AC 2011-1938: EVALUATION OF STEM+ART COLLABORATION FOR MULTIDISCIPLINARY ENGINEERING TECHNOLOGY LABORATORY

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Evaluation of STEM+Art Collaboration for Multidisciplinary Engineering Technology Laboratory

Abstract

The need to restore manufacturing competitiveness in the United States has become increasingly evident over the past decade. A common weakness that has been identified in much of the related literature is that engineers need a broader skill set than is currently contained in the core engineering curricula. Key skill deficiencies that have been identified include creative thinking, entrepreneurship, and the ability to work effectively in multidisciplinary groups.

For the past 3 years, a project at Youngstown State University dubbed the Cooperative Laboratory (CoLab) has brought together students from STEM and the Fine and Performing Arts to work on challenging design problems. Through the CoLab project, engineering technology students have been able to work on real-world, open ended projects with both technical and non-technical constraints. Thus far, initial development of the program has focused on Mechanical Engineering Technology students from STEM. Through the program, students have gained opportunities to:

- develop innovative solutions to loosely defined problems
- work with diverse multi-disciplinary colleagues towards a common goal; this involves negotiation and compromise
- maintain design intent while addressing cost and market factors
- practice leadership and self-direction in completing the project
- communicate technical aspects of designs with non-technical colleagues
- be responsible for project planning and scheduling considering resources and deadlines

This paper explores the relevance of the identified metrics from the perspective of industry, specifically local and regional. It presents a preliminary evaluation of the effectiveness of CoLab by comparing students who have gone through the program as compared with those who have followed a traditional Engineering Technology curriculum. Current issues with implementation, student evaluation and outcome assessment are addressed. This includes a discussion of how the goals that the Performing Arts can be met compatibly with the needs of the Engineering Technology program. Finally, recommendations for future adaptation, improvement and expansion of the CoLab methodology are proposed.

I. Introduction

America's dominance on the global economic stage is due largely to the strength of its ability to innovate and then to put those ideas to practical use. This ability won World War II and has made the standard of living in the U.S. the envy of the rest of the world.

In recent years, this ability has waned. Increased competitive pressure from countries such as China, India and Korea has shown that the U.S. position can be challenged. China has surpassed Japan as the second largest economy and they are not slowing down. Other countries have also shown improvements and are also catching up.

Recent studies have shown that the industrial capability of the U.S. is declining in relation to other countries and that the quantity and quality of graduating U.S. students is also declining. A decreased interest in the technical fields along with classroom practices (both K-12 and college) that do not engender and hold the students interest in STEM fields is creating a climate where the brightest students are moving into other areas of study. A steady decrease in the pool of quality STEM graduates is leading to the erosion of the industrial and manufacturing base of the U.S.

II. Background

As a practicing engineer and a professor, the principals noticed that the students and class materials have been largely turned into presentations that lead students to think about problems in a certain way and to use reference materials to arrive at a solution by looking for a similar problem. Although this is a valid method in some cases, it is totally devoid of free thinking – just 'follow the process'.

Many students learn to pass through college by being able to memorize a few formulas, figure out how to find the variables from the givens in the problem, then work out a solution. This is mainly because of the methodical approach to problem solving.

There are three large problems here:

1. there is no practice of the synthesis of a problem, just the analysis. Even though the principles can be used for design, they are not presented that way.

2. there is no method for solving a problem that is different than what the student has been exposed to.

3. there is no environment to 'spark' the students' imagination and to generate interest in the material

Although the first two are the most important for the students to overcome, if the third isn't achieved, many students are lost to the engineering field.

Some universities have tried to address this issue with undergraduate research programs, but typically these programs are too limited in access, scope and budget to make a meaningful impact to a significant portion of the student body. Basically, too few students have access to these research opportunities. They take a lot of resources in money and faculty time, and typical research problems do not lend themselves to large numbers of students working on them. Much of it ends up being repetitive work.

Two years ago, the principals of this research paper formulated a premise to address the issues stated and presented it at the ASEE conference in 2010. Since then, the program has been run three times (once per year) and it has expanded each year. This has provided meaningful data on the success of the program, principally the increased interest of the students, increased student performance and implementation issues so others can duplicate the work.

III. Co-Lab Development History

The principals addressed the previously stated problems with the development of the Collaborative Laboratory named because of the collaboration between the STEM school and the School of Arts at Youngstown State University. Although this program has many advantages for the Arts students, only the STEM perspective will be covered here.

Although the developmental aspects of the Co-Lab were covered in the previous paper, a brief summary is as follows:

The Co-Lab addresses the following issues:

1. provide a setting for the students to use the skills they learn in class to solve problems in creative and innovative ways
2. increase students' ability to handle loosely defined and open ended questions
3. develop communications skills with non-technical colleagues
4. develop negotiation skills and the art of the compromise while still achieving the end goal
5. learn how to plan a project and develop the discipline to hold to it

The goal is to develop an environment where STEM students can work with multidisciplinary teams to break out of the typical rote problem solving procedures of many STEM programs. By working with students from non-technical disciplines, the STEM students learn to communicate in plain language while approaching a problem in a less restrictive manner.

Although the Arts program was used in this effort, other disciplines may be used. In this case, the Arts program had a well-developed sculpture program with extensive lab facilities that complimented the equipment that the engineering department had. Additionally, the faculty in the Arts department were looking for a collaborative avenue to address some issues in their discipline. It's important to note here that the Art program requires the students to fund the cost of their projects depending on the materials required. This was maintained when their project was used in co-lab.

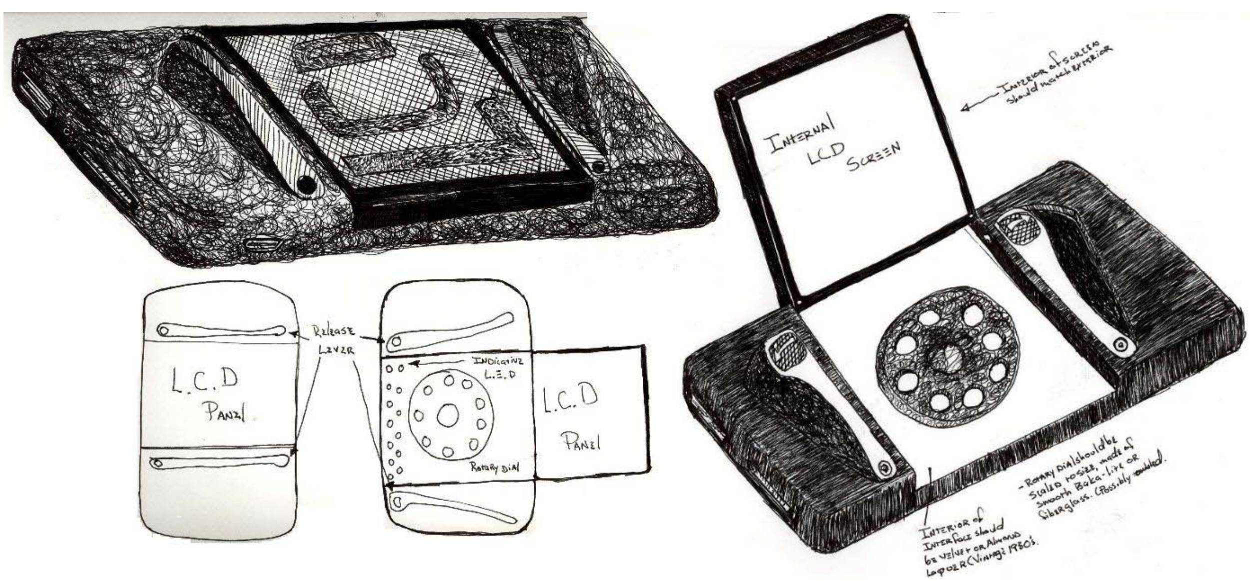
IV. Co-Lab Projects

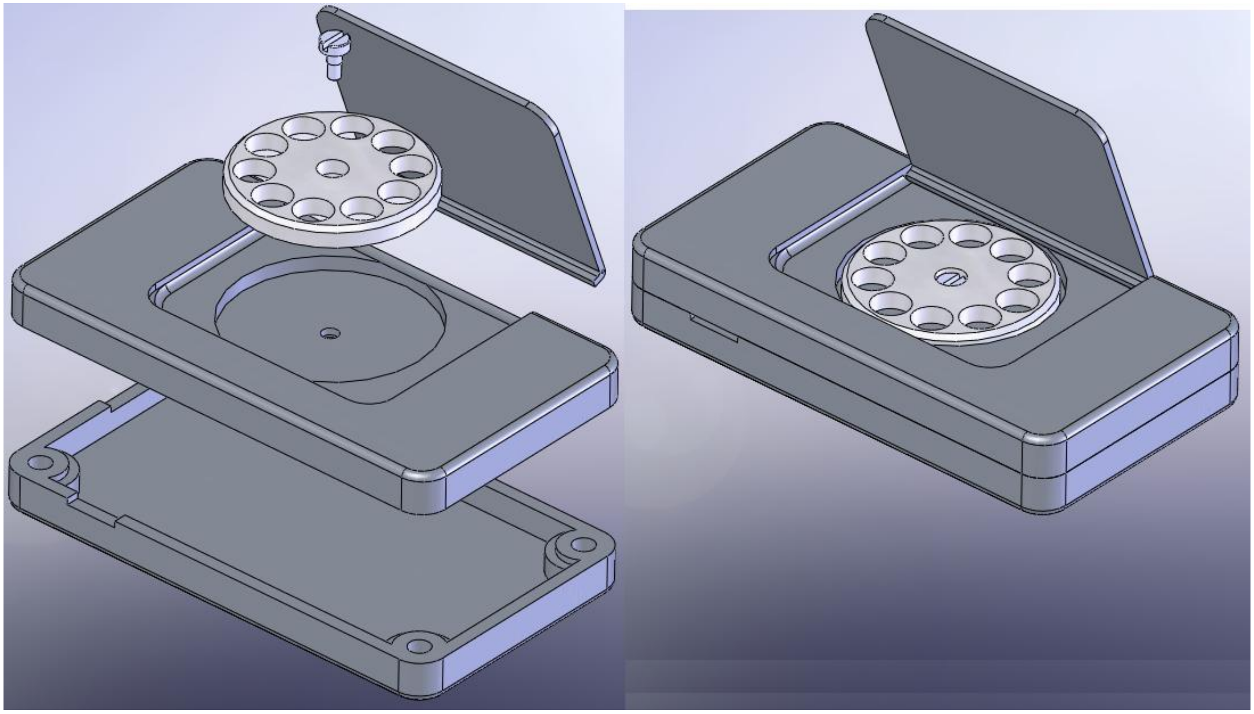
The projects conducted in the Co-Lab are not devised by faculty, nor are they repeated. Rather, they are developed by the students and then solved by them. The projects are handled by pairs of students, one from engineering and one from the arts. The arts student proposes a project to be built and the engineering student has to help the arts student build it using engineering principles and practices. Each project is to be fabricated in a manner to allow for mass production economically with an acceptable degree of attainable quality. These rules are not absolute although most projects adhere to them closely. The projects are vetted at the start of the class to make sure that they can be built with the equipment on campus and in the time allotted (typically a semester although larger projects are two semesters). A condition of completing the project is to present the project at the annual Quest event.

Examples of past projects include:

<u>Retro-styled Cell Phone</u> – a cell phone with ‘steam-punk’ styling. The Arts student produced a sketch of what he wanted to make and then the two students worked together to develop a manufacturing plan including the methods and a time line.

This project was 3D modeled in the Engineering computer lab using Solidworks by the engineering student, printed in the engineering rapid-prototype lab, then investment cast in the Art’s casting lab. Machining was done in the engineering CNC lab and final assembly completed in the Arts lab.

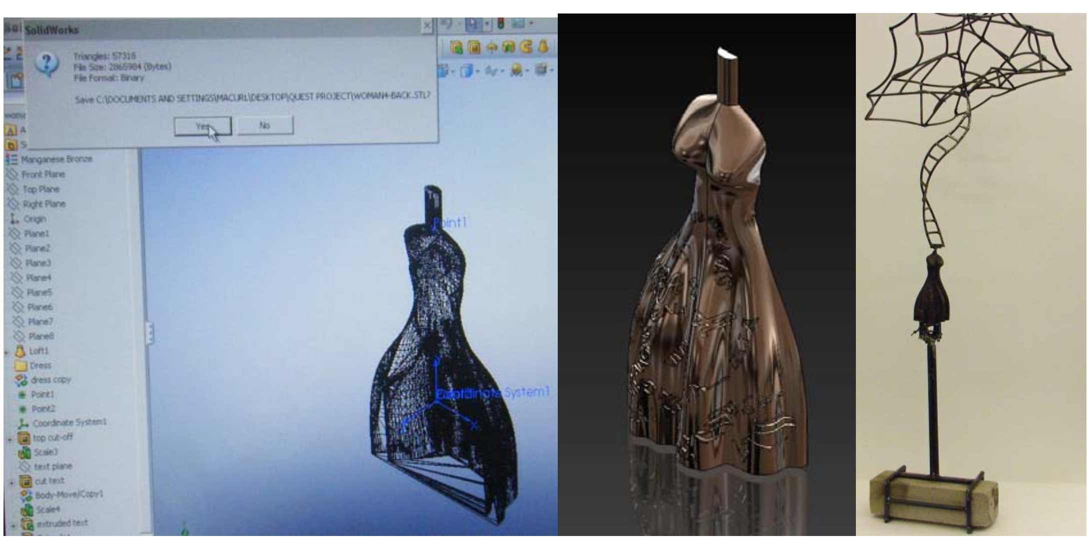




The bronze casting was setup in such a way that it could also be used as tooling for creating vacuum-formed plastic models of the phone also. This project was completed in one semester and presented at the Quest event.

<u>Gaia</u> – mass-producible sculpture with visual effect

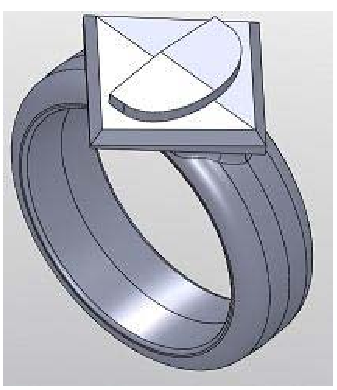
This project was an impressionist sculpture but the Art student wanted a text message presented on a figure in such a way that it could be read from only a certain perspective. The engineering student was able to devise a method to not only create the effect, but also do it in a way to make it mass-producible economically. The figure was modeled by the engineering student in the 3d modeling lab, a 3d print was made and then cast in the art's sculpture lab.



Nest – experience piece to give the observer the feeling of a bird's point of view

The art student wanted to make a nest that was large enough for a person to climb into to get the view of the world of a bird. The nest needed to strong enough to hold two average people safely while still appearing like a normal birds nest in construction and feel. Another challenge was that the venue did not have any trees that were strong enough to support the nest by themselves. The engineering student was able to devise a method of support between 3 trees with a spiral staircase and a rope ladder to enter the nest which was suspended 15 feet in the air. Additionally, the construction had to be inexpensive enough to fit in a budget. This particular project did not fit into the 'mass-producible' category, but it had enough challenge to exclude that.

Hero Ring – make a cheap mass-producible ring that signified a super-hero



This project is a ring that is to be passed out to people at certain comic events to promote a cartoon character. The engineering student was able to take the art student's sketches and produce a model with drafts and parting geometry to allow the fabrication of an inexpensive mold for the engineering department's injection molding machine.

V. Effects of the projects on the engineering students

The students chosen for participation in the Co-Lab projects were only chosen because they had time in their schedule to participate and were willing. Grades varied from above average to average. What was of interest was to provide a setting where these students could get motivated and interested in engineering while providing them the opportunity to build experience in approaching and solving loosely defined engineering problems while fostering their innovative abilities.

As previously stated, the Co-Lab addresses the following issues:

1. provide a setting for the students to use the skills they learn in class to solve problems in creative and innovative ways
2. increase students' ability to handle loosely defined and open ended questions
3. develop communications skills with non-technical colleagues
4. develop negotiation skills and the art of the compromise while still achieving the end goal
5. learn how to plan a project and develop the discipline to hold to it

Seven students have participated in the program so far. Initially, an improvement in grades was hoped for. The following table shows the students' GPA in engineering classes before and after the class.

Student Number	GPA before	GPA after	Change in GPA	Obtained Job
1	2.66	2.93	.27	Yes
2	2.57	2.67	.10	Yes
3	3.54	3.50	-.04	Yes
4	3.12	3.25	-.13	Yes
5	2.75	*		
6	3.50	*		
7	2.98	*		

* denotes the students are currently in the co-lab project

Put simply, the hope of the Co-Lab experience is to increase the quality of the student's learning experience. Several key academic issues have already been stated and these will be addressed shortly. Before those, however, it should be noted that there were other significant benefits that were not anticipated.

On average, students who completed the Co-Lab experience demonstrated a modest increase of 0.11 points in their GPA. The improvements in the grades, while positive are not that large and were less than expected. For comparison purposes, a random sample of MET students at the same level of academic progress was chosen as a control group. For that control sample of 10 students it was found that the average change in GPA over the same period was -0.41. As only the relative change in GPA was considered, effects of varying student quality were mimimized.

An ANOVA of the sample data shows that despite the small sample size, the grade relative performance of the Co-Lab group is statistically significant at power of p=0.304. With nearly 70% confidence based on the small sample size, the statistical support for the effectiveness of the Co-Lab project is encouraging.

An additional major benefit, it was discovered, was not reflected in the grades. Discussions with each student were held and it was discovered that the students had the following important outcomes:

1. <u>interest in technology was increased</u>

The students were able to apply their skills to a problem in the way that they saw fit. They felt this was rewarding in itself. Typical technology classes provide little opportunity for students to deviate from set ways of approaching a solution to a problem. Although the students sometimes made mistakes in the co-lab project, they understood first-hand what the problem was and were able to devise a better course of action.

2. <u>the emergence of their own abilities for self-reliance and self-direction.</u>

The projects are only overseen by the faculty, the path to the solution is completely up to the students, as are the techniques and planning to get to that solution. Most students began to work ahead in their engineering classes because they could see a path to the problem solution from the beginning instead of being lead there. One student described it as 'waking up' – he was in a trance to just follow what the instructor or book said and then memorize that methodology. Now, he can see his own way through and the presented material is a guide instead of a rigid plan. As a consequence, he has been able to apply the concepts he learns more broadly and appropriately.

Another benefit is the strengthening of the student's confidence in their own capabilities and decision making. The Co-Lab experience is completely opposite of the typically focused and rigid engineering curriculum. While they need to use engineering concepts to arrive at a solution, they choose the path they take based on criteria they set and the facts that they determine. Typically, their original plan doesn't work, and they have to take a step back and re-evaluate how to proceed. They learn that this is ok and is a normal part of the synthesis of a novel solution. This is in stark contrast to the typical engineering example that is contrived to illustrate a particular point. While this has it's place and is necessary, the ability to make mistakes and recover is critically important to a successful engineer.

Self-reliance is also stressed in the Co-Lab. While the faculty are available for consultation, we are very careful not to 'solve' the problem for the student. Frequently, they find they need to do some research to help them solve the problem and they need to find non-traditional sources of information. A good example of this is the use of a spiral staircase for the nest project. While there are many ways to provide entry to the nest, a method was needed that was safe while still preserving the ambiance of nature. The student investigated 'natural craftsmen' – people who build using only natural building materials for their work. The student was able to use some of their concepts to build a staircase directly under the nest and then providing a way to get out from under the nest and over the side safely and economically. No faculty guidance was used in developing the solution.

3. <u>they developed better discipline in completing their studies</u>

The nature of the collaborative experience, with the students responsible for much of their own direction, enabled the students to develop the independence and necessary skills to properly plot out the tasks and required time to complete a project. This skill translated over to their regular classes. These skills enable the students to maintain or raise their GPA while carrying the same course load as even while taking on a part-time job.

A sense of loyalty and belonging is also developed during the projects. The students 'buy in' to the project they are working on. Even though the arts student developed the concept, the engineering student builds an understanding of the goals through good-faith negotiation and a sense of team spirit is born. This makes the difference in just 'making it work' to finding a solution that maintains the original design intent while economically and safely solving the problem.

4. <u>a clearer direction for their career interest was realized</u>

The students were able to see the aspects of the technology field that they liked and had the best aptitude for. Some saw that they liked manufacturing aspects, others likes the design side. They also looked into different industries such as automotive, defense, entertainment, automation and production.

5. <u>pursuit of practical experience (internships, co-ops or part-time jobs) opportunities</u>

This became very important for each participant. All of the participants started looking for career opportunities on their own as their interest in technology increased. Each student that completed the class has been able to get real-world experience in engineering through a co-op, internship or discipline-related part-time job. All the students were asked if the co-lab experience was helpful in securing their positions and all said that it was. The employers were contacted and each said that they felt that the experience was meaningful and, although it was not the main reason to hire the student, it was a major component.

6. <u>transfer of interest to other technology students</u>

The students that went through the program suggested the class to other students. They also were able to convey the importance of the things they learned. Other students began asking to participate in the program and looking for work experience. As an example, the first student to complete the co-lab program is graduating after the Spring 2011 semester. The graduating class is 15 students and only three of them do not currently have a job in their discipline. Although the co-lab student didn't have an impact on all of them, there was some.

7. <u>communication and collaboration with diverse coworkers</u>

The engineering students sometimes enter the project thinking the art student isn't very knowledgeable and quickly find that they have a lot to learn from them. They learn first-hand that pre-conceived notions can be wrong and that they can learn from any discipline. Typically, they find out that they learn quite a lot and develop friendships with groups of people they ordinarily would not seek out.

One of these was getting the students out of their 'comfort zone' in the standard engineering curriculum. This involves new surroundings – much of the work is done in the Arts department where there are different faces, different politics and a different view of the world. Most students found this change refreshing and invigorating while it broadened their understanding. Curiously, the majority of the students realized this only after the class was over and they went back to the standard engineering environment.

VI. Implementation Aspects

Typically, when co-lab is discussed with others, it appears that it was relatively easy to setup and manage. This is misleading because of the many factors that were successfully managed to bring it about.

The most critical thing was interested faculty from both the engineering discipline and the non-engineering discipline. In our case, we had a willing partner in the Arts that had both students in a position to gain from this interaction and lab facilities that made them an equal partner in this endeavor. Briefly, the Arts wanted their students to have an understanding of more technical methods of making things, aspects of mass-production and exposure to a practical application of the scientific method. From their point of view, we also brought significant lab resources that allowed their students hands-on work. This leveraged the cumulative resources of both schools (Arts and Engineering) towards a common learning experience. The deans of both schools were also interested in a collaborative initiative, and while they had not developed a formal outline of a program, the Co-Lab met all of the criteria they were trying to achieve. Additionally, the chairs of each participating department saw value in it and helped with the implementation of the class in the standard curriculum. The arts department was particularly interested in the presentation of the project at the Quest event as that is something that arts students do not typically get exposed to and the oratory skills are valuable in the workplace.

Both departments also had goals that were complimentary – although not apparent at first, thoughtful discussion by both disciplines quickly showed that the goals paralleled each other and the projects provided mutually beneficial (though different) learning experiences.

An important issue that is difficult to predict is the cost of materials and resources required for each time the class is run. Since each project is unique, there can be substantial costs involved to actually manufacture the design. This usually is mitigated at the start of the class when the Art student is presenting their ideas. If they can make the project with materials that are on hand, every effort is made to adjust the project to allow this. Some projects, however, just aren't able to be adjusted like this. In these cases, the Art student needs to fund the cost of the materials as is typically done in the Art department.

Another resource that is critical to manage is the time of the faculty to run this program. The projects must be vetted properly so that the students can reasonably be expected to complete it. Many times the students' projects are over ambitious since they may not have the ability to assess the time required to complete it. The project may also involve more complexity than the students can handle on their own. These projects may require the faculty to check the project for safety and proper design. The faculty needs to assess this at the beginning.

IX. Assessment

The objectives of this class are:

Provide a way for the technology student to work on engineering problems creatively and to arrive at novel solutions through processes that are their own.

Expose the student to collaborative environment with non-technical team members.

Instill a better sense of what it takes to be an engineer in the 'real world' – deadlines, project assessment and planning.

Assessment of these objectives are primarily accomplished by monitoring the projects as they are performed and at completion. The teamwork aspect is the most critical to assess during performance. Communication and teamwork are critical to completing the project while maintaining the design intent. Two projects failed when the technology student was unresponsive to the needs of the project and were picked up by other students. It was determined that the unresponsive students did not 'buy into' the projects. One withdrew and the other received a failing grade as he did not meet any of the project objectives. The replacement did an excellent job. A chance was taken on the failing student on the hope that a turnaround would happen in academic performance – it didn't. This was a calculated risk by the faculty.

At the completion of the project, several key objectives are evaluated:

1. Were the goals of the project met? This is the most straightforward objective to assess. The project goals are stated at the start of the project. A timeline is also developed to guide the project. The process that the student used to meet the design intent and to make manufacturable is rated. This is where the student's creativity can be seen and assessed. A rating of the work process is completed and recorded, but since 'creativity' can't be measured with a standard scale, this information is not used in the grade of the student, but is recorded for use in improving the class. The majority of the class grade is based on the successful meeting of the project goals.

2. A presentation must be given to discuss the project and explain the plan and how the project progressed. This presentation is given during a campus wide event with third-party judges rating the presentations and the work. This provides an impartial evaluation of the work from others and also gives the students a 'drop dead' point for the completion of their project. It also provides the technology student with an opportunity to use their communication skills to present the technical aspects of the work to a non-technical audience.

3. Continuing progress of the technology student. Since the class is designed to develop the student's creativity and work skills, it is impossible to completely evaluate the impact of the class on the student's abilities during the class. Academic performance is only one area to analyze. Discipline and work skills have been seen to improve after the co-lab experience. As described earlier, the fact that these students are securing discipline-relate work before graduation while maintaining their academic performance is notable as is the effect on fellow students.

X. Continuing the work

In order for this project to continue, all the contributors need to get something from the bargain. In the case presented here, the arts department and the engineering departments both have made significant gains in the quality of the learning experience for the student. The only limitation that we have seen is when the engineering student isn't that interested in the arts component.

Alternatives such as criminal justice, business, athletics or humanities may be compatible with the proper projects and faculty that are interested in pursuing this direction. We are currently looking into developing projects with criminal justice and business as we have ongoing relationships with those departments.

We are also exploring the possibility of making this a recognized component of the general education requirement (GER) in our program. There are several key areas that are directly addressed by this class and the benefits are directly applicable to both students' outcomes.