Experience with Multi-Disciplinary Student STEAM Teams

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Abstract

STEAM is an initiative to add Art (A) and Design to the national agenda of STEM (Science, Technology, Engineering and Math) education. STEAM proponents suggest that the divergent, creative features that are associated with the Arts are needed to increase integrative learning and improve creative problem solving in the STEM disciplines. This paper details experience with using multi-disciplinary STEAM student project teams of college students to develop mobile web applications for clients. Two methods were used for creating and running those teams and the positives and problems encountered for each are detailed. While the ideal approach for STEAM education might be project courses in which students from different disciplines enroll and receive course credit in their respective disciplines, this paper has shown that there could be significant administrative hurdles to overcome with that approach. The two approaches described in this paper can be used to help instructors experiment with creating STEAM teams within their existing administrative infrastructure and highlight the problems they are likely to encounter when doing so.

Keywords: STEAM, STEM, multi-Disciplinary, student Teams, authentic Learning.

1. INTRODUCTION

STEAM represents an integration of the Arts (A) into traditional Science Technology Engineering Math (STEM) disciplines. The goal of this type of education is to combine the different approaches to problem solving and risk taking to solve contemporary challenges. It suggests that multidisciplinary working and learning empowers students to work in an increasingly connected world (Norman & Klemmer, 2014).

This paper will describe two methods for using STEAM projects at the college level and details the administrative challenges as well as the positives and problems encountered with each approach.

2. STEAM TEAMS

An Overview of STEAM

Much of the STEAM literature concerns the benefits of STEAM in K-12 grades. In this setting the focus is on the individual learning benefits to the students as a result of integrating the Arts in with traditional STEM topics. Sousa and Pilecki (2013) suggest that some of the benefits associated with the arts include:

engaging young brains, developing cognitive growth, improving long-term memory, promoting creativity, advancing social growth, introducing novelty, and reducing stress. The STEAM movement suggests that these benefits to learning the arts can also be had in STEM classes if the arts are integrated into the curriculum.

The 2009 National Assessment of Education Progress reported that across multiple grades students were able to memorize facts and report data but they were unable to explain them. They could demonstrate rote memorization but not identify or explain the scientific principles involved (Sousa & Pilecki, 2013). One dimension of understanding this problem is Convergent vs. Divergent thinking. Convergent thinking is most often used in analytic situations where the goal is to find the one right answer. Divergent thinking generates new and creative ideas and assumes that there is no one correct answer (Sousa & Thominson, 2011). Sousa and Pilecki (2013) suggest that traditionally the STEM disciplines are strongly associated with convergent thinking because K-12 STEM disciplines are traditionally taught with an emphasis on memorization and finding the correct answer. This can lead to a failure to engage student's interest in these fields with long-term impacts later in life when they decide what areas to pursue in college.

STEAM suggests that the divergent, creative features that are associated with the Arts are desperately needed to engage student interest, improve long-term memory, increase integrative learning (as opposed to rote memorization), and improve creative problem solving in the STEM disciplines.

Steam and Innovation

Use of the STEAM model is not as prevalent in higher education. Some examples of using the STEAM model include the RISD STEM to STEAM program (Rhode Island School of Design, n.d.) and the OpenLab project at the University of California Santa Cruz (Open Lab Network Project, n.d.). These efforts share the STEAM objectives of more integrated learning, different learning paths and engagement while providing students with experience working in a multi-disciplinary environment.

Experience working in multi-disciplinary teams is not typical in college courses but some feel that it is crucial for developing solutions in the modern world. Maeda (2013, p. 34) states that "Science, Technology, Engineering and Math – the STEM subjects – alone will not lead to the kind of breathtaking innovation the 21st century demands. Innovation happens when convergent thinkers, who march straight ahead towards their goal, combine forces with divergent thinkers – those who professionally wander, who are comfortable being uncomfortable, and who look for what is real."

Boy (2013, p. 4) suggest that "Systems need to be investigated and tested as wholes, which requires a cross-disciplinary approach and new conceptual principles and tools…. Science; Technology, Engineering, and Mathematics (STEM) should be integrated together with the Arts to promote creativity together with rationalization…" He describes the Apollo program as a demonstration of dealing with complexity and achieving the goal of getting to the moon. He suggests that it was a "… very successful cross-disciplinary endeavor, one of a kind during the 20th century. It combined creativity and analysis."

In a survey of 1,500 CEOs, an IBM report found that CEOs felt that an increasingly complicated world requires creative leaders who can invite disruptive innovations, consider new ways to radically change their organizations, are comfortable with ambiguity, and who are capable of inventing entirely new business models (Tomasco, 2011).

While STEAM is widely applied in K-12, STEAM goals are also very relevant to preparing college students for a workplace in which they will need to work in project teams to develop creative, innovative solutions to business problems.

Steam Teams For Web Development

While there are clear benefits to creating STEAM teams, and they are very common in the 'real world', there are some very significant challenges to setting them up in a university educational environment without an existing STEAM curriculum. In order for the teams to be truly multi-disciplinary they must actually contain students from multiple disciplines and experience a collaborative project that connects to ideas unique to his or her discipline, and learn to problem solve is new ways.

One real-world development team that is inherently STEAM is a web development team. Unless the development project is very small it will need a project team that (at the very least) will contain one or more programmers and one or more graphic designers. Designing web-based products integrates technology and programming, visual design, functionality and usability (Curtis, 2002).

While two different methods will be described to create STEAM teams, both methods used a Computer Information Systems (CIS) Capstone course in the College of Business as a starting point. This course provided the programmers for the STEAM teams. The designers in the STEAM teams were graphic design majors in the university's School of Art and Design. All of the STEAM teams worked on mobile web development projects for actual clients.

The following sections detail each method and describes the successes and problems encountered with each.

3. *SEPARATE-COURSES* METHOD: CIS AND DESIGN STUDENTS IN SEPARATE CLASSES

Process: CIS Students

CIS students were responsible for the functionality of the mobile web application. Each of the CIS students on the project team had unique, non-overlapping responsibility areas (front-end development, back-end development, quality assurance, etc…). In a weekly progress report meeting each CIS student informally presented to the team the tasks they were assigned, their progress on those tasks and then the team would discuss what they might work on for the next week. The following day the instructor would email each student with their tasks for the coming week.

Process: Design Students

The students enrolled in a required graphic design studio class were assigned to develop the theme and graphic elements for the web mobile application. There was a preliminary meeting with the CIS instructor and the CIS team members to introduce the project and each other. The design students met with the client independently to gain background on the subject and the purpose of the app. With the problem defined, each design student continued research, developed concepts for the opening graphics, explored typefaces, color schemes, how the information would be structured and sequenced throughout the app and designed and drew the graphic elements. Each student then presented his and her visual ideas to the clients and the CIS team for feedback.

The CIS team and the client selected various components from individual student presentations. These were then combined and revised into a single work. The tasks for revising graphics and adding additional graphics as needed were assigned to all students.

Depending on the size of the class, the presentation and feedback process can take the full studio class period. It should be noted that this was not the only project assigned within this design course although several weeks were dedicated to this project.

Supervision and Evaluation

While the programming instructor and project clients gave feedback, the supervision and evaluation of the design students was done entirely by the design instructor and the supervision and evaluation of the CIS students was done entirely by the CIS instructor. The two instructors met a number of times to discuss timing of the project, where the project fit into the design course, deliverable due dates and the timing of the first meeting in which the designers showed their initial designs.

Positive Outcomes

The Designers developed some very nice design ideas. Both the CIS students and instructor agreed that they would never have come up with the quality and creative range of ideas developed by the design students. CIS students visited with the designers independently and demonstrated how the programming would work in making the app. Some design students were so interested they later enrolled in a CIS class to learn more programming that goes beyond what is covered in the design curriculum. The experience for both the CIS and Graphic Design students created awareness and appreciation for the skills each brought to the project.

Problems and Concerns

Because the two courses were entirely separate, neither the CIS students nor the design students were very knowledgeable about design and development processes used in the other discipline and this created problems in translating designs from Illustrator into formats that could easily be implemented in HTML. With this project being only one of several projects assigned in the graphic design class, there was little time to work together with the CIS students directly and to revise the graphics into an acceptable format.

Although the design students had previously taken a course in building websites using HTML and CSS and saving graphics developed in Photoshop and Illustrator for the web they had no experience working with JQuery Mobile, which was a technical component of the project. Ideally, technical specifications should have been made clear prior to launching the project and the technical skills necessary to implement the project built into the design students' experience.

File sharing among the graphic design students presented some problems. It quickly became evident that layers within the Photoshop and Illustrator files had to be organized with clearly labeled layers, and students needed to be diligent in uploading and downloading files from the shared storage space.

Finally, as detailed there was very limited interaction between the design and CIS students over the course of the semester. Certainly each group was able to see the results of the other's work, however, there was not time for one-on-one interaction between the programmers and the designers. One of the goals for the STEAM team approach was to give programmers and designers opportunities to work and interact together, so this approach had only minimal ability to meet that goal.

4. *SAME-COURSE* METHOD: CIS AND DESIGN STUDENTS IN THE SAME CLASS

In this method graphic design students actually enrolled in the CIS Capstone course. There were a number of administrative challenges that had to be overcome before this approach could be attempted.

Initial Challenges: CIS and the College of Business

Since the capstone is for CIS Majors, there were a number of pre-requisites required before a student could sign up for it – only one of which it was likely a design student would have taken. So a formal request had to be made to the Associate Dean explaining the rationale for allowing these students to take the course without the necessary prerequisites. Luckily our administration is very supportive of creative, cross-discipline work and the Associate Dean let the students into the course.

Initial Challenges: Graphic Design and the School of Art and Design

At our university the Graphic Design major has limited free electives, so it was unlikely we could get a student to participate in this project if we relied on that. However they have a number of studio requirements and the Graphic Design faculty proposed to the Director of the School that the students take the CIS capstone course in lieu of a studio course to meet the requirement. Again we were fortunate with to have an administration open to and supportive of exploring STEAM opportunities.

Process: CIS Students

As in the Separate-Courses method the CIS students were assigned to project teams in non-overlapping job roles such as front-end development, back-end development, Quality Assurance, etc…). In the weekly progress report meeting each CIS student informally presented to the team their assigned tasks, their progress on those tasks and then the team discussed what they might work on for the next week. The following day the instructor emailed each student their tasks for the coming week.

Process: Design Students

While the process of the CIS students was essentially the same across the two methods, the process for the Design students was very different. In this approach rather than just seeing the CIS students several times briefly over the course of the semester the design students were in every one of the weekly progress meetings and participated exactly the same way as the CIS students: they presented what they were tasked, the progress they made and what remained to be done to the entire group of all of the web development project teams.

Supervision and Evaluation

In this approach supervision and evaluation was entirely by the CIS instructor – since both the CIS and Graphic Design students were enrolled in the CIS capstone class. The CIS instructor provided the weekly tasks and feedback about those tasks, performance reviews for both the technical and graphic design components of the project over the semester and a final grade for the course.

Positive Outcomes

This approach really maximized the opportunity for the CIS and Design student to see each other in action, ask questions, share insights, and get to know each other. It seemed to do a much better job of meeting the goals of multi-disciplinary teams that were desired. It also gave the instructor and other team members many more opportunities to provide feedback as the design progressed. This was helpful for both the design and CIS students as well as the overall project quality.

Problems and Concerns

While having the design students in the same class as the CIS students greatly facilitated communication among them, this method also encountered some difficulties.

Programming Language Problem

The design students and design faculty did not fully understand the scope of the technical skills required for working on the STEAM projects within the CIS capstone class. The design students thought they would design and develop layouts using software familiar to them such as Adobe Photoshop and Illustrator, however, there was an additional step. These layouts needed to be implemented in HTML. Unfortunately during the semester when this was encountered, two of the three designers had no interest and seemed to lack the technical skills necessary for implementing their design in HTML. After some negotiating, it was decided that those two designers would just create the mockups without implementing them in HTML. This was still valuable for the team but not what had been planned on by the CIS instructor.

Levels of Motivation

This was the capstone course for CIS students and many were graduating seniors, so for the most part they came to the course enthusiastic and looking for new challenges. The design students also were graduating seniors, but this course was not the capstone for their major. This seemed to impact the willingness of some design students to take on new, unstructured areas in which the students were expected to explore and learn a new area with minimal help from the instructor. This was framed in terms of being a more real-world type of problem where your boss asks you to explore a new area of technology to find out if it is something that should be used by the team. This is quite different from most of the prior STEM coursework where the material might be difficult, but the boundaries were clear and the instructor could be counted on to answer any questions if needed.

Although unclear boundaries and exploring new ideas is at the core of the design process, most students (both CIS and Design) found this fairly stressful. However, the CIS students (possibly because they were expecting this for a capstone course) seemed to buy-into the value of this while the design students (at least the ones not interested in programming) seemed much more skeptical. In feedback the CIS students often mentioned the experience felt more 'real-world' while the design students seemed to feel at times that it reflected poor planning on the part of the CIS instructor.

Different Design Processes

Not surprisingly, the processes used by the design students to solve problems was quite different than that used by the CIS students. This turned out to be quite difficult for the CIS instructor to manage at times. Weekly tasks lists, rapidly changing requirements and adapting to this seemed to work well with the programming problems encountered. But this approach didn’t always mesh well with the divergent, idea generating, critiquing and revising process that was familiar to the design students.

5. A COMPARISON OF ADMINISTRATIVE CHALLENGES

Following is a comparison of the two methods in terms of administrative challenges.

Course Credit

For the Separate-Courses method, in which separate classes worked collaboratively on a project, there were no unusual course credit issues – the CIS students signed up for a CIS class and the Design students signed up for a design class. For the Same-Course method, in which all participating students were enrolled in a single CIS capstone class, there were some significant barriers for the design students. This depends on the willingness or ability take a CIS course as an elective, or if there are other courses within their curriculum their department would be willing to substitute. This will conceivably vary greatly between schools and programs.

Scheduling

The Separate-Courses method had the most scheduling problems that needed to be solved. The first and foremost was the different schedule for the two classes. Without a common time and day to bring all of the students together, meeting the goals of the STEAM team was difficult. A longer term answer to this would be to schedule the classes at the same time, but this must be done in advance, early in the previous semester, and sometimes – given other scheduling constraints in each of the disciplines – may be essentially impossible.

If the classes can determine a time that works for meeting, the next challenge would be to determine the frequency and spacing of those meetings over the course of the semester. While more is probably better from a learning perspective, the number of meetings possible may be very limited by pedagogical issues in both courses: is the collaboration just one project during a course composed of many different projects? If so, realistically how much of the semester can be devoted to the STEAM project before needing to move on to other topics which must also be covered.

On the other hand, the Same-Course method has the scheduling problem solved. Design students in our situation, enrolled in the CIS course, they met exactly as frequently and as often as is built into that course. There were no unique scheduling problems at all with this approach.

Student Supervision

In the Separate-Courses method there were no unique supervision issues, the Design students were directed by a Design instructor and the CIS students were directed by a CIS instructor. The Same-Course method however has the potential for difficulty because Design students are supervised by a CIS instructor. As detailed earlier, the disciplines are unique and how the classes are managed and the role of the instructor in supervising the students can be very different. This raises the possibility of misunderstandings and problems arising from differing expectations between the Design students and the CIS instructor, and the differences in learning and problem solving processes.

Evaluation of the Students

Again for the Separate-Courses method there were no unique problems for this issue, each group of students were evaluated by an instructor from their discipline based on criteria unique to that discipline. However that is certainly not true for Same-Course method. Evaluating a student in a manner perceived by that student as fair and accurate is a very fundamental expectation for students. If they perceive that is not being done it is difficult for them to see how things are going to go well. This may include expectations of what the students are expected to do (as detailed earlier), how much they are expected to do, and the metrics used to evaluate quality of their work on so on. Additionally, the students must assume in this situation that the CIS instructor and the CIS student team members have the credibility to provide informed and constructive feedback to the design students. An ideal solution would be to establish a separate required course scheduled at the same time and is team taught by the faculty from the various disciplines representing the students enrolled in the class for the STEAM project.

6. A COMPARISON OF MULTI-DISCIPLINARY STEAM TEAM ISSUES

While the comparison of the two approaches from an administrative perspective seems to favor the Separate-Courses method, that is not at all true from the objective of creating multi-disciplinary STEAM teams. No matter which approach was taken the project teams were STEAM, but the second approach seems to have some clear benefits from a multi-disciplinary team perspective.

Regular Meetings

In the Separate-Courses approach the CIS and design students saw each other only two or three times during the course of the semester. In the second approach they saw each other weekly throughout the semester.

Individual Interactions

In addition to meeting more frequently, the meetings also allowed and encouraged individual interactions among the CIS and Design students. Certainly the CIS students and Design students working on the same team interacted before and during the meetings. Also, they frequently needed to communicate out of class as they were working on their respective tasks.

A Better Understanding of What the Other Discipline Does

During each weekly team meeting all the design students and CIS students presented and discussed what they had accomplished that week. As each discipline was presented with tasks and challenges and overcame those challenges (as discussed weekly) it gave the opportunity for a much more nuanced understanding of the role, challenges and terminology of the other discipline. Not all design students approached their tasks the same way and not all CIS students did either. The weekly meeting provided an opportunity for students in each discipline to observe, comment on and help other discipline team members work through problems as they presented themselves and to gain a better understanding of the range of challenges the other discipline faced and the variety of approaches (some successful and some not) they could use in solving those problems.

Feedback from another Disciplines Perspective

After each individual presented their progress each week, there was generally feedback given about a technical feature or design idea. Both the design and CIS students were accustomed to feedback and constructive ideas from others in their discipline, but the meetings really provided the opportunity to get feedback from people who were from a very different discipline and who had not been in the same classes for the last several years.

Changing Demands and Focus over the Course of the Project

The projects provided all of the students with the experience of not having the instructor ready to provide all answers and often (as we explored new areas) not having the answer at all. For example, for the CIS students one of the programmers might have been tasked to explore a new technology that might improve the topic. For the Designers, in addition to creating icons needed for their project, they also were tasked to explore the current state of icons for mobile web applications and provide some documentation and guidance for future designers. This might change weekly depending on the needs of the project. This is quite different than an orderly progression towards a final design or the step by step addition of features needed for the final application. It provided both the CIS and Design students with a taste of the often multiple and frequently changing demands on their time encountered in a less structured environment than they were accustomed to in a traditional educational setting.

Overlapping of Design and Programming

As the design students explored how to integrate their design work with the programmers work, limitations and constraints became clear. Designers had to be constrained and aware of the limitations the programmers faced technically regarding graphic elements and had to design graphic solutions in a way that could be successfully integrated into the programmers' work.

Working Through Problems with Different Criterions

The design and CIS students were accustomed to the range of solutions and their relative merit being dictated based on the standards of their own discipline. Designers used the design principles and processes that they had been trained with and programmers used the programming design principles they had learned to evaluate competing alternative solutions. However as the teams worked on specific problems, both disciplines had to have a say in defining the 'best' solution and the criterion were not fixed but changeable and often based on negotiations between the disciplines. While a particular page design might be better from a design perspective, if the programmers could not implement it then another solution or compromise had to be found.

7. CONCLUSION

This paper detailed experience with multi-disciplinary STEAM student project teams. Two methods were described for creating and running those teams and the positives and problems encountered were detailed – both in terms of class administration and the theoretical reasons for creating STEAM teams. While the Separate-Courses method had the fewest administrative hurdles to be overcome, it did not give nearly as much opportunity for the inter-disciplinary interactions between the STEM students and the Arts students as the other method.

The Same-Course method resulted in more multi-disciplinary interactions but was more challenging from a class supervision perspective. We discovered that instructors must be aware and allow time for discussing the learning processes used in the class and the responsibilities expected of each student from both the STEM and Arts disciplines. A clear understanding of these responsibilities also provides the design instructor with valuable information to be shared with the design students. In addition, through individual conversations with the design students the design instructor can better determine if the student would be a good fit for the course -- prior to enrolling in it.

In many ways the ideal approach would be a STEAM project course in which students from the different disciplines enroll and receive course credit in their respective disciplines. Ideally this course would be team-taught by faculty from both the STEM and Arts disciplines. As this paper has shown, though, there could be significant administrative hurdles to overcome to accomplish this and it probably should be viewed as a long-term goal to work towards.

In the meantime the two approaches described in this paper can be used to help instructors work through the learning curve associated with introducing STEAM into their curriculum.

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