THE IMPACT OF AN AUTHENTIC, STUDENT-CENTERED ENGINEERING PROJECT ON STUDENT MOTIVATION

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Abstract *– The Student Projects In Rocket Investigative Techniques (SPIRIT) project used teaching innovation and flexibility to forge a highly successful and popular two-year project course at Penn State University. A combination of traditional and non-traditional teaching methods were used to: 1) maintain a base of common knowledge pertaining to the scientific/engineering mission among a highly diverse student population, and 2) allow students to focus on the knowledge and skills of most interest to them. This paper discusses the impact of this course and project on student motivation levels as measured by the Motivated Strategies for Learning Questionnaire (MSLQ) and student focus groups. Initial results show that even without academic "rewards", SPIRIT students demonstrated a consistently high level of motivation and enthusiasm for the project. In addition, first and second year students rated the SPIRIT project more motivating than a comparison course to a statistically significant extent. The impact of these results in terms of future curricular reform is also discussed.*

Index Terms – Assessment, electrical engineering, motivation, rockets.

INTRODUCTION

The Student Projects Involving Rocket Investigation Techniques Program (SPIRIT) was a two-year series of projects and associated courses designed to give undergraduate students an extended opportunity for hands-on learning in a meaningful research program. Approximately 75 students from various disciplines (including non-engineers) participated at Penn State, SUNY Geneseo, and Lincoln University. With the help of local faculty and NASA engineers (see Figure 1), these students had responsibility for designing, building, and testing a rocket payload and the payload structure. The SPIRIT Nike-Orion rocket successfully launched at 6:18 a.m. on Wednesday, May 17th, 2000. See the SPIRIT web site for details (http://spirit.ee.psu.edu/).

As the project began and proceeded, we were struck by the enthusiasm with which the students participated in the project. Why would a busy student spend roughly ten hours per week on a project and course that offered only one credit? We suspected that the real engineering project that was the focal point of SPIRIT was exciting and motivating to students, and thus regardless of the presence or absence of external rewards, students invested a great deal of effort. In order to confirm (our refute) our hypothesis, we developed a study to examine student motivation and levels of student effort. We measured motivation levels using the Motivated Strategies for Learning Questionnaire (MSLQ) and student focus groups. This paper discusses the study results and their impact on future curricular activities. We begin with a discussion of the context in which the project was designed, the pedagogical approaches used in the course, and how these might influence student motivation.

COURSE AND PROJECT DESCRIPTION

Many engineering educators are introducing experiences into their classes intended to excite and motivate students, and ultimately lead to better learning [1] [2]. The SPIRIT project used many strategies to motivate students, encourage learning and make the project successful. In this section we briefly describe the project and the instructional and organizational methods used during the project. For a more thorough description of these items, contact author Tim Wheeler.

The focus of SPIRIT was the design and construction of a sounding rocket payload to calibrate new methods for measuring mesospheric temperatures. All together, teams of 7-10 students built six experiments, three transmitters, three PCM encoders, as well as the physical structure and payload support subsystems. This payload is to fly on top of a 2-stage Nike-Orion rocket from Wallops Island, Virginia. A one-credit course, an active publicity campaign, several component test events and a K-12 outreach program complimented the work on the payload.

Student responsibility for both the course and the project was one of SPIRIT's crucial aspects. The basis for this responsibility was the student teams. During the first semester, the instructor helped the students to form six teams (experiments, power and wiring, structures, telemetry, publicity, and education /outreach) that would accomplish the work of designing and building the payload.

The instructor, knowing the challenges each team would face, followed several steps for ensuring team success. First, having developed a "profile" for the kind of person who would be best for each team, he conducted one-on-one interviews with students to ascertain their interests and skills. This information helped him to make good decisions *with* the students about which team they would join. Secondly, he gave the teams an opportunity to learn from

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each other. All the groups had good dynamics, yet they all functioned differently. The instructor (with initiative from the teams) ensured that teams shared their work processes with each other so all would benefit from project management strategies that worked, and avoid known pitfalls. Thirdly, each team had a leader who guided the team through their problem solving and project management. Leaders were not formally trained, however the instructor did extensively work with individual leaders to ensure their success.

FIGURE 1
SPIRIT STUDENTS GET GUIDANCE FROM A NASA ENGINEER.

The SPIRIT course spanned four semesters. Over those four semesters, students gradually assumed more and more responsibility. The instructor realized that it was critical to the success of the program that students actually do the work, and also that the student teams would not necessarily be ready to take on responsibility immediately. Thus, he gradually introduced more and more student responsibility as the course evolved. The first semester, the SPIRIT course was conducted largely using traditional pedagogical methods. The instructor delivered lectures on pertinent topics, and guest speakers helped the students develop skills in teamwork and other areas critical to the project. Students were assessed via written papers and a final exam. The instructor intentionally chose instructional methods he felt the students would be comfortable with, but at the same time he began to introduce them to the idea that they would have more responsibility as the project continued. The first semester was used as a time for the teams to define the problems they would face.

During the second semester student teams began to work on designing their systems. The course itself retained many of the traditional aspects from the first semester. The instructor still lectured, but additionally each group took turns being responsible for a class meeting. Groups would prepare and present material on pertinent topics such as "telemetry". During the third semester as the students began to build, the instructor transferred the preponderance of responsibility to them. Students ran the class periods by delivering status reports and focusing on cross team issues. By the fourth semester, the class periods consisted of discussions around a circle of weekly status reports and problem assessments.

A last important element of the course and project was the regular use of feedback mechanisms. Students regularly completed peer evaluations of their teammates, course evaluations and the standard teaching effectiveness evaluations used at Penn State. While some students ultimately felt "over surveyed", these evaluations were instrumental in continuing to improve the course.

STUDENT MOTIVATION

The SPIRIT project is one example of the numerous curriculum redesign efforts occurring throughout engineering education. These redesign efforts must consider many factors, such as learner objectives and pedagogical methods, in order to create successful learning experiences. Underlying these fundamental design considerations, however, is the concept of student motivation. Intuitively, we as educators all know the importance of motivating our students and the delight of teaching students who are motivated. But what is motivation really? How can we measure it and, most importantly, can we determine what attributes we must design into our pedagogical strategies to encourage motivation? We explore these questions in this section.

Motivation refers to the choices individuals make regarding the experiences and / or goals they will seek or avoid, and additionally the amount of effort they will expend in these experiences. Motivation can be distinguished from ability in that motivation refers to "what a person *will* do, whereas ability refers to what a person *can* do" [3] (p. 388). Research has shown that projects that have similar motivational characteristics to SPIRIT (hands-on design, multi-disciplinary teams, and activity-based class sessions) can and do have a significant impact on learning [4, 5]. For instance, intrinsic and extrinsic strategies embedded into instruction-enhanced motivation of college learners and their performance on a test of content knowledge [6]. Additionally, in a soil mechanics course that was updated with situated learning experiences and other activities designed to improve student motivation, Cabral and his colleagues [2] found that students reported positive effects on their understanding of the importance of the knowledge acquired, their future professions and also perceptions of their ability to transfer the knowledge to other situations. Other documented consequences of motivation include the intensity of performance on a task, persistence on task, and overall better learning [3]

Such results are pertinent, yet to be of most use to us, we must determine whether our teaching and learning experiences are creating a motivating environment, and then further ascertain exactly what aspects of the learning situation are helping to motivate students. Only then can we with confidence design these experiences consistently throughout our curricula. As with many engineering courses that included hands-on, real-world projects [4, 5], we suspected that these aspects of SPIRIT were intrinsically motivating to students. With this research we set out to measure our hunch in a systematic way and then apply our results both to this project and the broader curriculum.

METHOD

One of the main goals of the SPIRIT project was to motivate students in their engineering studies via meaningful activities that contributed to this authentic engineering project. Many researchers argue that better methods are needed to measure academic motivation [7] [8]. In spite of this belief, a number of questionnaire-type, self-report measures exist for motivation constructs such as locus of control, achievement motivation and curiosity. In some cases, researchers assume the curricular activities will increase motivation and simply seek to measure the impact of the motivating experiences on other aspects of learning. We chose to measure the project's effects on students in two ways: focus groups and a specific measure of motivation called the Motivated Strategies for Learning Questionnaire (MSLQ) [11, 12].

The MSLQ is a student self-report instrument based upon an information-processing model of learning. It is designed to assess college students' motivational orientations and their use of different learning strategies for a college course. Students respond on seven-point Likert type scales where one means "not at all true of me" and seven means "very true of me". See Figure 2 for sample MSLQ items. We chose the MSLQ for its validity [9], and its flexibility. The MSLQ offers fifteen different subscales that may be used separately or together [10]. . These scales address motivation, cognitive, metacognitive and learning strategies. We chose four motivation scales from the fifteen; these scales contained items most pertinent to our investigation [13].

FIGURE 2
MSLQ SAMPLE ITEMS

1. I prefer course material that really challenges me so I can learn new things.
2. If I study in appropriate ways, then I will be able to learn this course's material.

Two of the chosen scales address different aspects of goal orientation – which is a student's perception as to why she is engaged in a learning task. The *intrinsic goal orientation* scale examines the extent that a student's participation is motivated by factors internal to the student such as curiosity or challenge. In contrast, the *extrinsic goal orientation* scale measures the degree to which students see themselves participating in a task for external rewards such as grades, rewards (e.g. credit hours) and evaluation by others. Thus having an intrinsic orientation towards the goal would mean students pursue the activity as an end in and of itself, whereas an extrinsic orientation would mean students pursue the task for some externally defined reward.

The *task value* scale differs from the goal orientation scales in that it addresses the student's evaluation of the task's interest, importance or usefulness. To clarify, the goal orientation scales address "Why am I doing this?", and the task value scale examines "What do I think of this task?". If students perceive a class activity as having high task value, this should lead to more involvement and effort in their learning. The last scale, the *control of learning beliefs*, explores whether students believe that their efforts to learn will have positive results. It ascertains whether students believe their success is linked to their own efforts versus external factors such as the teacher. If students feel that they have "control" over a learning situation, they should be more likely to exert effort on the activity. For a complete description of the MSLQ, refer to Pintrich [13, 14].

The authors also designed a focus group protocol to complement and enhance the selected MSLQ scales. Focus groups had three objectives: 1) to explore the motivation for student involvement in the project; 2)
to explore the characteristics of the project that had an impact on students, and 3) to explore how this course fits into the major and compares to other courses.

Subjects

Subjects were all students involved in the SPIRIT project at Penn State University during the 1997 - 1998 academic year. There were 75% electrical engineering students, 10% communications, 5% education, 3% aerospace and 2% other majors. Note that while the project is primarily an engineering one, the public relations and project management aspects attract students from other majors as well. During the fall 1998 semester, thirty-nine students (33 men and six women) of the 59 SPIRIT students completed the MSLQ. Fifteen students participated in focus groups.

Procedures

Two focus groups were held with SPIRIT students during the spring 1998 semester. One focus group consisted only of team leaders; the other group included non-team leaders. Fifteen students participated in focus groups; eight team leaders and seven non-group leaders.

We knew that focus group transcripts would provide us with a rich qualitative description of students' impressions of the project and their reasons for participating so actively. The MSLQ, however, offered us an opportunity to quantitatively and systematically measure motivation. Because we had noted how students invested substantial time and effort into SPIRIT, we decided to compare students' motivation levels for the SPIRIT project to another university course.

To obtain this comparative data, we asked students to complete the MSLQ items both for their SPIRIT experience and for a "comparison" course. In all cases, before responding to the items, students recorded the comparison course name and number on the questionnaire. We wanted students to use a "fair" comparison course – one that would have the greatest chance of including an authentic task, such as what SPIRIT provided. Given that students are more likely to encounter such experiences in courses in their major area, these courses would provide the fairest comparison. To this end, students in their third year and beyond (who are in a specific discipline major) chose a course from their major as a comparison. This was an electrical engineering course in many cases because of the large percentage of electrical engineers participating in SPIRIT. First and second year students are not typically taking courses from their major yet, but rather are fulfilling general education requirements. Thus, we instructed these students to choose a general education course as a comparison.

RESULTS

We begin with the focus group results. Since this paper addresses student motivation as it relates to the SPIRIT project, we will summarize only two of the three focus group objectives: motivation for being involved in the project and the project characteristics that affected students. Results regarding students' initial involvement in the course correlated with whether or not the students participated as group leaders. Group leaders tended to be recruited for the project. Several mentioned that a faculty member had suggested they get involved in the project. Non-group leaders indicated they found out about the project in more informal ways, such as talking with friends and classmates.

Once involved in the project, all students described similar impacts and outcomes of the course experiences. Three themes emerged around this topic. First, students described the positive impact of the student-run nature of the course. They expressed that having responsibility, not only for the project work, but also for organizing and managing the work, had a significant and positive effect on their learning. One group leader said "I think it makes you learn more, other than depending on a teacher, it makes you figure it out for yourself." Another indicated, "it's more like working in the real world." Secondly, students noted the real-world and project nature of the course as being valuable. They expanded their comments describing the benefit of working on something that would actually be used and functional! "I just did it for the experience; to actually work on something that's not just for a class – for actual use."

Finally, students also discussed teamwork. While several admitted that they didn't necessarily enjoy working in teams all the time, they acknowledged the experience would be good for their future careers. One student explained, "I think it's necessary to work in groups because everywhere you go, either a chem[istry] career or into English, you have to work in groups."

We analyzed the MSLQ results in two ways. First we ran paired t-tests for each of the eighteen items, comparing responses for SPIRIT and the comparison course. Results were most meaningful when viewed via the four motivation scales: task value, control of learning beliefs, intrinsic and extrinsic motivation. Students reported statistically significant differences between SPIRIT and the comparison course for three of the four items comprising the extrinsic motivation scale. Table I reports these results. The "Mean - C" or "Mean - S" denote "comparison" and SPIRIT respectively. Asterisked items are significant. No other comparisons were significant.

TABLE I
EXTRINSIC GOAL ORIENTATION PAIRED T-TEST RESULTS

N	Mean - C	Mean - S	2-tailed significance
Item 4. Getting a good grade is the most satisfying thing for me right now.			
37	5.08	3.76	.000 *
Item 7. The most important thing for me is getting a good GPA.			
37	5.00	4.08	.000 *
Item 8. If I can, I want better grades than most of the other students in this class.			
37	5.68	4.30	.000 *
Item 18. I want to do well in this class to show my ability to my family, friends, employer or others.			
37	4.81	5.03	.339 *

For our second analysis, we wished to test whether our results would vary by semester standing. Given that students defined their comparison course based upon whether they were in their first or second year versus third or beyond, we defined our data analysis groups using that same delineation. For eight of eighteen MSLQ items used, students in their first and second years (lower division students) rated the SPIRIT experience and their comparison courses significantly differently (at the .05 level) than those students who were already in a major. An additional two items were significant at the .10 level. Table II presents these results. For example, for item three, "I think I will be able to use what I learn in this course in other courses I take", lower division students average rating for SPIRIT was 6.7 and for their comparison course 3.6 (both on a 7 point scale). The upper division students rated the SPIRIT course 5.1 and their comparison 5.79 for the same item. Thus the lower division students' *difference* between SPIRIT and comparison was significantly different than that *difference* for the upper division students.

TABLE II
DATA ANALYSIS BY CLASS STANDING

1st /2nd Year N = 29			3rd Year + N = 10		
Item	F	Sig.	Item	F	Sig.
1	5.67	.025 *	10	3.31	.077 +
2	1.18	.284	11	1.20	.280
3	28.4	.000 *	12	1.79	.190
4	0.42	.840	13	7.09	.012 *
5	.437	.513	14	1.89	.283
6	8.94	.005 *	15	4.177	.049 *
7	.301	.587	16	4.762	.036 *
8	1.06	.310	17	3.796	.060 +
9	6.20	.018 *	18	6.74	.014 *

* Significant at .05 level. + Significant at .10 level.

DISCUSSION

Both the statistical and focus group analyses indicate the SPIRIT project impacted students and their motivation levels. We begin with a brief discussion of the analysis by semester standing. Recall that the lower division students' *difference* between SPIRIT and comparison was significantly different than that *difference* for the upper division students. The explanation lies in the course comparison. We asked the lower division students to use a general education course as a comparison – since they are not taking courses in their major yet. Many of these "gen ed" courses are either large lectures, or else courses that students do not see fitting clearly into their majors or career plans. It seems likely that the hands-on authentic experiences in SPIRIT were much more motivating than such courses. While this explanation may appear to lessen the importance of the finding, we would argue to the contrary. Many institutions, including Penn State, are structured so that lower division students enroll in mostly general education courses outside their majors. We imply no fault in this policy but emphasize that an experience like SPIRIT can then be *all the more valuable* to these students. SPIRIT provided an intrinsically motivating and interesting curricular experience at a point in these students' studies such experiences did not consistently exist otherwise.

Regardless of semester standing, students reported that the SPIRIT project was significantly less driven by *extrinsic* motivation factors such as grades and credit hours than their comparison courses (see Table I). This is not surprising given that at most students received one-credit per semester for their involvement. What is surprising is that in spite of the lack of external types of motivation, students routinely invested 10 hours per week on the course.

The focus group results provide an explanation of this last observation. These results confirm that students found significance and value in the same pedagogical activities that the instructor so carefully designed -- teamwork, and a hands-on authentic activity. Additionally, students sent a strong message about the importance of the student-run nature of the course. All of these factors combined seems to have caused students' motivation and effort levels to remain high, in spite of small extrinsic rewards.

As for the remaining paired t-tests, it would appear that any potential differences are canceled by the differences in responses between freshman and sophomores as compared to juniors and seniors.

CONCLUSIONS

The SPIRIT project allowed undergraduate students from multiple disciplines to design, develop, troubleshoot and, in the near future, participate in the launch of their payload for a NASA rocket. While focus group results indicated that all students benefited from the project's attributes, analysis of results on the motivation scales of the MSLQ indicated that the first and second year students were impacted in significantly different ways than upper class students as measured by 10 of 18 MSLQ items. Additionally, relative to a comparison course, students were significantly less motivated by extrinsic rewards for SPIRIT.

Drawing from prior research, we know that increasing student motivation can promote deeper processing of knowledge, foster improved study habits and help students transfer what is learned to new situations [4, 5]. In this study, we systematically measured and confirmed an important assumption of educational innovators: That student-centered, authentic, hands-on activities can positively affect student motivation. While it is true that the experience affected motivation more for students not yet in their major, all students were positively affected as shown by focus group results and measures of extrinsic motivation. We don't intend to simplify the complexity of creating such motivational experiences for our students, however we do wish to underscore that such efforts do make a difference – and that is certainly worth knowing as engineering education reforms continue.

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REFERENCES

[1] J. T. Bernhard, "Awakening the tinkerer within: Re-introducing first year students to hardware for motivation," presented at Frontiers in Education, Pittsburgh, PA, 1997.

[2] A. Cabral, R. Viau, and D. Bedard, "Situated learning and motivation strategies to improve cognitive learning in CE," presented at ASEE Annual Conference, Milwaukee, WI, 1997.

[3] J. Keller, "Motivational design of instruction," in *Instructional-Design Theories and Models: An Overview of their Current Status*, C. M. Reigeluth, Ed. Hillsdale, NJ: Lawrence Erlbaum Associates, 1983, pp. 383-434.
[4] M. Liu, "Studyof engaging high-school students as multimedia designers in a cognitive apprenticeship-style learning environment," *Computers in Human Behavior*, vol. 14, pp. 387 - 415, 1998.
[5] R. M. Felder, R. J. Beichner, L. E. Bernold, E. E. Burniston, P. R. Dail, and H. Fuller, "Update on IMPEC: an integrated first-year engineering curriculum at N.C. State University," presented at ASEE, Seattle, WA, 1998.
[6] T. B. Means, D. H. Jonassen, and F. M. Dwyer, "Enhanced relevance: Embedded ARCS strategies vs. purpose," *Educational Technology Research and Development*, vol. 45, pp. 5-17, 1997.
[7] J. M. Keller, E. A. Kelly, and B. Dodge, "Motivation in school: A practitioner's guide to concepts and measures," Syracuse University, Syracuse, NY, ERIC document 1978.
[8] W. W. Cooley and P. R. Lohnes, *Evaluation research in education*. New York: Halsted Press, 1976.
[9] R. C. McClendon, "Motivation and cognition of preservice teachers: MSLQ," *Journal of Instructional Psychology*, vol. 23, pp. 216-220, 1996.
[10] P. R. Pintrich, D. A. F. Smith, T. Garcia, and W. J. McKeachie, *Motivated Strategies for Learning Questionnaire Manual*. Ann Arbor, MI: National Center for Research to Improve Postsecondary Teaching and Learning, 1991.
[11] J. Benson, "Review of Motivated Strategies for Learning Questionnaire," in *The Mental Measurements Yearbook*, O. K. Buros, Ed. Highland Park, N.J.: Rutgers University Press, 1998, pp. 680-682.
[12] P. R. Pintrick and E. V. DeGroot, "Motivational and self-regulated learning components of classroom academic performance," *Journal of Educational Psychology*, vol. 82, pp. 33-40, 1990.
[13] P. R. Pintrich and G. R. Johnson, "Assessing and improving students' learning strategies," in *The Changing Face of College Teaching*, vol. 42, M. D. Svinichi, Ed. San Francisco: Jossey-Bass, 1990, pp. 83 - 92.
[14] P. R. Pintrich, "A Process-oriented view of student motivation and cognition," in *Improving Teaching and Learning Through Research*, vol. 57, *New Directions for Institutional Research*, J. S. Stark and L. A. Mets, Eds. San Francisco: Jossey-Bass, 1988.