

2006-2338: INTEGRATING ENTERPRISE DECISION-MAKING MODULES

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Integrating Enterprise Decision-Making Modules into Industrial Engineering Curricula

Abstract

Organizations today have become process-focused, linking engineering, product development, order fulfillment and service operations across functions and around the globe. This process orientation is supported by enterprise resource planning (ERP) systems that provide an integrated view of cross-functional processes through linked software applications build upon a common database. As both design and production activities are sourced internationally, companies need employees who are able to use integrated ERP data to make decisions. Yet undergraduate students rarely have the opportunity to use commercial systems as part of their curriculum. In this paper, we describe a framework for teaching enterprise decision-making, and examine the value of incorporating a hands-on module using the Oracle E-business Suite in a production planning and control course. We developed task-specific measures of student achievement and self-efficacy to examine learning, and found that use of the ERP-based modules improved students' confidence in their knowledge of ERP-based systems as well as traditional production planning and control topics.

1. Introduction

Today's organizations are structured around integrated business processes (e.g., product development, supply chain and order fulfillment) that require close coordination among employees across functions and around the world. Organizations use Enterprise Resource Planning (ERP) systems, e.g., SAP, Oracle Applications or similar computer systems, to provide an integrated view of their many organizational processes through linked applications built upon a common database¹². The linked applications capture transaction and activity data across functions such as manufacturing and finance, increasing data quantity, availability and quality. The desire to use such data to improve performance is driving significant growth in business intelligence software¹⁹, but success depends on having employees who can analyze software results and implement solutions⁴.

While the curriculum in both engineering and management programs addresses models and tools for functional decision-making, such techniques are rarely presented in an integrated, data-rich environment. Organizations need employees who have the ability to find the right data, understand what it means, and apply it to support functional decision-making⁴. In most programs, students do not have the opportunity to practice these skills. In addition, because the primary focus is on learning methods or techniques, data quality and the global impact of local decisions in an integrated application are ignored. Yet these issues often complicate application of methods in practice.

In this paper, we examine the value of incorporating a hands-on module using the Oracle E-business Suite in a production planning and control course, taken primarily by industrial engineering majors. This study is a prototype for a larger project addressing ERP-based

decision-making, which involves creating learning modules for a variety of undergraduate engineering and management courses. Each module focuses on a decision-making problem that is traditionally part of a functional course (e.g., production planning), and presents it in the context of a major business process, e.g., product development or supply chain and order fulfillment. The process focus allows students to explore the impact of their decision on other parts of the organization as well as its customers, suppliers, and network partners. The modules are based on the same enterprise, providing a common scenario linking concepts and topics across courses. Mistry et al.¹⁴ describe the results of a similar prototype study in a management accounting course. Strong et al.¹⁸ describe the framework and overall project in more detail.

To measure the effectiveness of the ERP-based production planning and control module, we focused on two aspects of student learning. First, while exposure to new technologies and decision-making scenarios is important, there is a concern that it may come at the expense of core concepts. In this project, we therefore wanted to measure students' knowledge of the core course material, and we scored student work to measure the ability to apply core knowledge. Second, we examined student self-efficacy, defined as a personal judgment of one's capability to perform a particular activity¹, a construct that has been positively linked to motivation and academic performance^{3,9}. Because these learning measures are task-specific, the questionnaires and rubrics we developed for their assessment are important research outcomes.

We used a repeated measures (pre-post) experimental design, with experimental and control conditions to compare student learning of core topics taught with and without the Oracle-based module. Comparisons suggest that inclusion of the Oracle-based exercises not only did not detract from functional learning, but also increased self-efficacy about technology.

In the next section, we provide a rationale for our approach by examining the use of commercial software in courses, particularly ERP systems, and their impact. We also examine the basis for using academic performance and self-efficacy as learning measures. We then describe the Oracle-based exercises, examine the questionnaires and rubrics used to evaluate them, and describe the research design. Finally, we present the study results followed by a discussion of the contributions and implications for further research.

2. Literature Review

While effective use of ERP systems requires technology-savvy individuals who understand business processes and recognize opportunities to improve performance, few engineering and management programs have responded to this need. In the late 1990s, universities began participating in academic initiatives permitting them to use enterprise software from leading vendors (such as SAP and Oracle) in various courses. While ERP systems were recognized as a means of curriculum integration in business schools, curriculum changes have primarily addressed the technology rather than the new opportunities for linking functional areas and processes^{6,11,15}. The focus in IE on process¹³ and on identifying opportunities for improvement suggests that IE graduates can play a key role in helping organizations to effectively use ERP data and systems. The IE curriculum should offer opportunities to practice data-based decision-making with an enterprise focus. The framework we propose addresses this need, not just for IE, but more broadly for engineering and management education.

Although the introduction of ERP software to the classroom is relatively new, the arguments for providing such experiences have been debated for other types of commercial software. Because students need to use software effectively when they graduate, using it in an undergraduate curriculum provides practice and familiarity. In addition, using software can allow students to explore more complex relationships and conduct sensitivity analysis¹⁷. Finally, because software can provide a hands-on, active learning experience, it may be more effective in teaching core topics¹⁶. On the other hand, because familiarizing students with software and examining complex relationships often represent additional learning outcomes for a course, some argue that incorporating software can detract from the learning of core topics⁸.

While students generally are positive about the use of commercial software in courses, less attention has been given to measuring the impact on student learning. One contribution of our study is the focus on measuring learning outcomes. We examined student performance on exams as a measure of student ability. Self-efficacy is another construct that has been linked to learning, defined as a personal judgment about one's ability to carry out an activity^{2,3}. Self-efficacy has been positively correlated with greater motivation and interest, as well as better academic performance^{2,3,9}. We also examined student self-efficacy in our study, because willingness to use and understand technology is important for long term success, as employees adapt to technology upgrades and innovations.

3. Enterprise Decision-Making Framework

The framework that we propose for teaching enterprise decision-making is highlighted in Figure 1. The framework centers around enterprise decision-making modules, which are designed for use in traditional functional courses and focus on a decision-making problem that is traditionally part of the course. The decision problem is presented in the context of either the product development process or supply chain and order fulfillment process. These decisions affect and are affected by other decisions that are part of overall business process and general management processes. Such a framework is consistent with the process view of organizations¹⁰ and allows students to explore the impact of their decision on other parts of the organization as well as its customers and suppliers.

Each module is based on the same company, supported by a detailed database describing company operations, to provide a common scenario linking concepts and topics across courses. The decision-making exercises forming the core of each module require students to use a commercial ERP system to find appropriate data, and to explore the benefits and risks of their decision on other functional areas. As examples of modules:

- A product design module, which requires students to investigate product design choices using ERP data on manufacturing capability, bills of material, and customer information regarding performance. The goal is to coordinate with marketing and manufacturing as part of the broader product development process, to reduce costs and generate more successful products.

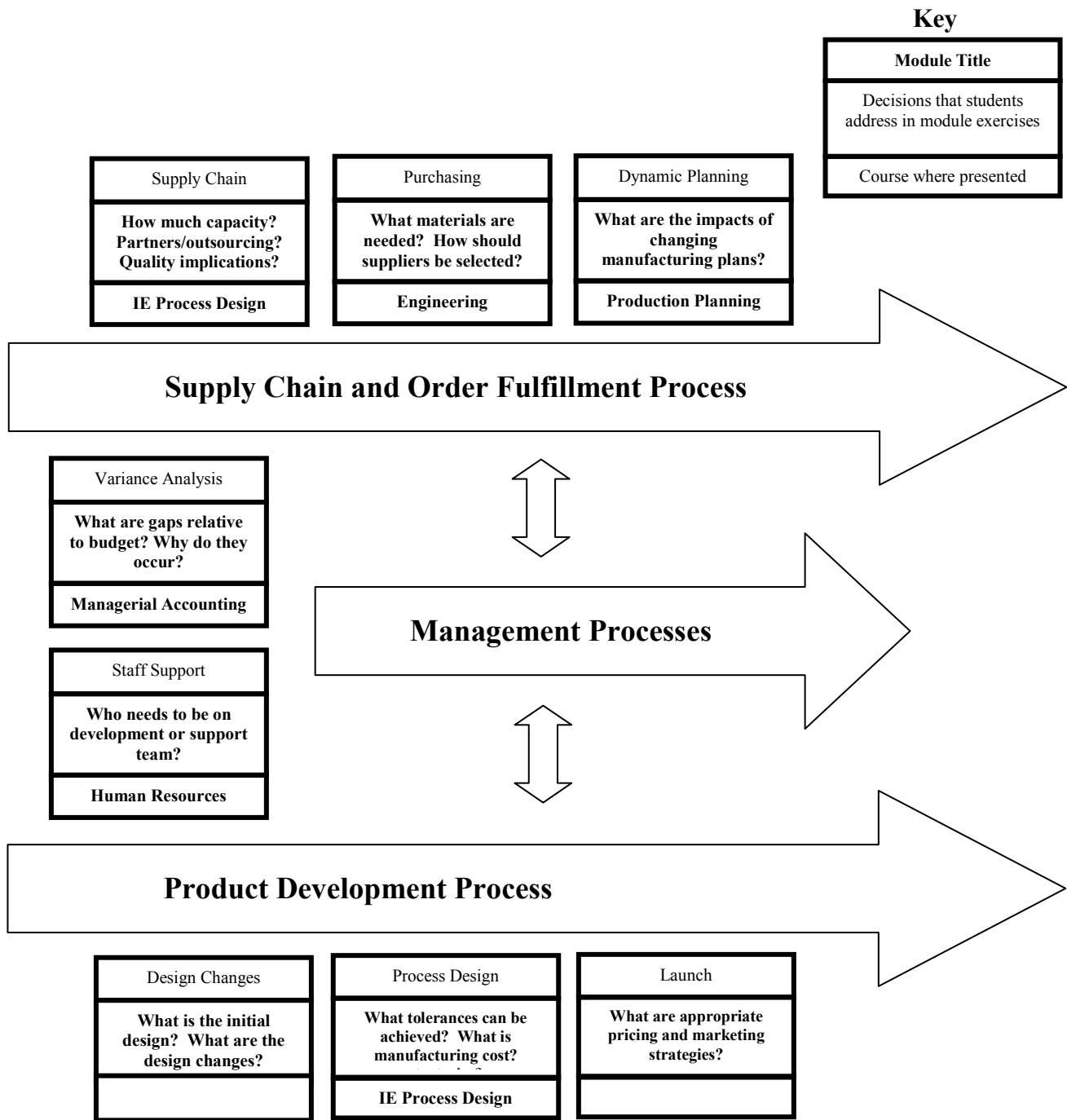


Figure 1: Framework for Enterprise Decision-Making Modules

- A dynamic planning module, which allows students to explore how a manufacturing plan fits into the overall supply chain and order planning process. As time passes, students respond to late part deliveries, marketing promotions affecting demand, and quality problems by using the ERP system to explore the impacts of these changes on their plans and customer deliveries.

The modular approach is adaptable, and mimics how ERP systems are used in practice. Because modules cover independent topics, which can be taken in any order, the overall structure is flexible. A student taking just a single course with such a module will be introduced to the concept of business processes as well as the complex data environments that support daily decision-making in organizations. Students taking several courses with modules will develop a deeper understanding of integration as a day-to-day issue, across many different decisions. Each module is expected to require 2-3 classroom hours, with a 7-10 hour homework assignment.

Prior to working on their first decision-making module, students need some background on the software and the case study company. A foundation module introduces students to the basic navigational features and functional areas in the ERP system, as well as the product development and supply chain and order fulfillment processes of the case study. Each decision-making module then builds on the foundation module. Operationally, students will encounter one or many modules as they move through their academic program, but they only need to complete the foundation module once. The foundation module is designed so trained undergraduate assistants can teach it as a 2-3 hour exercise to other undergraduates. Students in a course who have not yet completed the foundation module schedule time in a computer lab with the undergraduate assistants, and work on it outside of the classroom in addition to other homework.

During the 2002-2003 academic year, we developed and tested two functional decision-making modules as part of a pilot study to investigate the feasibility and effectiveness of our framework. An inventory control and material management module was created and tested in a production planning and control course and a budgeting module was created and tested in a managerial accounting course. These modules are based on the Oracle e-business applications suite (Oracle 11i), an integrated set of software modules that each support a major business function, and use a common underlying Oracle database. The associated foundation module includes basic navigational information about Oracle 11i, as well as a brief overview of a fictional company. Operational data about this company were available in the Oracle Vision database supplied with the Oracle software. Each module focused on a traditional topic taught in the course, and students used Oracle to answer questions and solve basic problems. Undergraduate assistants were trained and led the laboratory sessions where students completed the modules so that we could examine the effort and effectiveness of using such assistants.

4. Production Planning and Control Pilot

In the pilot module developed for the production planning and control course, students used the Oracle software to perform inventory transactions (e.g., moving inventory from one location to another), to create bills of materials, to perform re-order point planning, and to examine an MRP plan. Students worked in groups of two to complete the module, during two 2-hour laboratory sessions that were run by an undergraduate student assistant. The student assistant had taken the course previously, and was familiar with inventory and material planning topics. Because the

assistant was not familiar with Oracle, he completed approximately 15-20 hours of self-guided Oracle training.

In 2003, the Oracle ERP module was used in a production planning and control course taken by 19 students, most of whom were industrial engineering majors. The Oracle ERP module replaced a case study assignment. To examine the impact on student learning, we compared this sample to 20 students who took the same course in 2004, but without the Oracle module. In both courses, the course content and grading criteria were similar, but the courses were taught by different instructors.

4.1 Measuring Self-Efficacy

Because learning depends on context, one challenge in measuring student learning is the need to develop instruments that are specific to the subject area. General self-efficacy measures have little validity, so self-efficacy measures need to be tailored to the domain of interest^{2,5}. In the production planning and control course, desired learning outcomes included the ability to apply core knowledge as well as an understanding of ERP system technology. Because these represent two different task domains, we created two 10-item survey instruments for measuring self-efficacy, one focused on core operations and production planning knowledge and one on technology. Sample questions from each survey are shown in Table 1.

Table 1: Sample Questions from Operations and Technology Self-Efficacy Surveys

		Not at All Confident	Moderately Confident						Totally Confident			
		^	^						^			
Sample Operations Survey Questions												
Q-1	I can generate forecasts and use them in production planning.	Yes No	1	2	3	4	5	6	7	8	9	10
Q-6	I understand the relationship between MRP and ERP systems.	Yes No	1	2	3	4	5	6	7	8	9	10
Q-10	I can provide examples of how production planning and control decisions are linked to accounting/finance.	Yes No	1	2	3	4	5	6	7	8	9	10
Sample Technology Survey Questions												
Q-1	I can navigate around the Oracle Applications system to find what I need.	Yes No	1	2	3	4	5	6	7	8	9	10
Q-5	I can determine the amount and location of inventory using the Oracle Applications system.	Yes No	1	2	3	4	5	6	7	8	9	10
Q-10	I understand how using data about customers, products, manufacturing, and accounting in the Oracle Applications system aids in managerial decision-making.	Yes No	1	2	3	4	5	6	7	8	9	10

A measure consistent with the self-efficacy construct includes questions that measure judgments about personal ability and is task, rather than skill-oriented. For example, in Table 1, the question on forecasting is framed in terms of the student’s ability to generate and use forecasts, rather than a general statement about the difficulty of forecasting. The format and scales for the two surveys are identical to previous self-efficacy measures and are tailored as recommended to the particular task by developing ten questions that capture increasingly difficult tasks within the task domain^{3,7}. Self-efficacy questionnaires capture two dimensions of self-efficacy: magnitude of self-efficacy measured as the number of tasks with a ‘yes’ response and strength of self-efficacy measured as the average of the conviction or confidence ratings for each task ability (with ‘no’ scored as zero)^{3,7}. This paper reports only the measure for strength of self-efficacy. With low strength scores, students are frustrated more easily by obstacles, while higher scores suggest that students will not be deterred by difficult problems³.

4.2 Results and Observations Related to Student Learning

In our evaluation of the impact of the pilot module on student learning, we examined three issues. First, we compared pre-course and post-course self-efficacy scores for students who took the production planning and control course with the ERP-based module in 2003. Second, we compared the post-course self-efficacy of students taking the 2003 course with the ERP-based module to that of student who took the course in 2004 without the ERP-based module. Finally, we compared student work as measured by scores on similar exam questions.

Nineteen students took the production planning and control course in 2003, and 17 students completed both the pre- and post-course self-efficacy surveys. The pre- and post-course results for both the operations and technology surveys are shown in Table 2. The measure of self-efficacy strength for students entering the course indicated moderate ability to apply the core subject matter of the course, as measured by the operations survey, but low ability relative to the technology self-efficacy measure. Paired sample t-tests were performed to determine the significance of the increase in scores. The paired sample t-test for the operations self-efficacy measure was significant ($t=-8.9, p=0.000$), indicating that students’ had increased self-efficacy for production planning and control topics by the end of the term. Similarly, the paired sample t-test for the technology self-efficacy measure was also significant ($t=-9.9, p=0.000$), indicating that they also had improved self-efficacy on Oracle-based technology by the end of the term.

Table 2: Results of the Self-Efficacy Surveys

Course	Self-Efficacy Measure	Pre-Course		Post-Course	
		Mean	Variance	Mean	Variance
2003, with ERP Module, n=17	Operations	4.5	4.1	8.1	2.9
	Technology	1.8	4	6.7	3.1
2004, without ERP module, n=20	Operations	2.4	3.7	6.6	4.9
	Technology	2.1	4.3	2.85	4.9

In the 2004 production planning course, 20 students completed both the pre- and post-course self-efficacy surveys. The ERP module was not used in this course. The pre- and post-course results for the both the operations and technology surveys are shown in Table 2. The measure of self-efficacy strength for students entering the course indicated low ability to apply the core subject matter of the course, as well as ERP technology. As is evident from Table 2, average scores increased from pre- to post-test on the operations measure, but there was limited improvement in the technology score. Paired sample t-tests were performed to determine the significance of the increase in scores. The paired sample t-test for the operations self-efficacy measure was significant ($t=-7.4$, $p=0.000$), indicating that students' had increased self-efficacy for production planning and control topics by the end of the term. The paired sample t-test for the technology self-efficacy measure showed no significant difference ($t=-1.2$, $p=n.s.$) between pre-test and post-test self-efficacy, as expected without the ERP module.

We also compared the gain in self-efficacy, measured as the difference between post-test and pre-test scores, when the production planning and control course was taught with the ERP module (2003) and without the ERP module (2004). The results are shown in Figure 2. The gain in operations self-efficacy was not significantly different between the two courses ($t=-1.15$, $p=n.s.$). The gain in technology self-efficacy was significantly higher for the course with the ERP module included ($t=4.92$, $p=0.000$). Relating to course learning objectives, the results provide some evidence that including the ERP module did not detract from students' evaluation of their core knowledge gain in operations, while improving their confidence in technology.

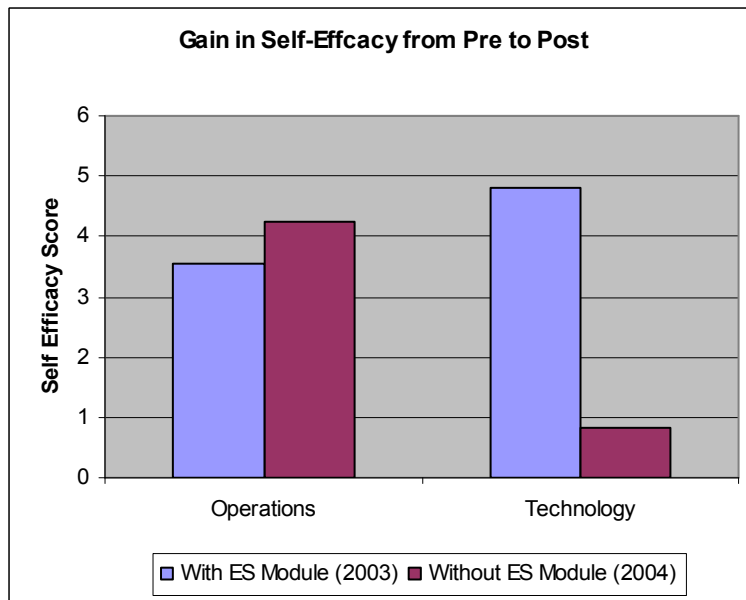


Figure 2: Gain in Self-Efficacy from Pre- to Post-test, with the ERP Module and without the ERP Module

Finally, we compared the average scores students received on two questions given on the second exam during the term. The first question covered manufacturing resource planning (MRP), a topic that was included in the Oracle module in 2003 as well as covered in lecture and traditional homework problems. In 2004, the MRP explosion and dynamic planning were only covered through lecture and traditional homework. The question used on the exam in both years was the same, and the same rubric was used to grade them. As shown in Figure 3, students did significantly better on the MRP question when the course was taught with the ERP module ($t=2.41$, $p=0.02$). We also examined results for a scheduling question, a topic that was not included in the ERP module and thus taught in the same format in both 2003 and 2004. The difference in scores was not significant ($t=-0.89$, $p=n.s.$) for the scheduling question. The results again suggest that inclusion of the ERP module did not hinder learning of core topics, and in fact, may support increased learning by engaging students more actively.

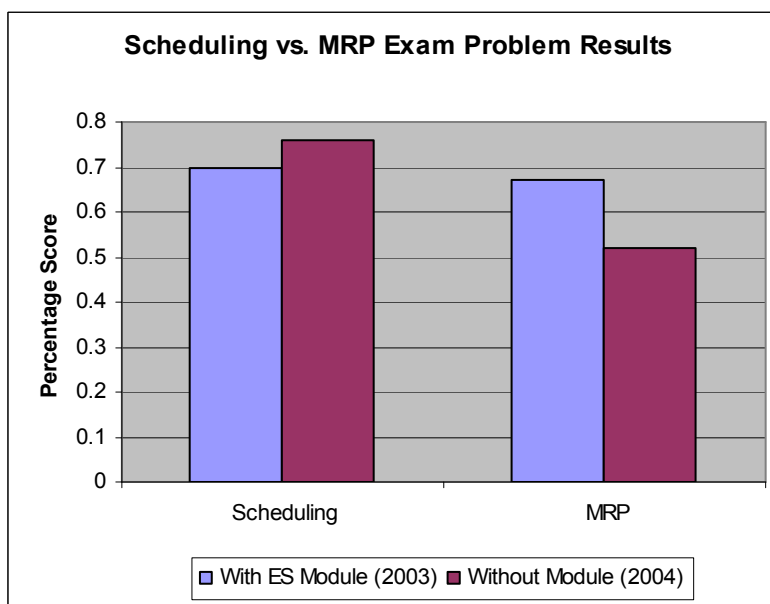


Figure 3: Comparison of Test Scores for an MRP and for a Scheduling Problem, with the ERP Module and without the ERP Module

5. Conclusions

In this paper, we described a general framework for teaching enterprise decision-making in management and engineering curricula, as well as the impact of a pilot module used in a production planning and control course. The purpose of our pilot study was to evaluate the feasibility and effectiveness of the general framework by examining the effort required to deliver the module and the impact on student learning. There is significant effort involved in developing the enterprise decision-making modules, but our pilot showed that the modules could be delivered to students efficiently. Student and faculty evaluations for the undergraduate student assistant, who ran the sessions where students completed the pilot module after self-directed training, were positive. The pilot module exercises were completed by students outside of class time, and replaced a short case-study assignment.

Our preliminary assessment on the impact on student learning is also positive. Students' self-efficacy with regard to technology increased significantly when the ERP module was included in the course, relative to a course section where it was not included. In addition, students' perceptions of their own abilities increased significantly post-course compared to pre-course, in terms of both the application of core topics and the ability to use ERP technology. In comparing student knowledge as measured by exam questions, we found students did better on an exam question related to material covered in the ERP module, while the difference was not significant for a scheduling question not related to the module. While the sample size is small, and other environmental variables cannot be eliminated, the results suggest that the ERP module might improve learning of core material, by actively engaging students in the material. Including the ERP module did not detract from students' ability to apply the core planning and control topics that are traditionally part of the course.

In our future work, we will continue to evaluate the impact of the pilot production planning and control module, considering the relationship of self-efficacy to academic performance. In addition, the next step in testing our framework involves developing an enterprise focus in the modules, creating appropriate learning outcomes related to integrated decision-making, and then measuring the effectiveness of the modules in achieving these outcomes.

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