SimInt: A Structured Experience to Develop Mature Engineering Mindset

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***Abstract*—This Innovative Practice Work in Progress presents using the concept of a simulated internship to transition students to problems (and environments) which resemble those found in industry or research. New engineering graduates struggle not just with the lack of technical skills specific to a company but have issues in generalizing their existing skill set. They also lack procedural knowledge that is contextual to industry (e.g., dealing with stakeholders, communicating solutions). This requires an educational setting that is more conducive to practical problems than a typical course – students already acquire the needed technical skills but instead need to practice applying and integrating them. This can be supported with the creation of a simulated internship (SimInt) environment that aims to enable development and assessment of outcomes that more accurately capture solving real world problems than current technical skill outcomes. Although students who can complete an internship are already able to mature their skills, some students, for many reasons, are unable to pursue such opportunities. This can be addressed with SimInt. We propose a course to mimic the environment of an internship: students would be assigned a large-scale problem that is open-ended and ill-defined and solve the problem in the context of a simulated company. The focus of this experience would be on maturing problem-solving skills rather than practicing specific technical skills. This would involve integrating aspects of process (e.g., applying with a resume, interviewing, etc.), the environment of working with different stakeholders, and the development of solutions. In this work, we contribute a model for a real-world work environment that captures aspects not found in a typical classroom environment. We describe the differences between typical content-based course (e.g., lecture, flipped) and the new model. The model is described in terms of system elements and interactions between them that are conducive to student learning. SimInt is intended to offer an experience similar to a capstone while supporting scalability and being more appropriate as a formative experience.**

***Index Terms*—engineering education, software engineering, industry preparation, problem-solving**

I. Introduction

Real-world engineering problems are open-ended, and ill-defined. An open-ended problem has no ideal solution, or form of that solution; in an ill-defined problem, the basic requirements, or the actions that can be taken, may be underspecified. Unlike many course experiences, these problems existing in a broader context [1], [2]. Engineering programs aim to educate students to succeed in engineering careers. However, prior to a capstone, most courses offer a curated experience that does not expose students to the practicalities of real-world problems. For instance: assessments may focus on a single topic, or be self-contained. When students transition to industry or research positions, they may struggle to transfer their knowledge, or adapt to environment norms.

Teaching real-world problem-solving requires an environment that is more conducive to practical problems than a typical course – students already acquire the needed technical skills and instead need to practice applying and integrating them [3]. As a solution, we propose the creation of a simulated internship environment that aims to enable development and assessment of a specific set of outcomes that more accurately captures solving real world problems than current technical skill or high-level program level outcomes [4]–[6]. Although students who can complete an internship are already able to mature their skills, some students, for many reasons, are unable to pursue such opportunities, which we can address with this work. Our previous work involved the development of the Analysis-Design-Justification (ADJ) methodology [7] for developing real-world problem-solving skills within technical skill courses. With the SimInt work in progress, we suggest the next step in instructing problem-solving ability.

We propose for a course to mimic the environment of an internship: students would be assigned a large-scale problem that is open-ended and ill-defined and work to solve the problem in the context of a simulated company. The focus would be on maturing problem-solving skills rather than practicing specific technical skills. To enable a simulated internship, students would be placed into a simulated "internship" environment. This would involve integrating both aspects of general process (e.g., applying with a resume, interviewing), and the environment and/or norms of working with different stakeholders. The SimInt experience is intended to be enacted after students have been introduced to solving open-ended and ill-defined problems with a problem-solving framework like ADJ or similar, and before summative experiences like a project-based capstone. It would be positioned as a required junior level course serving as a prerequisite to a capstone. Although SimInt is proposed in this work as it would be used in software engineering, it is applicable to any domain by constructing an appropriate model for that industry and its norms.

The goals of our work are twofold: first, to develop techniques to mature student problem solving within technical skill courses, and second, to investigate the potential to increase student success in real-world projects by a simulated internship environment. The long term outcome of this work is an internship simulation framework that can be used by educators to create custom courses within their respective engineering programs.

II. Background

A. Virtual internships

Related work in the area of virtual internships by [6], [8]–[10] focus on providing an engineering design task in a collaborative environment in freshman year courses where students have no engineering training. These virtual internships engage students in authentic engineering design practice. This kind of approach is important so students begin to learn problem-solving, however, it is also important that the learning evolves as students go through their technical courses in the sophomore and junior year and have a mature approach by the time they experience capstone projects. An example of virtual project approaches is the Runestone project [11], [12]. The Runestone project focuses on providing a substantial real-world problem and supporting collaboration between students at different universities virtually. This approach uses an entire course to provide a realistic team environment where students design and implement a solution to a complex problem, requiring them to independently make decisions, and identify resources.

B. Analysis-Design-Justification (ADJ) Framework

The ADJ framework is an approach to the instruction of real-world problem solving related to problem-based learning (PBL) [7]. PBL is an approach to problem solving based on the use of real-world problems, requiring additional information, and typically solved in a group setting with a facilitator [13]. The ADJ framework includes three elements: process, outcomes, and problems. The first element is a three-step process that helps students to structure problem-solving. The outcomes provide a trajectory for the instruction of real-world problem-solving skills. ADJ problems are open-ended and ill-defined problems, to model real-world problems. ADJ was developed to address issues in applying other PBL related techniques to the setting of a large public university. The ADJ approach supports a curriculum with: established course syllabi, large scale classes, multiple modalities, and student population heterogeneity [7].

Although ADJ offers a method to instruct problem solving, we need an environment that is more conducive to practice, and allows students to experience the organizational context of problem-solving. As a solution, we propose SimInt as an experience that follows the initial development of problem-solving in a course using ADJ, to add a model of a real-world environment.

III. SimInt

We refer to a course which is composed primarily of a simulated internship as a SimInt course. A SimInt course is fundamentally different than a technical skill course: it is about the experiential process of problem solving in a realistic setting, to mature problem-solving skills beyond the extent that is allowed by other courses. The outcomes for this course match the ADJ outcomes. A key observation here is that a SimInt course is experiential, and growth oriented. A student could be expected to be able to take a SimInt course multiple times and each time come away with a more mature skill set. SimInt courses do not instruct specific skills, but rather focus on practice and integration of ideas. A SimInt course is comprised of two aspects: a framework for modeling the environment (and hence experience) of an internship at a company, and, second, an appropriately open-ended and ill-defined problem/project. The framework would include:

- A broad problem that is open-ended and/or ill-defined. This problem may be sliced into components or assignments that can be tracked.
- An open communication structure: information flow is potentially bi-directional among stakeholders.
- Assignments exist in the context of the same goal. This means that content must be related, and that results for one assignment might impact other assignments (forming a feedback loop).
- Students exist in a social context, where multiple people are working on the same problem even if they do not have similar skillsets, and success and failure is dependent upon communication.
- Success is not defined in terms of points or another metric that evaluates individual class deliverables but on the student's performance as a problem solver.

A simulated internship is similar in nature to a capstone but is formative instead of summative since faculty determine the initial problem and facilitate the execution of the course. This contrasts with the potential for inconsistency in a capstone, and the limitations inherent with asking students to apply technical skills to an open-ended or ill-defined problem for the first time (e.g., students do not have the opportunity to learn from mistakes). Functionally, a SimInt course serves as a bridge from technical courses to capstone and/or a real-world work environment. Figure 1 shows how a capstone course compares with a SimInt course when characterized by information flow. The problem statement given in the course would aim to more closely match project specifications as given in a capstone course than assignments from a technical skill course.

The SimInt approach has important advantages over existing capstone approaches: capstone courses represent a final step in the growth of engineering students on the trajectory towards industry employment. A key limitation of the capstone model is that they are summative experiences, rather than formative ones. For some students, they may be the first, and only, time that they work on a large-scale open-ended problem. They do not have the opportunity to learn from any mistakes made during the experience. A second limitation of capstone courses occurs in their consistency and scalability. Although they provide the ability for students to experience a real-world

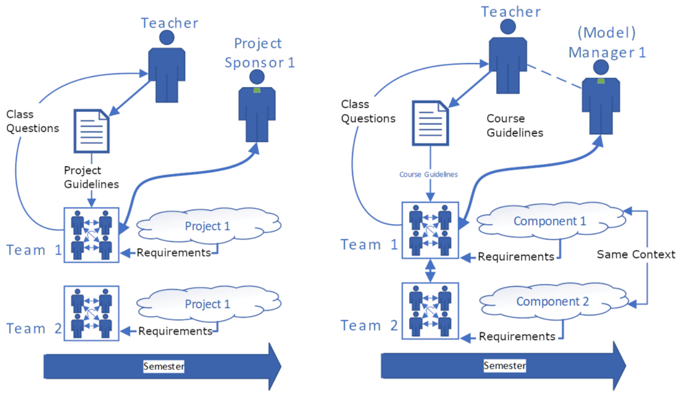

Fig. 1. Left: Information flow in a capstone course. Right: Information flow in a SimInt course.

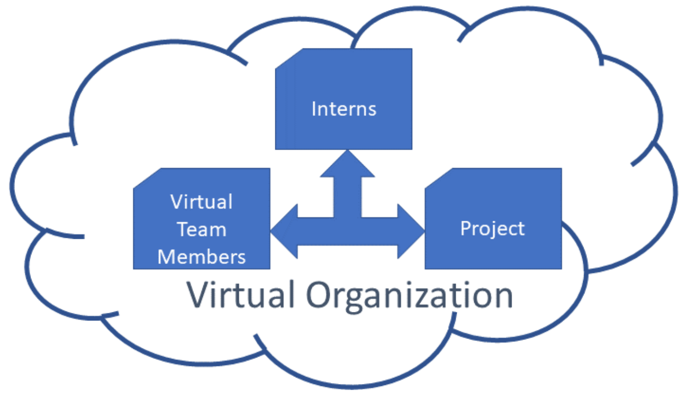

Fig. 2. Abstract model of Students working with Virtual Team Members on a Project, within a Virtual Organization.

environment, students ultimately work on different projects under different mentorship. Students taking the same capstone may have divergent experiences that are difficult to assess. Capstone courses are also difficult to scale. Degree programs may struggle to find adequate support in terms of project mentors. SimInt addresses these concerns by modeling an environment that can be guided and replicated.

A. ADJ Outcomes

As introduced in [7], the five main ADJ outcomes are:

- ADJ-LO1: Defend problem solving as a learning and growth process.
- ADJ-LO2: Construct a sound and evidence-based solution to a problem.
- ADJ-LO3: Create solutions to open-ended problems without a specific correct solution.
- ADJ-LO4: Create solutions to ill-defined problems with problem descriptions which interfere with problem solution.
- ADJ-LO5: Construct solutions based on the contextual needs of a problem, team, or customer.

In formative technical skill courses (such algorithms, operating-systems, software design), ADJ LOs can be used to improve ability to solve real-world problems. In these types of courses, course level outcomes are likely to align with LO2, LO3, and LO4 (e.g., [14]). Although this positions students on a trajectory towards solving real-world problems, technical courses may be constrained due to their academic context and have trouble instructing and assessing LO1 and LO5. SimInt supports this gap by increasing the complexity (e.g., open-endedness, ill-definedness) and scale (e.g., problem size, broader impact) of problems that student tackle, therefore enabling instruction and assessment of LO1 and LO5.

B. Environment Model

In addition to the specification of a real-world problem, SimInt includes aspects to model elements of a real-world work environment not typically seen in a classroom environment. The social aspects of the work environment are modeled using personas, which describe a fictional person who is archetypal within a context. A SimInt model is comprised of: interns, project, virtual team members (VTM), all which exist in the context of a virtual organization (VO). See Figure 2. Virtual elements are those which are simulated (fictional) rather than being interactions with a real environment. Interns: Students within the SimInt course. At a high-level students act (or role-play) as interns that interact with technical and social aspects of an organization's environment. Project: The project that a team within the organization is being developed. The project (e.g., requirements) evolves over time due to direction by VTMs (e.g., a product manager), and the VO. Changes to the project are reflected in changes to student tasks. VTM: Other members of the organization which are involved with the project. Interacts with students to provide guidance or complete component level tasks. VO: Provides the overall context for how work is performed. Changes to the VO may result in changes to the project, or potentially student roles.

In a typical lecture course, only students and a problem are present, with student communicating ad-hoc, and the problem being well-defined and close-ended. These same elements exist in a flipped course, although problems may be complex, and student communication encouraged (it remains ad-hoc). In a capstone course, a industry sponsor may be involved (not represented in the SimInt model), leading the project to be more real-world in nature, and giving organization context. SimInt adds depth by adding VTMs, and promotes understanding of an organization setting through the VO. As indicated in Figure 1, students may be divided into teams based on the VO, and work on sub-components according to the project. A component might be ”developed” by several VTMs.

Adopting SimInt requires the development of VTMs and VO. This involves the creation of personas for various VTMs that students may interact with, and defining the VO context:

- VO Background: context (e.g., branding, mission statement, norms), and job posting.
- VO Hiring Process: Students must submit an packet containing a cover letter, resume and project portfolio (e.g., GitHub repository). Students may also be asked to complete online interview questions.

- VO Onboarding: Once the course starts, student receive an onboarding packet which includes information on project and company policies (e.g., communication, security, development, performance evaluation). Students are provided an organization chart that lists both other students, and the virtual team members (which are defined with personas).
- VO Infrastructure: After or during onboarding, students should be given access to internal infrastructure (e.g., organization wikis, version control systems).
- Virtual Team Members: Teams should include personas for project managers, senior engineers, and so on. For example: a entry level persona might describe someone who is a recent hire (e.g., can only answer some company questions), who knows a specific part of the system in detail, and who is known for being picky when approving pull requests. Personas should emphasize diversity in roles, ability, attitudes, motivation, personality, and communication styles.

IV. Research Plan

The research goal of this work is to investigate the potential to increase student success in real-world projects (either in capstone or industry) by maturing their problem-solving abilities in a simulated internship environment.

The concept of SimInt was used in [14], where students acted as interns at a company specializing in storage. The project was to improve the company's infrastructure that monitored areas and managed security. Students were provided a description of an event where an object was inappropriately removed from storage, necessitating system improvements. Only two VTMs were modeled: a manager who answered questions, and a virtual intern. The virtual intern was not interactive but rather appeared in project artifacts (e.g., an existing software solution). The project was divided into smaller problems, e.g., monitor contents of a secure area, monitor properties of a stored object, and control access to an area. Although the experience developed problem-solving skills, the minimal number of VTMs, and no VO model meant that students did not practice working in a context. This experience took place in an existing technical skill course and motivated the need for a complete course where all VO aspects can be conducted.

A. Phases

Phase 1 Develop SimInt Environment: This is our current stage. Work focuses on producing a model specification of a work environment. The goal is to capture the qualitative essence of a real-world setting with attention to aspects that make it distinct from academic course experiences. A second goal is to ensure that instructional activities within the model support scalability, consistency, and assessment. Using industry input, a set of norms will be elucidated within the parameters of the model framework to create a simplified representation of a real-world work environment. Finally, a specific real-world problem aligned with the simulated environment will be identified for use in a SimInt course.

Phase 2 Evaluate SimInt Environment: At the next stage, the focus will be on the execution of a SimInt course. This involves using the model, model parameters, and problem from Phase 1 to run a class within an undergraduate program. A cohort of students will be recruited to take the course. Students taking standard courses will not experience SimInt and will provide a baseline. A second aspect of this phase will be developing a set of metrics for measuring ability to solve open-ended and ill-defined problems. Students from both cohorts will be evaluated on their problem-solving ability to provide a view on how the SimInt experience impacts students.

B. Evaluation Strategies

Formative Evaluation: The course materials, model, and project being used in SimInt will be presented to our university's industry advisory board to ensure alignment with latest industry norms, needs, and standards to ensure that a trajectory for improving students' problem-solving skills and career-preparedness is being provided through a real-world work environment in academic program. Qualitative feedback obtained at these meetings along with quantitative student data collected in Phase 2 will be analyzed using mixed methods analysis [15], [16], findings incorporated into the project for future iterations, and documented as project results.

Summative Evaluation: During the second stage, we intend to capture the students' ability and self-efficacy to work on real-world problems brought about by a SimInt course. Per this goal, mean difference tests will be used to assess the strength and direction of changes that result from exposure to SimInt. A secondary aspect of importance is students' self-efficacy to work on real-world engineering problems [17]. A self-efficacy scale for engineering career-preparedness such as [18] or similar will be adopted.

V. Conclusion

In this paper, we have discussed our work in progress towards the development of a simulated internship framework. This framework is designed to provide a formative experience for students to acquire real-world problem-solving skills. This contrasts with the summative experience offered by capstone courses. The simulated internship is structured as a course where students work in teams on a large program, but where additional aspects of an industry environment are modeled. Students entering the internship are expected to have skills for solving open-ended and ill-defined problems (which approximate real-world problems), while the internship provides an appropriate means for students to mature problem-solving skills related to learning/growth, and constructing solutions based on contextual needs. The experience also provides an opportunity for students to practice technical skills on a complex problem. For future work, we plan to conduct a virtual internship course and evaluate students' ability and self-efficacy to work on real-world problems to demonstrate the effectiveness of the SimInt experience.

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