance -- a necessary part of establishing that the goal has been met."

These comments seem to challenge the capstone project process to provide projects that "i-gen" representatives can get excited about while at the same time recognizing the natural flow of project progress, particularly as it relates to problem statement development.

When considering problem statements from the perspective of what students should develop, the data were consistent in starting with vague, open-ended proposals that require students to interact with their project sponsors/customers to develop a full understanding of the characteristics indicated in the characteristics listed above. Perhaps the most telling comments were those addressing separation of the components/characteristics, to wit:

"You have combined "solution path and goals" above. I would separate these. There is the GOAL which is defined in my exemplar problem statement below, but then there is the PATH that my students define as they solve their problem. The PATH is what students figure out, so this is NOT given at the start. Of course, there are constraints: available equipment, available team skills, available money, and time that will define the boundary of their path."

Reading between the lines, it may well be that what is commonly referred to as a problem statement is nothing more than a design report format requirement that has been confounded by the requirements of complete communications and not in providing the simplistic basis for initiating design. This is illustrated in the next subsections discussing exemplary problem statements.

Exemplary Problem Statements

Fourteen respondents provided exemplary problem statements. Two respondent emailed examples, one in the form of a MSPowerPoint® presentation. The provided problem statements varied from simple one line questions to summaries of ~550 words. All of them had their particular merits, a discussion of which is

beyond the scope of this paper. Perhaps more telling were the reasons given as to why these were exemplary problem statements. A list of reasons is show in Table 4.

Table 4: Reasons why a problem statement is exemplary
- identifies/conveys a (specific) need
- concise and clear.
- single sentence that introduces key vocabulary terms
- degree of open endedness
- contains (all) requirements and deliverables
- includes metrics for success or performance criteria.
- does not suggest design approaches, constraints or objectives.
- avoids any restrictions to problem solution.
- appropriate context and specifications to understand the topic and scope.
- focused and well-defined.
- Covers everything needed. Outlines expectations without tons of verbiage.
- Easy to read, to the point, and worked very well with a spoken presentation.

While on the surface these reasons have some conflict, in context they are complimentary and the conflicts are based on programmatic needs and requirements. Complementariness comes from the fact that each of the respondents have identified what is working within their context and in that sense, the diversity reflects their constituencies needs. The data indicates that across capstone surveyed, there is no one best way. This is exemplified in the following two comments:

> *"It* [problem statement] *is focused and well-defined. It does not mention an approach, constraints, or objectives---these are critical to solving the problem and conducting the senior design project, but their inclusion only leads student*[s] *too quickly to restrict their thinking."*

> *"A Capstone design problem statement is more than likely a comprehensive report."*

One comment came in the form a confession:

> *"While reading through the problem statement from my capstone project experience, I came to realize that I didn't find it to be exemplary. The actual specific project statement was weak. Fortunately, constraints, goals, established customer need, current art research, deliverables, success metrics were all included. However, practicality and identified design methods could have been fleshed out better.*

Perhaps this statement is the underlying "learning" of capstone, whether it be in the form of developing a problem statement, patenting a design concept or maybe

in learning from failure. Reflection is powerful in creating life-long learning opportunities.

So what

The study has provided an opportunity to incorporate pedagogical changes in my own capstone course based on the diversity of perspectives provided by the survey. During the fall semester, students developed and applied their own problem statement assessment rubric. The results caused re-writes of their preliminary problem statements and improved their receptivity to critiques of their work. At the time of this writing, assessment data was not available to determine if KSAs associated with developing problem statements have been improved. This will be considered when data is available. Additionally, student input regarding development of KSAs has not been acquired and therefore not analyzed. This is an opportunity for further study and could benefit from a multi-institutional study.

In summary, this study points to a need for a broad approach to problem statements. It may serve the capstone community to separately define problem statements and problem definitions. An expanded version of this paper has been developed for the 2012 ASEE Conference and addresses this approach. For purposes of this paper, it is recommended that actual problem statements reflect a concise general statement that is embellished with the characteristics discussed earlier. The problem definition should include the details required for the design process (constraints, deliverables, schedule, budget, etc.).

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