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SUMMARY & CONCLUSIONS

Student involvement in any engineering project introduces an element of risk. This risk is particularly pronounced with small spacecraft projects, as a failure of the spacecraft on-orbit can result in a complete failure of the mission. However, student involvement in these projects is critical to allow research aims to be accomplished, in a university setting, and to train the next generation of spacecraft engineering professionals. The nature of risks posed by student involvement is discussed and a framework for assessing and mitigating these risks presented.

1 INTRODUCTION

The involvement of students in small spacecraft development projects in a university environment can provide significant benefit to both student team members and the project. Students gain valuable hands-on experience and demonstrable evidence of their capabilities. The project benefits from having access to intelligent, highly motivated and low cost resources. However, the involvement of students in a project introduces significant project risks not present in the commercial settings that are typically the focus of the management literature. These risks include high low-notice-time turnover, inexperience, scheduling and availability difficulties, and difficulty retaining project knowledge.

This paper proposes a two-part risk analysis and management model, the Student Qualitative Undertaking Involvement Risk Model (SQUIRM), specifically for student-centered projects (particularly those involving undergraduate students) related to spacecraft development (and, broadly, applicable to any student-centered research effort). The first part of this model reflects traditional risk analysis techniques that focus on the technical, schedule and other well-understood risk sources without consideration of student involvement. The approach presented can utilize virtually any common risk model (e.g., [1] is relevant to a project involving small satellites). This flexibility allows broad use of this technique outside the specific fields discussed.

The second part of the model deals with the risks inherent to student workers and team leaders. Unlike traditional corporate environments, virtually all students come to a university with departure foreseen (and actually as a goal). Additionally, students may commit to participation only to find the effort trumped by academic or other commitments. Some students, particularly those that are not participating for course credit or pay, may simply stop participating arbitrarily with little or no notice and no hand-over. While turnover-related risks are clearly present in any work environment, they are intensified in the university environment where student academics are commonly agreed to be more important than participatory activities and professional behavior (e.g., notice standards) are still being instilled in students.

2 BACKGROUND

The fact that projects including student participants involve risk is undeniable. Any project, even one that simply performs a task that has been done numerous times before, has risk factors. The majority of the literature regarding student project participation focuses, however, on the benefits to the students and faculty. It, generally, fails to examine what intervening factors may impair the ability of students, faculty and sponsors to attain these benefits.

Seymour, et al. [2], for example, highlight the numerous benefits that undergraduate students can obtain from participating in research projects. These benefits, they proffer, include increased confidence, enhanced skills and preparation for future activities. Zydny, et al. [3] offer similar findings. They compared students involved in a formal undergraduate research program at the University of Delaware with those that did not participate in this program. Their key finding was that the value of undergraduate student research participation increased with the duration of participation. They posit that this is either due to benefits accruing over time, or due to a correlation between bad experiences (possibly attributable to project, student or faculty issues) and shorter durations of participation. Risk occurrence could clearly be one factor that could cause non-retention of students in research. Nagda, et al. [4] proffer that research participation has a positive effect on undergraduate student retention. They noted that this impact was most pronounced for African American students with below-median performance levels.
Other work by Zydney, et al. [5] suggests that faculty see undergraduate participation as valuable to achieving their research objectives, with 50% of faculty respondents indicating that the contribution to the research program was an “important” or “very important” reason for involving undergraduates in research. Prince, et al. [6], alternately, look at the link between the level of research performed by a faculty member and student education; from this, they proffer that the notion of “faculty research productivity” enhancing student education has been discredited. They look at a variety of ways of enhancing and evaluating faculty efforts to involve undergraduates in research.

Outside the research-inclusion-in-education literature, psychology [e.g., 7] has looked at the differing perceptions of risk factors as a function of age, in other contexts. From this, it is clear that perception of risk applicability and impact generally grow with age. Extrapolating from this, it follows that traditional-age undergraduates may fail to appreciate that their actions, inaction or behaviors may create project risks and the associated impact of risk occurrence on themselves and others involved in the project.

3 TECHNICAL, SCHEDULE & OTHER STANDARD RISKS

Every project, including ones involving students, must deal with numerous possible risk factors. Project managers attempt to control many of these risk factors, assume others and are, ultimately, forced to ignore a large set of risks that they have no insight into or control over. Numerous standard risks are well documented in the literature [e.g., 8] and will not be reviewed in detail here. The impact of student participation on these standard risks is considered. For each risk factor, a brief description its nature is provided. This is followed by a discussion of how the risk factor is influenced by or may influence student project involvement.

3.1 Technical Risk

The technical risk category is comprised of the set of risks that could result from a failure of hardware and software or its integration and operations to perform as required to meet project objectives. Three aspects are considered: construction / fabrication of assemblies, failure of purchased components and their integration.

3.1.1 Construction / Fabrication

Construction and fabrication risks are inherent to any manufacturing process. Quality control processes including those designed to prevent defects and catch and remediate defects are generally included to mitigate these risks. In a student project, which generally doesn’t involve mass-production, one is confronted with two primary risks. First, standards-based quality control may be cost-prohibitive to implement. Second, students who lack knowledge and understanding of the characteristics of the product may be poorly equipped to detect evaluate the significance of errors.

3.1.2 Component

Components obtained from suppliers will occasionally be defective (either due to manufacturing or shipping issues). Production processes generally incorporate an acceptance testing procedure or supplier process validation procedure. A student project, generally, suffers from two risk factors with regards to third-party components (mirroring closely those discussed in section 3.1.1). First, the limited production (in many cases, producing only a single or small quantity of units) precludes the implementation of a standard quality process. Second, student inexperience may result in a failure to properly design acceptance tests or detect latent issues.

3.1.3 Integration

The process of combining components together introduces risks due to design and implementation failures. Design failures may result in a system, which, irrespective of how well it is assembled, cannot perform the desired task. Implementation issues may result in degraded performance, non-operation, or failure after a period of time operating. Student designers and workers generally have traits that significantly increase the probability of these risks eventuating. Having an incomplete or largely untested understanding of the design process or specific design elements may result in wholly unworkable designs or designs with latent and hard-to-detect flaws. Limited time and resources will generally result in a comparatively lower level of testing being conducted. The fact that this testing will likely be performed by inexperienced (student) testers further exacerbates the problem. Even if a perfect design is produced, inexperience in the techniques required for construction may result in sub-par construction, component attachment, solder connections and such. These may cause the assembly to not work initially or to be prone to failure.

3.2 Schedule Risk

Every project faces the possibility that its schedule will not be met. External factors, such as the unavailability of key components, and internal factors, such as staff absences or equipment failure, may result in delays. When these delays impact the critical path, the project schedule is impaired. Key areas of consideration for projects involving students include schedule estimation error, critical path risks and schedule creep.

3.2.1 Estimation Error

Estimation error occurs when the time projected for task completion is different than actual task completion. A certain amount of error is to be expected; however, when tasks are consistently taking longer than projected, the project’s schedule is at risk. Estimation error is common, even for experienced estimators. Students, who do not have significant experience may fail to consider anything other than the best-case scenario. Alternately, they may not completely understand the process that they are estimating and, thus, omit the time required for overlooked process components. Either of these can result in (possibly dramatic) underestimation.

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This, however, is problematic, as it may result in momentum being lost, if materials, tools or staff for subsequent phases are not available when a previous phase completes early.

3.2.2 Critical Path Risk

Critical path risk is a set of risk factors that impact the chain of tasks, which, in succession, take the longest amount of time. As the project is not complete until all of these tasks are done, anything that elongates the schedule of a task on the critical path (or another task, which becomes a critical path task due to schedule overrun) affects the project’s overall schedule. Critical path risk can be created by factors that are both external to and internal to the project. External factors may include impairment to the availability of supplies, unavailability of key equipment at the needed time, changes in laws or regulations and many other factors. Internal factors, however, are the primary area where projects with student involvement differ from conventional projects. Internal issues which may be exacerbated by student involvement include staff availability issues, delays caused by quality failures and, thus, the need to repair or recreate the improperly produced items, and delays caused by poor scheduling. Staff availability issues are discussed in detail in section 4. Quality issues have been discussed in section 3.1. Poor scheduling may be the result of a failure to identify precursor and successor tasks due to failing to identify required task inputs and outputs or, more simply, error in the actual creation of the schedule. Either of these can easily occur when a schedule is produced by an inexperienced scheduler.

3.2.3 Schedule Creep

Schedule creep is the schedule component of scope creep. Scope creep occurs when changes or documentation issues result in a more robust product being produced than called for by planning. The involvement of students, who are generally eager to please and may not understand the impact of accepting changes (or not understand that they are implicitly accepting a change) increases the risk of schedule creep. The fact that most academic projects are run by professors who are trained as researchers – not project managers and may have limited documentation further exacerbates this risk.

3.3 Cost Risk

With tight budgets and long-duration funding cycles, cost overrun is a significant risk to student-involved projects. Cost overruns can lead to reduced deliverable utility and/or quality. If severe enough (and supplemental funding cannot be sourced), they can even lead to project termination and failure. Risks that must be considered relative to student involvement include estimation error, cost creep, damage and rework costs, and costs associated with meeting schedule requirements.

3.3.1 Estimation Error

Cost estimation error closely mirrors schedule estimation error (described in section 3.2.1). It occurs when the level of cost required to be incurred for a given activity is different from the level forecast. While variation is expected, proper estimation should result in some tasks concluding with small overruns and others completing under budget. Generally, an allowance for unexpected costs is included in the budget as a separate line item to allow the absorption of additional costs, should the project average out to a slight overrun. As with schedule estimation error, students who may be estimating costs for the first time (or may have limited domain experience, even if they have performed cost estimating before) may be prone to underestimate, due to ignoring complexity or inadvertently omitting various types of costs or specific costs.

3.3.2 Cost Creep

Cost creep is the cost component of scope creep. As described in section 3.2.3, scope creep occurs when changes are accepted without commensurate changes in budget and schedule. Due to student inexperience and other factors, scope creep is likely on student projects. If scope creep occurs, it is likely that cost creep will occur.

3.3.3 Damage & Rework

Damage and rework costs are incurred when hardware, facilities, supplies or the item being created are damaged due to carelessness, accident, misuse or otherwise. Damage and rework costs are likely on a student-involved project. First, the lack of a production environment designed for the repetitive production of an item means that construction and integration jigs will be setup on the fly. This may result in inadvertent loss of control, dropping, or the application of unwanted torques or pressure to parts or assemblies. Second, the lack of a repetitive production environment means that there is not a set of well-tested task instructions that can be followed. Third, supply and equipment limitations may result in jury-rigging of various jig-elements, making damage more likely. Forth, horseplay or carelessness may result in damage. All of the aforementioned are exacerbated by having young and/or inexperienced individuals working on the project.

3.3.4 Buying Time

Costs can be incurred to resolve schedule issues. For example, a component could be purchased, at additional expense, to return the project to schedule or an external consultant could be hired to expedite a process. Due to this, schedule issues can become cost issues. Given the discussion, in section 3.2 of how student involvement can exacerbate schedule risk, it would seem that student involvement would heighten the possibility of transferring schedule overruns to cost in order to hit a key deadline.

4 RISKS POSED BY STUDENT WORKER INVOLVEMENT

Several risk factors are impacted so dramatically by student involvement as to deserve separate consideration from their standard counterparts. Each is now discussed in detail.

4.1 Scheduled Turnover

Scheduled turnover has a dramatic impact, but can be planned for. It is attributable to the fact that students only
participate in a given effort for a period of time. When this participation ends the student may be unavailable to provide documentation or assistance related to their work on the project. As students become task-experts, if documentation is not stressed, understanding can be lost – or a key component of an integrated system can become unserviceable. Compounding this issue is the fact that many students are not adept in documenting their work and lack an understanding of the need for documentation and what needs to be documented. Mitigation strategies for this risk include knowledge distribution, stressing documentation throughout a project’s lifecycle, and validating the usefulness of documentation by requiring its use prior to a student-worker’s departure.

4.2 Unscheduled Turnover

Unscheduled turnover is a risk factor present in all types of organizations. In corporate work environments, medical, personal and other factors may necessitate a worker’s immediate departure from the workplace. Mitigation techniques for this class of risk include duplication (or responsibility distribution) of key roles, wide knowledge distribution and stressing documentation and documentation validation.

4.3 Miss-commitment

Student miss-commitment can be more problematic than turnover. With turnover, the project leader has knowledge of the current status of the team member. With miss-commitment, the individual is still present and ostensibly working on their assigned tasks; however, due to conflicting demands for limited time resources (and the academic-trumping of most project duties) the student worker may not have time to make the requisite level of project progress. This is compounded by the cramming-centric work styles learned

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**Figure 1. SQUIRM Model Success Tree**
by many students, which lead to the belief that everything can be ‘made up’ at the last moment. With student miss-commitment, project leaders may not become aware of the issue until investigating the cause of a key deadline being missed. Mitigation techniques for this class of risks include defining tasks to have demonstrable milestones, creating an environment where challenges are reported instead of obfuscated, and involving multiple individuals in key tasks.

4.4 Inexperience

Inexperience is, of course, a problem that is faced by numerous projects in every sphere. A team member may be new to the workforce, or may lack experience in the specific areas required by a project. However, inexperience is a particular issue in student-centric projects as many students lack practical experience. This translates into misestimating and a lack of experience in problem resolution techniques. This class of risks can be mitigated by training students in the desired behaviors (e.g., how to estimate in a given sphere, how to deal with problems, etc.). This mitigation not only benefits the project, but also prepares the students for workplace entry.

5 ANALYZING STUDENT PROJECT RISK

Risk analysis for a project incorporating student workers is a four-step process. As depicted in figure 1, conventional risk elements are identified and the impact of student involvement on these risks is identified (as discussed in section 3). Student-project-specific risks are also identified (as discussed in section 4). Once all of the risks are identified and, if possible, quantified, the impact of risk mitigation efforts (discussed in section 7) should be factored in. While the above is quite simple, conceptually, it is more difficult as a practical matter, as those performing analysis may fail to identify some risks and/or risks may be miss-quantified or there may be insufficient information to quantify the risks at all. Further complicating efforts is the potential that a student may be performing risk analysis for the project. This introduces the potential for additional issues, due to potential inexperience.

6 A RISK MODEL

By combining probabilistic assessment of risks inherent to project design and SQUIRM-based assessment of the risks associated with the utilization of student workers and leaders in a project, we are able to arrive at a combined risk identification document. This document can be utilized to plan mitigation strategies and assess the suitability for student involvement (or the need for additional oversight) in areas where high levels of project risk would be compounded by student involvement risks.

SQUIRM is necessarily presented as a qualitative risk model, because insufficient data exists at present to accurately model the impact of involving student workers in a research project. For most projects, implementing basic risk-aware management techniques will maximize the cost-benefit equation: detailed task-level modeling would cost significantly more to implement than the benefit that it produces. However, if sufficient data is collected for a given area of focus, worker classification (e.g., traditional age undergraduates), and task set, the model could be applied quantitatively.

7 MANAGING STUDENT-INDUCED RISK

Managing risks for projects involving students has two key components. First, standard risk mitigation and management approaches should be utilized. This includes creating systems that will avoid and detect risk occurrence. Similarly, mitigation and response plans should be created for all risks identified and assigned a medium or higher severity level. When designing and applying these risk management techniques, student involvement should be considered. This takes two forms: the impact of student involvement on the success or failure of the risk management approach should be considered (e.g., does a particular technique require a level of experience in order to detect or respond to risks that a typical student participant might not have) and the opportunity for student learning from the risk management activities should be considered (e.g., can a given risk factor be mitigated or safely accepted so that managing this risk can be left entirely to the student leaders?).

Second, risk mitigation and management techniques for the specific student-centric risks should be employed. This may include offering training regarding workplace conduct expectations, workplace safety and technical aspects of the project. Validating assumptions about student experience is critical, as students may fail to realize or be unwilling to vocalize a knowledge, skill or experience gap. This category of risk management/mitigation activities is also where the transitory nature of student-project participants should be dealt with. Management techniques for this type of risk include assigning deputies to any key position (to take over for a student that graduates or leaves, etc.) and ensuring that project knowledge is documented in a known and accessible location.

8 DISCUSSION OF RISKS AND MODEL

Any project carries with it the possibility of failure. If a project doesn’t carry this risk, then its success is likely not a significant accomplishment. Student involvement in a project increases the likelihood and impact of standard-category risks and introduces additional risk elements. While giving it the “good college try” may be sufficient for students to earn good grades, this is generally not an acceptable outcome to faculty members or sponsors. A project suffering from factors related to student involvement can reduce or eliminate it; however, this reduces the value of participation for the students and constrains research productivity.

9 CONCLUSION

Student involvement in research activities is becoming an ever-more-integral part of the U.S. collegiate experience due, in part, to the Boyer Commission report [9]. This involvement may peak student interest in pursuing advanced degrees and/or serves to prepare students to analytically solve problems that they will be presented with upon entering the workforce. In order to be tenable, however, student research participation must benefit the student participant, the faculty mentor, and
others involved with the research. Projects that are not completed fail to maximize the benefit for the student and may actually be a detriment to the research goals of the faculty member and others. Proper management, which considers both standard and student-involvement-specific risk factors, of student research projects will not guarantee success. It does, however, increase the probability thereof.

REFERENCES


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