AC 2012-3039: EXPERIENCING CAPSTONE DESIGN PROBLEM STATEMENTS

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Capstone Project Problem Statements

Formulating a project problem statement can be a challenge for the capstone student. A review of capstone related literature indicates similar-not identical-approach to design that include various concepts of what is a problem statement, their development, evaluation and assessment. The literature focus is primarily assessment of the design report. There appears to be a variety of approaches to developing the capstone student's ability to craft a quality statement of the project problem. There are few specifics that are not quite as clear as to what should or should not be included in the problem statement and what is found reflects the preferred design process or programmatic requirements. To some extent, it appears that capstone instructors/coordinators take refuge in the approach that what is a thorough problem statement depends on the project itself.

This paper describes findings from a qualitative exploration of problem statements and problem statement assessments and evaluations directed at determining what characteristics are valued in developing a problem statement. The exploration was undertaken in an effort to align faculty and students in understanding the value and content of a quality design problem statement for use in a two-semester senior design capstone sequence. The research found that problem statements and associated 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. An alternative approach is provided.

Introduction

Engineering capstone design courses are recognized as "…a culminating experience" where students apply "…knowledge and abilities to practical engineering problems."[1]. The capstone experience permits students to connect theory and practice in the final academic process of developing professional skills of design and personal relationships through teamwork. Capstone texts each have variations of the design process such as stage-gate, systems engineering and systems engineering lifecycle; however, no consensus on what specifically constitutes engineering design was found[2]. These variations all include references to problem statements, problem definitions, problem scopes, problem formulations and/or problem framing. Research indicates that experienced engineers recognize that the common process being described by these terms is iterative in nature and integral to the design process. Research also indicates that experienced engineers will apply greater resources to the clarifying of the problem than will inexperienced problem solvers [3, 4].

As the engineering students' capstone experience is marketed, vetted[5], and assessed there seems to have been little work reported concerning the development of the capstone student's ability to develop/clarify a (quality) statement of the project problem. Lectures, handouts, guidebooks and textbooks have modest offerings on developing student abilities regarding problem statements. A review of research literature provides little pedagogy or methodologies for developing knowledge, skills and abilities (KSAs) within students that are useful in designing and crafting a quality problem statement. Some assessment rubrics were identified but these seemed to focus more on formatting than content. Little guidance was identified relative to lesson plans for developing problem statement design KSAs. This paper, describes some initial efforts toward developing problem statement KSAs within senior engineering students that have begun from some exploratory research and classroom experiences.

Background

The East Carolina University (ECU) initiated its first ever engineering program in 2004. The program culminates in a two semester capstone design project based learning experience for all engineering students. 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. The ECU engineering program relies on industry sponsored projects for most of the capstone design experiences. After five years, the supply of projects now exceeds student availability. Sponsor feedback has been overwhelmingly supportive of the capstone sequence. Generally, sponsor satisfaction with the project results has exceeded faculty assessment of students' design quality. This seems consistent with an industry tendency to focus on project success over learning outcomes[6]. The capstone process has begun focusing on improving design quality in order to meet academic goals. The first step in improving design quality has been to focus on project problem statements.

Industry projects are preferred because of their realism and for their ability to imitate the pressures of realty found in industry [7]. These projects are usually proposed as open-ended statements which are believed to increase student motivation, and to provide an introduction to the world of engineering [8, 9]. ECU seeks sponsored projects as part of a process requesting potential sponsors to provide project background, summary objectives/requirements, design expectations (deliverables) along with some administrative data including point of contact. Projects are vetted for selection[5]. Students are assigned project teams and their first assignment is to begin crafting a problem statement for their project. Lectures are held once per week and the problem statement development process[10] is discussed for one full class period and referred to frequently throughout the two semester capstone design course sequence. Faculty conducted assessments have consistently indicated 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 design has met customer requirements. The assessments have indicated a need for more focus on project statement development consistent with what others have found [4, 11, 12].

Relevant literature provides a variety in points of view relative to KSAs associated with crafting problem statements. Woods[13], recommends that students be taught to focus on the "define stage". Trainor, McCarthy, and Kwinn [14], recommend that students be taught to develop a clearly defined problem statement using stakeholder analysis techniques to compile customer needs, wants and desires as part of the problem definition phase. This broad description of a problem definition contrasts with what others consider to be a need for a concise problem statement. For example, Rehmann, et al.[15], cause students to apply systems thinking in order to view a problem broadly and holistically. ATMAN, et al., [4,] suggests a more rigorous approach that includes a set of activities that involve identifying criteria, constraints, and requirements; framing problem goals; gathering information; and, stating assumptions about information gathered.

In order to understand the rigors of developing problem statement skills across industry and academia, a survey was conducted among academicians and industry sponsors to determine the key points desired in 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.

Methods

A simple questionnaire was developed and distributed to the capstone community. This community was primarily developed from academics and their willingness to invite industry contacts. Participants included capstone instructors/ coordinators (N=41), and capstone sponsors as well as other industry representatives (N=16).

The survey was designed to be brief and general. Some comments received during data acquisition pointed out that the brevity of the survey contributed to a lack of clarity as to whether questions were dealing with sponsor problem statements or student derived problem statements. This lack of clarity was deliberate and was intended to parallel real-world, open, general problem statements provided to students often times. The survey was composed of a Likert scale question containing literature identified characteristics of problem statements in which respondents were asked to assign value on a 4 point scale of *doesn't matter* (1) to *must have* (4). Additional space was provided for *other* preferred alternatives. Qualitative questions addressed problem statement precision. Examples of exemplary problem statements were requested as well as reasons why the problem statements were considered exemplary. In analyzing the data, qualitative responses were categorized by subjectively assessing the responses. Responses addressing student problem statements were grouped and responses addressing industry proposals were grouped separately.

The Likert response question asked respondents to rank the value of pre-selected problem statement characteristics that were adapted from six recognized design text books (Table 1). As expected, concerns arose about what was meant by the terms describing the pre-selected characteristics used in the survey in the space provided. This was voiced by a considerable number of respondents and is assumed to reflect a lack of standard terminology within the capstone community. The lack of standard terminology also reflects the use of multiple design processes that are reflected in common design texts [2]. While there is similarity across the design processes there is enough diversity that no one clear process of design is center stage. This is not unlike what is found in industry where different design processes are associated with different disciplines, industry sectors and companies. This issue of varying design processes and terminology can compound challenges students face when trying to understand sponsor terminology/jargon found in a project proposal, particularly for those students who have no previous industry related experience. Most ECU engineering students are full or part time employees and have been so since high school. These students often have taken jobs in retail in order to get a job quickly as a way to finance their education. The language of retail is not the language of engineers or engineering design. The language of industry may not be typical of language used in the classroom or in the text book(s). While issues of jargon and terminology make clarity of communication via a survey challenging, it can lead to dialogue needed to achieve commonality in meaning. This dialogue was sought with the open-ended questions. In a paper, or survey; however, dialogue is still somewhat illusive. Nonetheless, by the time this paper is published, it is expected that some face-to-face dialogue on this area of capstone will have occurred at the bi-annual Capstone Conference (http://www.capstoneconf.org/).

Table 1: Problem statement characteristics (coding) used in the Likert scale question

- General statement, definition or description, an overview (GnrlStmt).
- Specific statement, definition; an exact problem statement (SpcfStmt).
- Constraints/criteria (Cnstrnt).
- Solution path, objectives, goals (SlnPthOjb).
- Established (customer) need (CstmrNd).
- Evidence of current art research (PrArtRsch)
- Deliverables (Dlvrbls).
- Practicality (Prctclt).
- Success metrics (ScsMtrcs).
- Identified design methods (IDDsgMth).

Results

General Statistical Data for the preselected problem statement characteristics are shown in Table 2. Means and ANOVA analysis were consistent in identifying that significant differences only occurred between academics and industry respondents for the problem statement characteristics *identified design methods* (IDDsgMth, p=0.040) and *evidence of current art research* (PrArtRsch, p=0.043). The industry sample showed a stronger preference for both of these characteristics as part of the problem statement than did the academic sample. This was somewhat unexpected. The belief was that *evidence of current art* would be perceived as primarily an academic pursuit. However, researchers have pointed out that experienced engineers are willing to spend more time understanding the problem context than do inexperienced students who seek to get to solutions quickly. For experienced engineers, understanding context includes what has been done to address a (previous) problem is valued in design practices common to industry [4]. This would support then the greater value industry places on investigating similar problem/solutions found in literature.

The problem statement characteristics question(s) also included opportunities for respondents to include additional characteristics (*Other*). While some respondents used this space to comment on definitional issues, other respondents provided additional characteristics (Table 3). From the additional characteristics offered, it appears that the academic sample has a stronger need for *completeness* 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 in contrast to the need for measurable (assessment) content required by academics. The common practice for classroom exercises seems to focus on in-the-box thinking[7]. The classroom's close-ended problems lend themselves to complete, closed-ended quantitative solutions may script the academic mind to require *completeness.*

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

Responses to additional characteristics and qualitative questions are provided below. These questions were posed in the form of blank space and open-ended questions. Consistently, responses to these questions were thoughtful and value added. This may be indicative that the topic of developing KSAs for crafting problem statements is regarded highly.

Table 3: Additional Problem statement characteristics (# of respondents)

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

Comments related to Characteristics/Components of Problem Statements

Comments seemed to largely reflect personal/program specific definitions of terms and perspectives, i.e., what is a "problem statement (or definition, scope, formulation and/or framing)." Notable comments provided further clarification and challenges to capstone instructors and coordinators. The examples provided below are unedited.

> *"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 GantI*[t] *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 quantified), 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 the various approaches discussed above and various points of view regarding problem statements. In context they are representative of a seemingly large diversity in what constitutes a problem statement. It seems that problems, their definitions and scopes may be programmatically defined rather than cookie-cutter from a single source of guidelines describing how to craft a problem statement. 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 should be, of necessity, program specific.

Responses were categorized, based on 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., use of 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 those students representing the "i-gen" can get excited about while at the same time recognizing the natural flow of project progress, particularly as it relates to problem statement development. Still, industry engineering projects range from the mundane to rocket science and all have value for the sponsor. 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. There were exceptions. For example one capstone coordinator takes input from the sponsors and writes each project problem statement in a way that meets programmatic needs and ensures students get a fast start on their project design. 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."*

From this point of view, actual problem statements should be a concise general statement and embellished with the characteristics discussed earlier as part of a broader problem definition. 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 a design endeavor. This is illustrated in the next subsection which discusses the questions related to exemplary problem statements. Again, responses relative to precision of and exemplary examples of, problem statements were well received and provided great depth of insight.

Exemplary Problem Statements

Fourteen respondents provided exemplary problem statements. Two respondent emailed examples, one in the form of a MSPowerPoint® presentation. One respondent provided a sponsor's proposed problem. The provided problem statements varied from simple one line questions to summaries of ~550 words. Perhaps more telling were the reasons given as to why these were exemplary problem statements. A list of reasons is shown in Table 4. Examples are provided in the Appendix 1.

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 reasons for designating a problem statement to be exemplary have some conflict, in context they are complementary. The conflicts appear to be based on programmatic needs and requirements. Complementariness comes from the fact that each of the respondents has identified what is working within the context of their academic/industry requirements and in that sense, diversity reflects constituencies' needs. The data indicates that across capstone programs surveyed, there is no one best way that is promoted. 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 of 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 is 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 [13].

Path Forward

Savage [17] suggests that the *design method* begins with a careful evaluation of the needs of a customer and that a specific application or problem must be solved using goals transformed from the customer's domain into the technical domain. Further, he recommends that functional requirements and constraints be identified that completely define what performance the application requires. The question remains, just as was found from the survey data, what part of this provides a clear, quality statement of the actual problem in a way that leads to a project meeting objectives related to cost, schedule and performance? While the simple answer is that all of this is required for project success, how much of this design method is a problem statement and how much is engineering specifications? For Adams, et al. [18], it is the *problem definition* that describes what the problem really is, what are the constraints, and what are the (performance) criteria. Woods[13], proposes that the define "stage" includes the stated objective, context, constraints, criteria (inputs and outputs) with a focus on classification of given information and not on understanding what really is the problem. A different perspective to be sure.

When considering both the commonalities in the study reported here as well as the literature reviewed along with the differences found, the need for a common definition of terms seems to exist only when communicating about capstone problem statements with other programs/approaches. Additionally, when considering assessment rubrics from a variety of authors, it appears that one rubric does not fit all. Appendix 2 provides a proposal that considers problem statement development as a development process that itself includes stages or phases. Saunders, et al. [19], describe a rubric as consisting of columns indicating levels of mastery and rows representing dimensions of interest or learning outcomes. Similar to spiral curriculum [20], problem statement development is iterative in that the problem statement is refined in stages. What is proposed represents a project inception problem statement rubric that would be used for students to assess the quality of their project problem statement within the first 30-60 days of the project life-cycle. The intention is to get students off to a well-grounded (crafted) start. Consistent with the format of the ECU engineering capstone project where the first semester ends with a conceptual design, the second phase rubric represents a more advanced problem statement. The advanced problem statement reflects on the student's need to revisit or iterate the problem statement and therefore requires an additional, or second stage, rubric. The second stage rubric is proposed to be used at the end of the first semester. Note that the rubrics presented only include the assessment verbiage for the expert level. Additional developmental levels are left for the reader to supply as the rubric is adapted to meet programmatic needs.

The inception rubric consists of two parts, problem statement and problem definition. The problem statement reflects the brief concise, elevator speech version of the intent of the project problem. The problem definition part is expanded in that it provides for early development of additional characteristics such as constraints, schedule and budget as part of a more specific definition of the problem that may be required for full technical reporting. This tiered approach satisfies a preponderance of concerns voiced by the survey respondents.

The conceptual design phase problem statement rubric reflects a recognition that the inception phase problem statement has been revisited (iteration), refined and expanded. The rubric incorporates directly, or through editing, the additional characteristics collected from the survey and in doing so tends to be quite prescriptive. This conception design problem statement reflects full problem development up to, and including, plans for evaluating alternatives (technical and economic feasibility). The capstone program at ECU has clear expectations that by the end of the first semester, students will have formulated plans for analyzing design alternatives and that even these plans are subject to review and adjustment during the detailed design process of the second semester.

So what

The study has provided a desire to incorporate pedagogical changes in engineering capstone sequence at ECU based on the diversity of perspectives provided by the survey. In order to pulse student understanding of what constitutes a quality problem statement, the 2011 fall semester students developed and applied their own problem statement assessment rubric (Figure 1). The results caused re-writes of their preliminary problem statements and improved their receptivity to critiques of their work. Faculty assessments of student problem statements are scheduled for the spring semester. Comparisons of previous years progress in student written problem statements will indicate if any progress is being made. Nonetheless, the dialogue on quality problem statements has begun.

Figure 1: Student developed problem statement rubric (only the highest level of assessment is included).

Problem definition/statement	Accomplished
Problem (general)	clear, readable, informative problem statement provides constraints, objectives, criteria, research, client needs/wants, with supporting style and format; clear motive for problem/project; appropriate level of detail; understandable by general audiences; recognizes client, client context and establishes design project background
Constraints/criteria	logical constraints/criteria, qualitatively and quantitatively measurable in a way that alternatives can be identified and selected, and endstate can be clearly achieved; impact of performance, budget and schedule addressed
Solution path objectives/goals	complete and realistic objectives/goals indicate feasible solution can be recognized/achieved or failure results in positive impact on body of knowledge; problem understood and supported by objectives/goals
Plan	applies engineering theory and reasoning across disciplines
Established need	correctly interprets client perspectives that integrate into objectives/goals and support development of design parameters
Research	extensive prior art/literature completed using research based literature yielding confidence in strong team understanding of project parameters/implications/context
Style/format	definition has no grammatical errors; convincing representation; reviews/editing on archived journal level; appropriate use of engineering vocabulary
Client problem definition/deliverables	Customers' needs/wants/challenges fully developed indicating clear project deliverables/milestones; customer involvement/dialogue evident
Format/Quality of Appearance	problem is convincingly defined for specific client expectations; team clear understanding of objective(s)
Design practicality	definition is formulated such that design will exceed one or more budget, schedule and performance constraints
Success measures	clearly defined way of measuring success
Methods	methods meet/support project deliverables

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Appendix 1 Example problem statements.

The first example is excerpted from a 41 page file. Only Section 1.1, Summary of Design Problem is included. Names and specific identifiers have been redacted.

> 1.1 Summary of Design Problem
> The [redacted] GPS Animal Tracking System ([redacted] ATS) was primarily designed for the purposes of ecological research but is also used to fulfill the needs of other researchers, resource managers, and livestock producers. The [redacted] ATS technological capabilities are currently acceptable and the current package configuration has worked successfully for cattle but researchers would like to use the capabilities of the collar to track smaller animals such as wolves, deer and elk.
>
> The current ATS Collar includes a Laminate Conveyor Belt, Satellite Modem, UHF/VHF transceiver, GPS receiver, Microprocessor Control board(w/ SD card slot), 4 D-Cell Batteries, GPS Antenna, Satellite Modem Antenna and UHF/VHF antenna. The new collar enclosure will only have two D-Cell batteries with the capabilities of adding two additional D-Cell batteries when the weight carrying capabilities of the animal will allow. The primary focus of this project will be to reduce the size of the electronics/battery package(s) paying special attention to the depth and height of the enclosures to ensure the animal's survival will not be compromised while wearing the collar. The co-primary focus is ensuring the electronics, batteries, wires and circuit integrity stay intact and the collar functions normally through all possible weather from the equator to the poles, including submersion up to 1 meter.
>
> The configuration of the electronics, batteries and antennas will be a major part of the project and [redacted] stressed that the only limitation is that the Satellite Modem circuit board and components can not be replaced or modified.

The second example was provided by an industry sponsor. The problem statement was provided in the form of a MSPowerPoint presentation file created by students.

> Overall: Design a separator grate cover that can be easily locked into position on the 2012 model year combine.
>
> - Manually operated
> - Future automation
> - Design cannot obstruct crop flow when open or closed
> - Safe design that keeps user away from moving parts
> - Design cannot conflict with current combine options

The third example was provided by a capstone coordinator and represents an industry sponsor's proposal for a capstone. The problem statement was provided in the form of a MSPowerPoint file for presentation. The capstone program requires sponsors to provide slide presentations to the capstone coordinator who in turn gives the presentation to students. Students "bid" on projects based on the presentations and are assigned to teams via the bid process.

> Problem
>
> - We would like to add demo capabilities to our radios

- When we take our radios to a show to present their capabilities many of them are difficult to showcase in a way a casual/new customer who hasn't worked with them before can understand
- Voice is one particular feature we are always asked to demo but with our current funding and test environment its not easy to do that outside a lab environment
- We would like to expose the voice codecs in a windows environment to be able to show a potential customer we have a working radio that is operational in a voice enabled network

The three examples provided demonstrate the diversity of understanding relative to what is a problem statement. However, all three represent valid problem statements within the programmatic context with which they were presented.

Appendix 2. Progressive Problem Statement Rubrics. The rubrics are Design focused, in that they have been designed to minimize documentation requirements (format, grammar, etc.)

Inception phase - Compiled Problem Statement Rubric

	Proficiency level - Expert
Context	Factual context established relative to pertinent customer needs. What is wrong/missing. Including (as appropriate): • history relevant to the "big picture" • description of the significance of the project • provides current status • answers "why"
Statement	Provides basis for formalized project management methods.
Enables path forward	Generic statement in that solutions are not scripted.
Customer	Stakeholder(s), end and transitory user(s) properly identified.
Assumptions	Basic considerations required for problem solution not otherwise defined.

Inception phase - Compiled Problem Definition/Scope/Frame Rubric

	Proficiency level - Expert
Deliverables	Defined project deliverable(s) that provide metric identifying when project is complete; functional and non-functional.
Constraints (must not)	Complete system of qualitative/quantitative limits to design alternatives including regulatory, managerial, and societal requirements and limitations as appropriate; i.e., capable of supporting preferred alternative/solution to project statement; functional and non-functional.
Performance/ deliverables (must)	System of qualitative/quantitative measurable requirements/objectives of preferred design alternatives (outputs) required to meet customer requirements; functional and non-functional. Systems engineering

	“’ilities” addressed.
Schedule	Demonstrates understanding of academic and project tasks and milestones and capable of communicating project progress formally and informally, with or without narrative. Supports “Crashing” as needed.
Budget	Project earned value analysis includes target ranges (±agreed upon range). “Discretionary set asides established if necessary.
Path Forward/ Action plan	Challenges to be addressed.

Conceptual phase – Problem statement

	Proficiency level - Expert
Iteration	Problem statement/definition have been refined appropriately given the following:
1) Current/prior art review	Support preliminary (SWOT, technical and economic feasibility, etc.) analysis of identified alternatives. Validate assumptions.
2) Alternatives	Reflects contrasted set
3) Technical analysis	Required technical analysis equations are clear, accurate, and labeled. Variables defined and units specified. Discussion regarding the equation development and use stated.
4) Economic analysis	Required economic analysis equations are clear, accurate, and labeled. Variables are defined and units specified. Discussion regarding the equation development and use support decision methodologies.
5) Decision tools	Decision methodologies are identified, constraints refined and “loaded”. • Supported by technical and economic analysis. • Methods reasons how design is constrained and provides sufficient depth to avoid second guessing of sufficiency of applied decision methods. • Includes risk assessment
6) Schedule	Indicates both reasonable progress and on-going updating/refinement. Resource loaded. Risk analyzed.
7) Start-up/ acceptance Test	Testing protocol outlined recognizing performance requirements, design constraints along with validation processes.
8) Quality	Capable of being (re)started by new team having no experience with project problem and continue design process; i.e., selections/decisions clear in design

Literature sources used to develop the phased rubrics for problem statement assessment:

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Sobek II, Durward K. and, Vikas K. Jain (2004). Two Instruments for Assessing Design Outcomes of Capstone Projects, 2004 Annual Conference Proceedings, ASEE.

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