Establishing Outcomes for Senior Capstone Projects In Industrial Technology

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Abstract

As part of continuous curriculum improvement and outcomes assessment for professional accreditation, the Department of Information and Management Technology at Arizona State University on the Polytechnic Campus determined that a mandatory senior project be established. The methodology for validating such a senior project included a descriptive survey of three constituent groups: students in upper division courses, faculty, and a jury of senior industry advisory board members. A comprehensive list of senior project key words was created from a broad sample of existing national senior project descriptions. An attitudinal survey instrument was created from this list of key words. The results of the survey were analyzed for the variability of response within and between constituent groups, and the direction of agreement on a five-point Likert scale. Conclusions were drawn as to which measures showed agreement or disagreement, and how those results might impact the implementation of the senior project course.

I. Introduction

Before instituting a senior project or capstone course, the Information and Management Technology Faculty at Arizona State University were interested in determining the level of agreement among students, faculty, and industrial advisory board members on outcomes exhibited by existing, successful programs that used this technique. Determining agreement before embarking on course design might point to outcomes that are important to one group but not to another. For example, if there are significant differences in how the three groups perceive the value of a senior project in initial and long-term employee success, additional investigation and intervention might be required.

Historically, the impetus for senior-level capstone experiences has come from industry. A review of literature available in engineering and technology education for the decade 1985-1995 shows considerable interest in the topic, both within academe and industry. Additional literature in the decade that followed shows lower interest. However, recent changes in accreditation guidelines that stress outcomes assessment have renewed interest in the topic.

The Association of American Colleges and Universities (AAC&U), in the 2004 publication "Our Students' Best Work: A Framework for Accountability Worthy of Our Mission," cites the need for advanced capstone or culminating experiences that demonstrate knowledge in both liberal

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education and knowledge relevant to the specific field of study. Further, the question of accountability requires that culminating work be regularly peer reviewed in the context of accreditation. [1]

By far, the literature answers the question: *Is it advisable to include a senior capstone experience in engineering and technology programs?* It is advisable. The only questions remaining are: *How can senior projects be efficiently implemented as a curriculum requirement, be validated by industry, and meet regional and professional accreditation guidelines?*

An extensive 1995 review of capstone projects at nearly 300 engineering departments in 173 schools [2] brought Todd and his fellow authors to conclude: "This type of educational experience is highly desired and had been strongly encouraged by industry." Although faculty are often concerned with how senior project advisement and mentoring is evaluated and rewarded in tenure and promotion, Todd's data showed that responding departments felt such activities to be beneficial to their students (8.6 out of 10.0 rating).

Moore and Berry [3] showed evidence that a senior capstone course that is the culminating experience of an integrated "design thread" may have a greater chance of success than a free-standing, totally independent course simply inserted at the end of a student's curriculum. A senior project should be able to close the loop with a significant number of program outcomes. In other words, it would be counter productive to develop a separate set of outcomes for a senior project. Instead, the activity should be an important step in assessing overall program outcomes.

Further anecdotal evidence of the importance of a curricular thread leading to the capstone experience was discussed by Adams in her investigation of E-teams. [4] She concluded that although students were positive about design teams, many felt they (the students) "lacked a clear understanding of the characteristics of effective teams," and that they needed "better training on the skills necessary to form, manage, and maintain effective teams." It could be argued in this case that the design thread—how design is implemented in teams—was not effectively established throughout the curriculum.

II. Status of the Senior Project

The Department of Information and Management Technology (IMT) at Arizona State University has embarked on establishing a required senior capstone experience for students in three curricular concentrations: Industrial Technology Management, Environmental Technology Management, and Graphic Information Technology. These program concentrations award the Bachelor of Science in Industrial Technology degree and are accredited by the National Association of Industrial Technology (NAIT). No department-wide senior project course currently exists, though each concentration has the freedom to use an upper division course in that manner. For example, a senior level project management course (taken by students in all three concentrations) emphasizes a capstone team design project. The Graphic Information Technology concentration offers an elective upper division portfolio course that may be considered a capstone exercise. However, neither course is advertised specifically as a senior project or capstone experience.

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A. Capstone Course Definition

Using a number of established capstone course descriptions as a guide, the following operational definition was established for the IMT department's initial course design:

> "The senior project is intended to be a culminating scholastic effort or capstone experience. The objectives are to refine skills in communication, research and information retrieval, critical analysis and criticism, and to demonstrate technical competence in each student's area of study. The senior project is evidence of potential for outstanding performance at the advanced level and is characterized by experimental, theoretical, or developmental work leading to meaningful results presented as a final paper and oral report at the end of the semester." [5]

This definition was created as a baseline for gathering attitudinal data concerning senior project perceptions from three stake holder groups: students enrolled in Information and Management Technology (IMT) upper-division courses during the fall semester, 2004; current IMT faculty teaching upper division courses; and, a jury of senior industry advisory members including chairpersons and senior members of the three concentration advisory boards.

A factor in promoting senior project effectiveness is the creation of a more purposeful educational environment that fosters service learning. The investigators hoped that by including advisory board members that a tie to this service learning component bight be fostered. In the AAC&U publication "Greater Expectations: A New Vision for Learning as the Nation Goes to College," there is significant concern over the "empowered learner," the "informed learner," and the "responsible learner." In discussing good practices in the new academy, the AAC&U indicated the following recommendation regarding culminating (capstone) activities and outcmes.

> "…these expectations for quality will focus new attention on the culminating year of college. Both institutions and departments should set standards for achievement of knowledge, skills, and responsibility, and require advanced work that demonstrates the expected outcomes. These culminating performances, which will vary with different fields of study, ought to provide evidence that students can integrate different parts of their learning. They can show how well students actually possess the intellectual, practical, and evaluative judgment and the sense of responsibility a college degree should represent." [6]

Collaboration with industry, faculty, students, and accreditation agencies positions the senior project as a successful indicator that the assessment loop has been closed. The senior project implementation methodology used by Arizona State University at the Polytechnic Campus was to survey these stakeholders to access capstone perceptions.

The data was gathered and analyzed to determine if a difference exists in the perceptions of senior project course outcomes by the three constituent groups. Knowledge of such differences, if they exist, could prove instrumental in the design of the course. The literature contains

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sufficient references to the importance of the various parties having "buy-in." Todd [7] concludes as to the results of the industrial customer directed senior capstone experience at Brigham Young University, "…the students are highly motivated to achieve successful products because they feel personally responsible to the sponsor. In addition, the industrial sponsor feels an obligation because they are now part of the educational process." Encouraging faculty buy-in presents "unique challenges to faculty coordinators and administrators." These challenges included a feeling that senior project coordinators "may have less time for research than their colleagues."

B. Capstone Courses and Accreditation

Although senior or capstone projects are generally accepted across liberal arts, science, engineering, and technology, there is no single model for the activity. Projects are conducted over one or two semesters, using individual or team projects, identified by internal or external sources, guided by faculty or external mentors, and requiring strict or open-ended formats, documentation, and oral reports. Job placement, graduate school admission, outcomes assessment, and program accreditation all were listed as justification for a capstone course. Dutson [8] reviewed the status of senior projects, spending significant time on Accreditation Board for Engineering and Technology (ABET) guidelines that were in place at the time. The guidelines at that time were explicit in the relationship of design in any such project. Although the words "capstone" or "senior" were not mentioned explicitly, the integrative nature of the activities mandated the activity be upper division and capstone in nature.

Current ABET Accreditation Guidelines [9] are outcomes-based, requiring a senior project course to demonstrate where the agency's A-K guidelines are met. In fact, a reading of the 11 outcomes is essentially ABET's description of what should be included in a senior project experience. Likewise, the Technology Accreditation Commission (TAC) uses a parallel A-K rubric that could be used as the basis for senior project outcomes. [10]

The National Association of Industrial Technology (NAIT)[11] has several standards in their current accreditation requirements that, when taken together, pertain specifically to a senior capstone project. These standards (6.3.10, 6.4.3, 6.14.2, and 6.16) form the basis of a senior project created to satisfy NAIT accreditation. As with other agencies, NAIT is considering greater outcomes specificity for accreditation.

Another professional accreditation that often coexists with engineering and technology is the American Association of Collegiate Schools of Business (AACSB). Similar to NAIT, ABET, and TAC, the AACSB 2004 accreditation standards that define learning goals and measure the achievement of those goals (standards 16, 18, 19, and 21) address using external guidance for setting these goals for degree programs. The AACSB guidelines state, "External constituencies can inject expertise and perspectives into the process that will be unavailable if the faculty operates alone." The study reported in this paper follows the AACSB suggestion that external constituencies (in this case, advisory board members) be included. It is critical to survey industry for current trends and issues that may provide a more practical application of the capstone senior project, and ultimately assist in securing career employment for students. The AACSB further addresses an approach to assuring learning by providing examples of demonstration through performance. The standards propose, "A thesis or senior project might be required to

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demonstrate students' ability to integrate knowledge across different disciplines." [12] In their comparison of accreditation standards of NAIT, TAC of ABET, and the AACSB, Ward and Dugger [13] indicated that Industrial Technology graduates often work directly with engineering and business graduates, and that the workplace would benefit from consistent standards of learning outcomes. However, this has not been accomplished and no initiative has been instituted.

Because accreditation agencies increasingly recognize the benefits of outcomes-based assessment, senior projects should be based on schema of identifiable and accepted outcomes. A good example of a senior project formed around identifiable outcomes can be found with the Department of Interdisciplinary Arts and Performance at Arizona State University West where projects are evaluated on seven distinct learning outcomes. [14]

III. The Study

This study sought to determine the level of agreement between the three stake holder groups involved in a senior capstone project: students, faculty, and advisory board members. In order to determine agreement, data concerning capstone project outcomes was gathered and evaluated.

A number of senior project descriptions and outcomes were perused on the Web (see Table 1) and a list of key terms was extracted. These key terms formed the basis of an instrument consisting of 31 questions asking for the respondents' level of agreement on a Likert-type (1-5) scale. The questions were grouped into two general categories: 1) the procedural operation of a senior projects course, and 2) outcomes that might be expected from participating in the course. An example of a procedural question would be: "An elective class could be substituted for the senior project." An example of an outcomes question would be: "The senior project should contain elements of criticism and self-reflection."

Interdisciplinary Arts and Performance Arizona State University West	Geography University of Minnesota
Computer Science University of Colorado	P. Stevenson Jr. Library Bard College
Social Sciences University of Hawaii	Industrial and Systems Engineering North Carolina A&T University
Physics Case Western Reserve University	Communications and Media Studies Tufts University
Robert E. Kennedy Library California Polytechnic State University	Engineering Western New England College
Honors Program University of Wisconsin-Milwaukee	Communications Villanova University

Table 1. Sources for senior project outcomes key words.

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The questionnaire was given to students (n=71), faculty (n=12) and a jury of industry advisory members to include chairpersons and senior members (n=11) associated with the Department of Information and Management Technology at Arizona State University's Polytechnic campus in the fall semester, 2004. Of particular interest were the levels of agreement within each group and the level of agreement between the three groups. For the student group, additional questions were asked to determine the impact that participating in a high school senior project might have on perceptions.

Because the three constituent groups had widely disparate number of survey participants, tests of statistical significance such as chi square or Pearson's product moment correlation were not used. The traditional use of standard deviation as a measure of variability in the distribution of data was used as a measure of agreement. The mean response score was used as a measure of direction (5=strong agreement, 3=indifference, 1=strong disagreement).

IV. Results

A. The Student Group

For the student group (n=71), the range of standard deviations was 1.116 to 1.652. Mean responses had the range 2.32 to 4.23. Two questions had mean responses above 4.0; there were no responses rated below 2.0. The average mean response was 3.20 with a standard deviation of .486

B. The Faculty Group

The faculty group (n=12) showed a range of standard deviations from .389 to 1.929. Mean responses had the range 1.33 to 4.83. Five questions had mean responses above 4.0; there were six responses below 2.08. The average mean response was 3.25 with a standard deviation of .889.

C. The Advisory Group

The faculty group (n=11) showed a range of standard deviations from .487 to 2.054. Mean responses had the range 1.45 to 4.73. Twelve questions had mean responses above 4.0; there were five responses below 2.00. The average mean response was 3.405 with a standard deviation of .908.

V. Discussion

A. The Student Group

The student group response indicates a moderate level of disagreement. The fact that standard deviations were consistent and above 1.00 shows wide variability in student perceptions concerning senior projects. The fact that only two questions registered outside a 3.00-3.99 neutral response range indicate that students not only disagree amongst themselves, but that their

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attitudes are not generally positive or negative. On two items (Table 2) responses showed a strong direction and moderate variance.

Question	Mean	Std. Deviation
13. Apply existing knowledge	4.23	1.017
22. Focus determined by student	4.20	1.116

Table 2. Student responses of strong direction and moderate variance.

On the issue of whether or not students had previous experience with senior projects, five respondents indicated that they had (7.04%). These students responded more favorably (4.80) on the two measures (questions 13 and 22) where student response had the most agreement. It would appear from the limited data that previous experience in high school with a senior project may impact both level and direction of agreement in a positive direction.

B. The Faculty Group

The faculty group showed less disagreement than did the student group (Table 3). Five standard deviations were below .900; five items received mean responses of 4.00 or greater; five responses received a mean response below 2.08.

Question	Mean	Std. Deviation
6. Elective substitute	1.58	1.165
7. Student identifies topic	3.75	.866
9. Stress individual work	4.42	.793
10. Stress group work	2.00	1.348
12. Letter graded	4.83	.389
13. Apply existing knowledge	3.83	1.115
16. Equal effort for similar credit	4.75	.622
20. Graded satisfactory/unsatisfactory	1.33	1.155
21. Flexible credit hours	2.08	1.379
22. Focus determined by student	4.00	.853
23. Broad focus but not deep	2.00	1.477
29. Open-ended problem	1.92	1.240
32. Acquire new knowledge	4.08	.900

Table 3. Faculty responses of strong direction and low to moderate variance.

The faculty group showed less disagreement as demonstrated by lower standard deviations on several measures. Faculty also exhibited stronger opinions, witnessed by more items with mean scores of greater than 4.00 (agreement) and less than 2.00 (disagreement). On the issue of previous senior project experience, none of the faculty had experience with supervising senior projects so no conclusion can be drawn on this issue.

Faculty also had relatively strong opinions and moderate agreement on both questions for which students had strong opinions (13 and 22). It may be concluded that both faculty and students

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have moderate agreement that senior projects should apply existing knowledge on a topic determined by the student.

C. The Advisory Group

The advisory board jury demonstrated the most agreement of the three groups as shown by the number of measures exhibiting standard deviations below 1.00 (Table 4). Not only was there less variability, the direction (agreement and disagreement) was stronger on more questions than either student or faculty groups. As expected from the literature, response was extremely positive to the directed question: "I support the senior project as a capstone experience."

Question	Mean	Std. Deviation
5. Required of all students	4.73	.467
6. Elective substitute	1.45	.820
7. Student identifies topic	3.91	.820
9. Stress individual work	4.00	1.483
13. Apply existing knowledge	4.00	1.095
15. Practical problem focus	4.18	.982
16. Equal effort for similar credit	4.64	.505
17. Oral presentation required	4.00	.894
18. Stress broad theoretical approach	1.82	1.079
22. Focus determined by student	4.09	.944
25. Identifiable solution	3.82	1.471
32. Acquire new knowledge	4.73	.467
33. Enhances employability	4.45	.522

Table 5. Advisory board jury responses of strong direction and low to moderate variance.

The advisory group showed even less disagreement as demonstrated by lower standard deviations on several additional measures. This jury also exhibited stronger opinions, as witnessed by more items with mean scores of greater than 4.00 (agreement).

The advisory board jury also had strong opinions and moderate agreement on both questions for which students and faculty had strong opinions (13 and 22). It may be concluded that students, faculty, and advisors share moderate agreement that senior projects should apply existing knowledge on a topic determined by the student.

VI. Conclusions

Looking at the survey questions, the following conclusions may be reached. Means and standard deviations are reported for students, faculty, and the advisory jury in that order. To increase the likelihood of success in implementing the senior project, differences in agreement of the three groups can be inspected and appropriate actions taken such as counseling, threading, or curricular revision.

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1. The student project should be required of all students (2.89/1.563, 3.75/1.357, 4.73/.467).

   Comment: potential employers may desire to compare students on uniform measures. Students are less positive about this while the faculty is indifferent.

2. The course should not allow an elective substitute (3.17/1.612, 1.58/1.165, 1.45/.820).

   Comment: students appear to desire greater flexibility than making the senior project a required course with no substitution. Alternative delivery methods (online, self-paced, intersession, etc.) may ameliorate this perception.

3. The senior project topic should be identified by the student (3.75/1.227, 3.75/.866, 4.00/.756).

   Comment: see point 9 below.

4. The senior project should stress individual work (3.37/1.437, 4.42/.793, 3.91/.831).

   Comments: surprisingly, both faculty and advisory jury disagreed with a "stress group work" question. This may be because students feel they already have sufficient opportunity for group work. The value of individual capstone work should be communicated to students.

5. A letter grade should be awarded (3.30/1.438, 4.83/389, 2.73/2.054).

   Comment: the faculty feels strongly that a letter grade should be awarded while students and advisory members are varied and relatively indifferent. Employers evaluate the project, not the grade. Students are accustomed to receiving grades and may not have entertained alternatives such as pass/no pass or satisfactory/unsatisfactory.

6. The senior project should apply existing knowledge (4.23/1.017, 3.83/1.115, 4.00/1.095).

   Comment: Positive agreement here, but consider the response to point 11, below.

7. The advisory committee jury expects the project to focus on a practical problem (3.63/1.198, 3.50/1.508, 4.18/.982).

   Comment: The value of solving a practical problem must be impressed upon both students and faculty. If industry feels that projects should focus on practical, as opposed to theoretical, problems, advisory boards should be tapped for potential topics.

8. The course should require a commensurate amount of work for the credit hours assigned (3.73/1.393, 4.75/.622, 4.64/.505).

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Comment: Because the advisory jury probably has little actual idea of work required by credit hour, their response is probably a reflection that they expect to see a *significant*, student-selected, practical problem.

9. Agreeing with point 3 above, project focus should be determined by the student (4.20/1.116, 4.00/.853, 4.09/.944).

   Comment: Although the literature strongly supports externally identified (and mentored) project topics, the three constituent groups show agreement that project focus should be determined by the student.

10. The senior project should have an identifiable solution (3.14/1.323, 2.83/1.946, 3.82/1.471).

    Comment: this parallels point 7 above (practical problem). The advisory board jury (potential employers) is less interested in open-ended, theoretical problems, than in focused, practical problems with identifiable solutions.

11. New knowledge should be acquired (3.90/1.364, 4.08/.900, 4.73/.467).

    Comment: Taken with point 6, above, it appears that a senior project should include both the application of existing and the acquisition of new knowledge.

12. A senior project enhances potential employment (3.62/1.571, 3.75/1.485, 4.45/.522).

    Comment: Both student and faculty groups had fair disagreement and indifference on this issue. However, the advisory jury had both very strong positive feelings and agreement that a senior project enhances employability. There appears to be a need for employers to communicate this more effectively to students and faculty.

In conclusion, the three primary stakeholders in this study (students, faculty, and industrial advisory board members) exhibited moderate variability and agreement on the instrument measures. Students were more diverse in their opinions, though as a group, were generally indifferent other than on measures 13 and 22. There were, however, several measures on which differences did exist between the groups. Data from the faculty group showed less variability and more positive agreement on measures relating to the operation of the course. Data from the advisory board jury showed even less variability and more positive agreement on the practical, applied nature of senior project topics.

Finally, administrative considerations for making the senior project successful include institutional funding for faculty mentoring, laboratory access, and archival capabilities to document the results. Dutson [8] suggests that a modular approach might be implemented to counteract administrative difficulties. Other authors, most notably Adams [4], entertain virtual teams as an alternative. As this study shows, support from the three constituent groups is critical for the success of a senior project initiative.

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