

STUDENT LEARNING THROUGH HANDS-ON INDUSTRY PROJECTS

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ABSTRACT

Learning is most effective when accompanied by doing. If someone desires to become a baseball player, being told how to play the game, watching others play and even understanding the rules of the game are mostly ineffective if the individual never “swings the bat”. This paper outlines the implementation of this method (swinging the bat) in Computer Science courses being taught at Indiana University Purdue University Indianapolis (IUPUI). Previously lecture-based courses were vastly improved by introducing real-world industry projects that allowed students to fully engage in the learning process. Partnering students with non-profit, educational and civic entities requiring professional deliverables mimics real-world business scenarios that require real-world professionalism. Typical industry projects encompass a wide array of skill sets, everything from time management and team collaboration to oral and presentation skills as well as the technology and processes required. While the success of these project-based courses has been overwhelming, this type of teaching pedagogy is not void of pitfalls and challenges. While outlining the process implemented in structuring these Computer Science courses to be project-based, this paper also addresses the challenges to be considered when choosing to adopt this teaching methodology.

KEYWORDS

Collaboration, Project-based, Industry-based, Engagement

1. INTRODUCTION

Learning by doing is proven to be an effective teaching methodology. Experiential Learning Theory (ELT) provides a holistic model of the learning process and a multilinear model of adult development, both of which are consistent with what we know about how people learn, grow, and develop. The theory is called “Experiential Learning” to emphasize the central role that experience plays in the learning process, an emphasis that distinguishes ELT from other learning theories. The term “experiential” is used therefore to differentiate ELT both from cognitive learning theories, which tend to emphasize cognition over affect, and behavioral learning theories that deny any role for subjective experience in the learning process.

Another reason the theory is called “experiential” is its intellectual origins in the experiential works of Dewey, Lewin, and Piaget. Taken together, Dewey’s philosophical pragmatism, Lewin’s social psychology, and Piaget’s cognitive-developmental genetic epistemology form a unique perspective on learning and development.¹

IUPUI has been aggressively promoting ELT and other proven alternative teaching pedagogies. To this end, IUPUI adopted an innovative educational model called RISE2. Research (undergraduate), International Study Abroad, Service and Experiential learning are the components of this educational initiative.

Experiential learning could also be considered Problem-Based Learning. Problem-Based Learning (PBL) is an instructional approach that makes the student the focus of the learning process, seeking to empower them such that they take responsibility themselves for their own learning. This differs from the traditional approach where the lecturer or instructor, acting as a transmitter of knowledge, drives the learning process. PBL is grounded in the philosophy of John Dewey, who believed that learning is based on discovery and that it is guided by mentoring rather than the transmission of knowledge. In this way the curiosity of the learner is aroused, resulting in them questioning, critically thinking about problems, and, hopefully, creatively solving problems³.

Two Computer Science courses; CSCI-N342 (Server Side Programming) and CSCI-N431 (E-Commerce with ASP.net) were transitioned from a lecture-based teaching methodology to a project-based interactive teaching and learning methodology. By immersing these students in real-world scenarios driven by real clients and real projects, a direct correlation is made between the content of the course and its application to industry.

2. PROJECT OVERVIEW

The project started by completely redesigning an approach that not only teaches all the topics of the courses to ensure that the learning objectives and outcomes are achieved, but also incorporates a project-based learning environment using real-world projects.

2.1 During the Design Stage, Intervention Included

1. Finding projects from non-profit organizations, IUPUI entities and local communities - This involved sending out flyers, going to networking events, attending community meetings, talking to friends and colleagues, etc. A screening process was conducted upon receiving emails of interest. After candidates were identified, meetings were scheduled with each entity to ensure that their projects were appropriate. A point worth mentioning here is that although some of the project requests were not a right fit for this class, other resources were suggested to help the clients achieve their goals, e.g. finding individual students who could meet their needs, establishing internships, or pointing them to the IUPUI Solution Center⁴. Many of the non-profit organizations involved did not realize that these resources existed. Even if they had budgets to pay for an internship, not all of them realized that they could contact IUPUI departments directly for student resources. Reaching out to them gave them a channel to connect to students and other resources which helped them achieve success with their particular needs.

2. Meeting with clients to finalize the projects - After the initial meeting, the clients were asked to provide additional documentation and detailed information such as paper forms used, existing databases (if they have any), future improvements, etc. A thorough understanding of the projects was crucial for the students' success because a project assignment that is inappropriate to the learning objective would highly affect the learning effectiveness. Clients were given ample time to collect this additional information. Clients with complex projects required multiple meetings before their project could be finalized. During the meetings, other than talking about the project itself, the following items were emphasized:

A. The risk of developing applications as a course project - Most students in the class do not have working experience. Even if the goal is to get the application into production, it cannot be guaranteed that all the projects will be up to the professional level. It is possible that future refinement will be needed such as bug removal or security enhancement. Additionally, a student may drop the class. In this case, adjustments within the class will be implemented to continue with the project, but there could be unforeseeable elements that will prevent the project from being completed by the end of the semester.

B. Do not give students access to their production server - If a project is to develop an improved version of the existing application, it will be convenient for the students to have access to the client's production server to get a thorough view of the current version. However, it is highly recommended that the client not do so because students may accidentally make some mistakes due to lack of experience. Suggestions of safe alternatives are offered to address this issue.

C. The client should consider the future project maintenance in advance - Some clients may not realize that a web/database application will need constant maintenance after it goes into production, e.g. renting or purchasing hosting spaces, software updates, bug removal or changes to the application. Clients are informed that students are not responsible for any future maintenance of the projects and they should have a plan on future maintenance issues before they start the development so that it will not be a surprise for them.

D. Class enrollment - The planning stage happens before the semester starts and how many projects the class can take depends on the size of the class which generally will not stabilize until one week into the semester. Thus a client needs to know that even if a project is chosen as a good candidate, there is still a possibility that it cannot be done in that semester.

3. Designing materials to be used during the implementation stage - New materials need to be developed such as evaluation forms, grading rubrics, slides, new syllabus, and background survey forms.

4. Finding a teaching assistant - Because the students are doing real projects, they may encounter problems that normally do not occur in a standard classroom setting. This requires the teaching assistant having not only strong technical background, but also leadership skills, project management skills and high problem solving abilities.

2.2 After the Course Started, Intervention Included

1. Helping form student teams - A background survey was conducted at the beginning of the semester to assess the students' skill level on the three most important areas integral to a successful completion of the class – web design, database and programming. Student teams were formed based on the principle that each team should have at least one member who possesses strong skills in each of the three areas. Students who chose to work in a team setting could pick their own team members. A student could also choose to work on a project on his/her own if he/she was strong in all three fields. Facilitating the team forming process made sure that each team had a well-balanced skill set. Another important step at this stage is to pick an initial team leader who is willing to serve and who exhibits good communication and leadership skills. The team leader's role is to 1) Act as a point of contact between the team and the client to handle communication with the client; 2) Facilitate group meetings; 3) Balance work load among team members; 4) Submit team project assignments. Team members could take turns to serve as the team leader so that more students would have a chance to practice their project management skills.

2. Helping with project assignments for different teams - Project descriptions were posted about one month after the semester started. At that stage, the students had learned most of the core concepts and had several lab assignments to practice on the important topics that they needed to know before they started the project. Instructor intervention at this stage was critical to ensure that each team was assigned a project that was the best fit. In the class, it was explained in great detail what each project was about, the goal of each project, who the client was, what skills were needed to do the project, how complex a project was and the potential challenges that they might encounter at a later stage. Students would pick a project that they were interested in and that fit into the team's skill level.

3. Organizing initial student/client meetings - As soon as the projects were assigned, a first meeting was scheduled to introduce the students and clients to each other. Since each project needs to have its own individual meeting and the client/students all had different schedules, this task required full engagement to find meeting locations and appropriate meeting times. Other than meet-and-greet in the first meeting, the client would talk in detail about the project expectations and requirements. Clients were notified in advance as to what they were expected to do in the first meeting so that the students could start the project immediately after the meeting.

4. Supervising the projects' progress - The students had about three months to finish their projects, and the development process was divided into a cycle of four stages - design, implementation, testing and delivery. Ensuring that they carry on their projects smoothly and complete their goals at each stage required close supervision for each project. A project presentation assignment was required at the end of each stage, and a carefully designed grading rubric was developed for each stage. Feedback was provided on the spot and the students were graded cumulatively, i.e. any weaknesses from the previous stage must be fixed at the next stage. No matter how hard students were willing to try, lack of industry experience prevented them from realizing some critical issues, thus real case scenarios were constantly brought in to help them understand how problems are solved in an actual working environment. The Computer Science (CS) department

provided hosting server space for the class, thus the students' applications were live on the internet at all times. This enabled test runs of the applications at any time which provided just-in-time feedback.

5. *Coordinating between clients and students* – Ideally, after the initial meeting when students and clients are introduced, the instructor should not have to serve as a go-between. However, there were multiple times when intervention was required, e.g. when a client did not reply to students emails after several days or vice versa. In general, students could come to the instructor for any questions they had when working with their client. This gave them a sense of comfort knowing that their instructor was there to help them with any issues they might encounter so they would not be intimidated by working on a real project without any real working experience.

6. *Handling Complications* - Some additional features can be implemented if the students are willing to do some self-studying. When this happened, student learning resources were pointed out such as lynda.com⁵, websites, tutorials, books etc. Students were also offered tutoring outside of the classroom. Some students were very excited and proud to present the work that they produced after walking the extra mile.

7. *Collecting Feedback* - Constant and prompt feedback is important in the student learning process. Several survey forms were developed to get feedback from multiple dimensions, including students to their peers, students to the instructor, students to the client, client to the students, client to the instructor. Some feedback was to be collected and dispersed immediately, and some were to be summarized at the end of semester for future improvements.

2.3 Technologies Used

Due to the nature of the real-world projects and team-based learning environment, students used various technologies such as IU Box⁵ for file sharing, video conferencing tools such as Skype for group meetings, project management software, videos on lynda.com⁶, and GitHub⁷ for source code management, etc. Numerous advanced technologies that are not part of the teaching objectives of the course were suggested by the clients and used by the students as well, such as mobile friendly platforms, data searching and sorting technologies, etc.

2.4 Pedagogies Adopted

Two typical pedagogies adopted in this class are project-based learning and peer-lead learning methods. Project-based learning enables the students to immediately apply the concepts learned in the classroom, and what's more, the learning process does not stop in the classroom. To finish a task, students often do research on their own using the library, internet resources, or any other means to find possible or best solutions. This not only increased their knowledge but also their critical thinking and problem solving abilities. Students also learned from their peers using collaborative group techniques, also known as conceptual learning.

Conceptual learning is the primary goal behind the use of collaborative group techniques. Research in the field of education shows that collaborative group work can facilitate learning. The instructor plays a key role in this process, by preparing students for quality interactions, structuring tasks to involve all group members, forming groups to maximize high-level discourse among group members, prompting groups to engage in quality interactions during group work, and structuring debriefing sessions to link group work to learning objectives. Importantly, each of the aforementioned variables affects learning to the extent that it promotes or hinders high-level verbal interaction during group work as well as during the subsequent debriefing with the instructor⁸.

Since each project was different, students learned a wide variety of techniques from others. It happened often that when a student or group implemented a neat feature, other students showed great interest in learning how this was done and asked for resources to learn about it. In a team setting, students helped each other and advanced together. If the team leader was technically strong, the leader would play a great role in help other members. Each project would require skills in three areas (web, database and programming); a student strong in one area would help other students to improve in this area. It is the goal of the class that students will be well versed in all three areas at the end of the semester, even if they were not at the

beginning. Many concepts obtained by the students in these courses were a result of “Active learning”, a well-documented method of preparing students to become lifelong learners.

Active learning in the college classroom has long been promoted as more effective than traditional lecture. Many studies measuring the impact of active learning determine that active learning strategies lead to better student attitudes, thinking abilities, and writing skills. Increased adoption of these instructional practices is recommended in several prominent national reports [NRC2011, 2012; PCAST 2012]. The National Science Foundation recently announced a program to encourage institutions to expand the use of evidence-based instructional practices with an emphasis on active learning [NSF 2013]. Practices are demonstrated effective through empirical studies. A variety of measures are used to demonstrate effectiveness including: student performance, successful completion of a course, retention in the major, and self-efficacy within the discipline⁹.

2.5 Principal Strengths

1) The opportunity for students to dive into a real software development environment that can help them develop skills in team working, project management, time management, presentations and business communications. These skills are vital in the real world but missing in a lecture-based classroom setting. Possessing these skills greatly helps them get their feet in the door of industry and benefits them in their future career advancement.

2) The pressure of the clients’ expectations of putting the projects into production, which transpired into students’ high motivation. Lots of students wanted to create something that could be put into their professional portfolio and something that they could talk about with pride. Generally speaking, the students did not have to be pushed to come up with their best work.

3) Impact to the community is one of the criteria in selecting projects for the class. Many of the projects completed will have a substantial positive impact to the community and in the long run, the impact could be invaluable and monumental. Some examples include:

- A healthy food guide (www.indylocalfood.org) that enables the general public to search for farmers markets, organic farms or other local food markets.
- An application for Drug Free Marion County (www.druggreemc.org) to allow general public and the administrators from the organization to search for license violations from local restaurants.
- An application for the Peers Project (www.peerproject.org) increases the productivity of the organization in tracking the teens involved in their education programs, which so far have reached 1 million students in Indiana.
- An application for the Health Industry Forum (www.ihif.org) to archive and access organizations or companies in the health industry and allow the members of the forum to search member information.

Some graphical examples of student projects are shown in figure 1.



Figure 1. Examples of student projects

4) Visibility of the CS department. The direct connection between the CS department and the outside organizations help spread the word to the community. At the end of each semester, a final presentation and reception session was held in the department. All current clients, colleagues, future clients, and industry partners were invited. This gave the students a chance to show case their projects. Students’ good work speaks for itself and requests keep coming in for future projects. This class has become a window that advertises the CS department as well as IUPUI.

2.6 Challenges Encountered

The biggest challenge lies in the unforeseeable circumstances that require immediate intervention and plan adjustment from the instructor. E.g. one student was not able to keep up with the pace of the team, so the student was pulled out of the team and given individual assignments to compensate for the course requirements; one student dropped the class due to health issues, so the other students on the team had to take on the additional work.

One surprise finding was that in some groups, the students were more motivated than the clients. There were times the clients were slow in responding to students, or the client couldn't come to the student presentations to check out their progress.

Another challenge encountered was that a project didn't seem to be difficult at the beginning, yet turned out to have a high level of complexity after the client devoted more thought to it and requested additional features later. How to achieve more for the client without causing too much stress to the students involves understanding and collaboration on both ends. An encouraging finding is that the clients were usually understanding and accommodating and the students were willing to do their best to accomplish as much as possible.

2.7 Student Learning Effectiveness

The learning effectiveness was greatly enhanced when the students saw the linkages between the concepts learned in the classroom and the application of them into a real project. As each project had its own requirements, students had to digest their clients' requests and determine what technique to use and how to use it. Sometimes students had to dig deeper into a topic that couldn't be expanded in the classroom due to time limit. This timely application of the concepts learned highly stimulated their interest of learning. Knowing that their project would be used for production upon successful delivery, students were motivated to achieve the highest standard.

A complete software development cycle is achieved during the semester, from the project design, project implementation until project delivery. Throughout the semester, students need to collect requirements, design an implementation plan, and consider possible risks and obstacles, handle unforeseeable situations, manage collaborations among team members, and finally work with clients' technical personnel to deliver their projects. In the past students mainly focused on the implementation stage in an imaginary project scenario. Now they had to go through the entire cycle thus the project management skills were naturally developed in this class.

Starting from the first meeting with the clients, students had to communicate with their clients through face-to-face meetings, email communications, sometimes conference calls or text messaging services. They were expected to deliver messages via a professional manner and they were evaluated by the clients on the timeliness, respectfulness and professionalism. Sometimes they had to discuss with their clients when or if they could finish a particular task because their client may want a feature that could not be achieved in this class due to time limitations or topics covered. Several students mentioned that they had never had to talk with a real client before and this class helped them realize the importance of business communications.

When students implement an imaginary project, they were their own client. There was no listening, digesting, and interpretation skills involved. Lack of real world experience prevented them from knowing the expectations of real users or how to best deliver information to the users. Clients know what they want, and some of the projects in the semester were the improved version of their existing database, thus they knew the weakness of the existing database and had a lot of specific requirements for the new project. Before the project design stage, students need to completely understand the project requirements, study the feasibility of each and determine on a reasonable scope of their project. The instructor's intervention is very important at this stage as not all the students could see the underlining difficulty behind a seemingly simple feature.

Four or five presentations were scheduled throughout each semester. Students were expected to treat each one as a professional endeavor. Presentation skills such as material preparation, concept delivery, voice level, body language, eye contact, timing etc. was part of the grading criteria.

At the end of the semester, each student group should deliver a project that not only works, but also meets the industry standards and achieves the highest possible professional level. Major concerns such as security

issues, efficiency, usability and mobile friendliness were all stressed in the class and tested by the users and by other students. Any problems found in the testing phase must be fixed before delivery.

Before the project, the learning outcome of the course was mainly on the knowledge and skills used to develop an advanced web/database application. This project tremendously helped students develop skills in the application of knowledge learned, critical thinking and research abilities, as well as team working spirit.

2.8 Evaluation

Assessment of course objectives was measured by several different means. Student surveys, client satisfaction surveys and course evaluations were administered throughout and at the end of each semester both before and after the project-based methodology were adopted.

From the student surveys, responses included:

“This class is one of my favorites. I had great fun working with teammates and testing others projects”.

“Great class. I knew nothing about php and database before taking the class, but I became quite advanced at the end. It was not an easy A but I learned a lot”.

“This class is a blast. I had so much fun making a web database for a real client. It is a lot of work, but the more time I put into it, the more I learned. Highly recommend this class to other students”.

From the client satisfaction surveys, feedback included:

"This has been a great experience and I'm pleased with the results. I have one more project in mind and hope to get a definition to you before the start of next semester”.

“I am eagerly awaiting production use of the web application. I am impressed with the finished app and the team’s work on it. I hope to participate in the service learning program in the future”.

“I really appreciated their attentiveness and effort, and was impressed by their drive to make sure they included all of our “needs” and as many of our “wants” as possible. Overall, very impressed! We are excited to begin using our new database”.

Cumulative client satisfaction surveys from both courses show an average satisfaction level 4.915 (out of 5).

Another indicator of the effectiveness of transitioning these courses from a lecture based format to a student-driven, client-centered project based format is summarized in figure 2. Final grades from both courses (CSCI-N342 & CSCI-N431) are given as evidence to show an overall improvement in student learning. Note: The grading rubrics remained the same both before and after the project-based method was implemented.

	Lecture-Based Course Structure			Project-Based		
	Spring 2011	Spring 2012	Fall 2012	Spring 2013	Fall 2013	Spring 2014
CSCI-N342		86.88	86.1	87.84	90.34	93.12
CSCI-N431	79.96	86.88		91.58		92.1

Figure 2. Final course grades before and after PBL implemented

3. CONCLUSION

These revised courses proved to be extremely successful and effective in instilling real-world, professional attributes into the students who were enrolled in these classes. By giving the students the opportunity to bridge the gap between the traditional learning environment and the professional setting, they clearly attained skill sets to not only bolster their confidence in their field of study, but to prepare them for industry

placement. One limitation to this pedagogy of teaching is the issue of sustainability. If another instructor is charged with teaching these same courses, they might not possess the motivation and drive (and extra effort) necessary to attain the same results. The applications of this type of teaching methodology are endless. From technical skills to advanced, critical thinking occupations, nothing can replace “swinging the bat”.

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