Integration of Art Pedagogy in Engineering Graduate Education

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Abstract

The integration of STEM with the Arts, commonly referred to as STEAM, recognizes the need for human skill, creativity, and imagination in technological innovations and solutions of real-world technical problems. The STEAM paradigm changes the dominant "chalk and talk" lecture and "closed-ended" problem-solving orientation of traditional engineering pedagogy to a hands-on, studio-based, and open-ended creative learning approach, typical in art education. A growing body of literature has provided evidence of the favorable impact of situating STEAM in K-16 education. The long-term objective of this work is to promote creativity in engineering students by integrating learning methods and environments from the Arts into graduate STEM education. To this end, an integrating engineering, technology and art (ETA) educational model is developed and is currently being tested. This ETA educational model systematically merges technical instruction with studio-based pedagogy. The ETA model consists of three courses, which were piloted in the year 2017. In each course, engineering and art instructors and students collaborated for 15 weeks on design projects. These projects ranged from drones to architectural installations.

1. Introduction

Engineering educators have increasingly sought strategies for integrating the arts into engineering curricula. The primary objective of this integration varies, but one common objective is to improve students' creative thinking skills [1, 2]. The integration of science, technology, engineering, and mathematics with the arts (STEAM) emphasizes the need for human skill, creativity, and imagination in technological innovations and the solution of real-world technical problems. The STEAM paradigm promotes changes from the dominant "chalk and talk" lecture and "closed-ended" problem, which are predominant in engineering pedagogy, to a hands-on, studio-based, and open-ended creative learning approach typical in art education [3, 4].

A growing body of literature has provided evidence of the favorable impact of STEAM in K-16 education through projects in robotics [5, 6], information technology [7, 8], and music technology [9]. While most of the studies are isolated and focus on undergraduate education, they provide evidence of the significant effect of a structured STEAM-based education model and the potential impact of integrating arts' learning methods and environments in graduate-level engineering and technology programs.

According to a survey by the Council of Graduate Schools [10], Master's students compose almost 75% of engineering and technology graduate students, while the remaining 25% are enrolled in a PhD program, for the first time enrollees in fall 2012. Furthermore, for the total enrollment in engineering and technology, Master's students account for about 60% of total students in fall 2012. Based on this data, the ETA courses are developed with a focus on Master's students, although undergraduate, Master's, and Ph.D. students can take these ETA courses.

This work presents the engineering, technology, and arts (ETA) education model for the Master's program of Mechanical Engineering developed at Indiana University-Purdue University Indianapolis. Relevant elements of the proposed ETA education include hands-on learning, multidisciplinary design projects, and the interaction of engineering students with art students. The anticipated goal of this model is the advancement of aesthetically-conscious technical innovation in engineering students. To evaluate the relevance of the proposed ETA model, three graduate-level courses are developed: Design of Complex and Origami Structures, Optimal Design of Mechatronic Systems, and Environmental Pollution and Emission Control. These three courses define a graduate design-track. The first course is offered in spring 2017 and the last two are offered in fall 2017. This paper evaluates the proposed ETA education model and is organized as follows. First, the proposed ETA education model is presented. Second, the proposed three graduate-level courses are described. Lastly, the course evaluations are presented and discussed.

2. The Engineering, Technology, and Arts (ETA) Education Approach

The proposed ETA education approach focuses on the following concepts: (1) creative thinking/idea exchange, (2) knowledge/tool acquisition, (3) problem redefinition, (4) constraint analysis, (5) obstacle identification, (6) multiple solutions, and (7) optimization. These concepts are achieved by introducing a new track or concentration area within the department of mechanical engineering under the proposed ETA education model. A balanced mix of the pedagogical methods from engineering, technology, and arts will be implemented in these courses, which include problem-based, studio-based, and immersive experiential learning techniques. The **hypothesis** of the proposed ETA education model is that integrating arts' design methods in graduate engineering and technology curricula enhances the creativity and innovativeness amongst the participating ETA graduate students.

To test the above hypotheses, three ETA courses are proposed: Design of Complex and Origami Structures, Optimal Design of Mechatronic Systems, and Environmental Pollution and Emission Control. Each ETA course is taught by a faculty team from the Purdue School of Engineering and Technology (Indianapolis, IN), the Indiana University School of Art, Architecture + Design (Bloomington, IN), and the Indiana University Ernestine M. Caclin School of the Arts (South Bend, IN). Distance learning solutions are used to address logistic challenges. Faculty teams consist of at least one person from the home school in Indianapolis and one person from the visiting school. In addition, student participation, collaboration and peer learning are stressed as an important part of the studio culture ethos. Students are given access to technological resources, computers, digital cameras, and printers. Additionally, access is given to fabrication labs, including laser cutters, 3D printers, and CNC machines, allowing students to experiment with material and production techniques throughout various stages of design processes. Additionally, the Additive Manufacturing Lab (Fig. 1A) and the Robotics Lab (Fig. 1B) at IUPUI are also made available. Students are also given access to the Additive Manufacturing Lab (Fig. 1A), Robotics Lab (Fig. 1B), and Mechatronics Lab (Fig. 1C) at IUPUI.

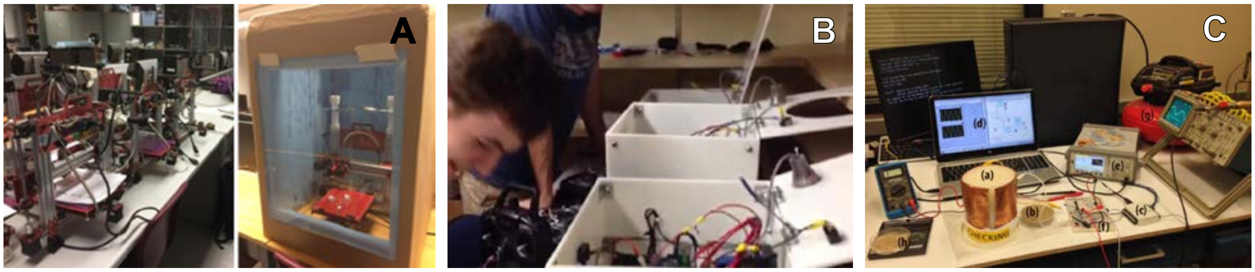

Fig. 1: Student facilities at IUPUI. (A) Additive Manufacturing Lab, (B) Robotics Lab, and (C) Mechatronics Lab.

3. Design of Complex and Origami Structures (ETA Course 1)

3.1 Objectives and methods

The first course in the ETA model is taught by Prof. Andres Tovar from the Purdue School of Engineering and Technology (Indianapolis) and Prof. Liangmei Wu from Indiana University School of Art, Architecture + Design (Bloomington). This course introduces fundamentals in art and design with a focus on irregular (organic), free-form, and origami structures (Fig. 2 and Fig. 3). This course is tailored to provide engineering and technology students with a sound grasp of engineering design methods for designing structures based on no manufacturing constraints, origami tessellations, and fundamental creative strategies used in the design thinking process. The first part of the course is conducted through a “hands-on” interdisciplinary art and design studio approach with an emphasis on studio-based pedagogy.

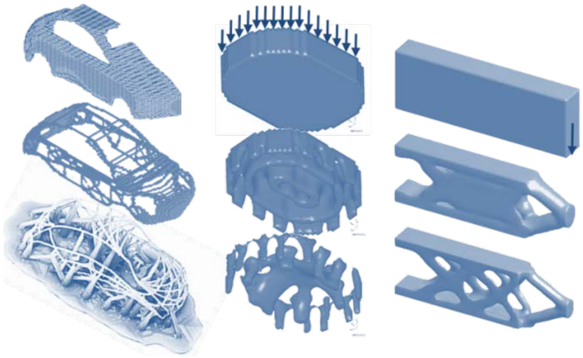

Fig. 2: Complex, free-form (topology) structural design of engineering structures. Source: A. Tovar.

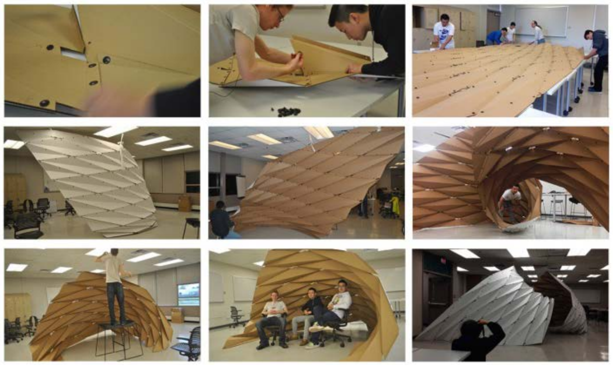

Fig. 3: Origami based architectural art creation by J. Wu, 2015 (http://jiangmeiwu.com/).

3.2 Course content

The course is divided into three modules: Complex structure design methods, Origami-based design, and Model-based design. The complex structure design methods module focuses on design optimization, particularly topology optimization [11]. This module is taught by Prof. Tovar (Engineering and Technology, Indianapolis). The origami-based design module focuses on origami math, modeling, folding, and structure. The last module, model-based design, focuses on the use of computer models in the design of structures. Topics of this module include computer experiment design, novel design approaches, and a collaboration with IU Bloomington interior design students. These last two modules are taught by Prof. Tovar and Prof. Wu. The course evaluation metrics include: (i) Research and pre-design of the problem; (ii) Schematic design refinement; (iii) Design development through a reiterative process; (iv) Professional communication; (v) Collaboration with an interdisciplinary team; (vi) Participation in group critiques.

3.3 Student projects

In the course projects, students are asked to design irregular, free-form, and origami structures in the context of material, construction, artistic form finding, and form making. Students are introduced to origami art and techniques of using paper folding as a means for form finding and form making. Following this, they develop schematic designs from multiple visual ideas and experiment with tangible materials, inspired by the art of origami. This is done to identify design flaws that are not easily apparent through software. Designs are further developed through iterative methods, with each version suggesting subsequent problems to explore. This is done to address the issues previously identified in the schematic design phase. Final designs are professionally presented to their peers, professionals, and visiting scholars. Some examples are shown in Fig. 4. Through the collaboration with the Purdue School of Engineering and Technology (Indianapolis, IN) and the Indiana University School of Art, Architecture + Design (Bloomington, IN), interior design students worked with engineering students on a folded origami inspired structure. This structure was structurally validated and built at North Christian Church in Columbus, IN (Fig. 4E).

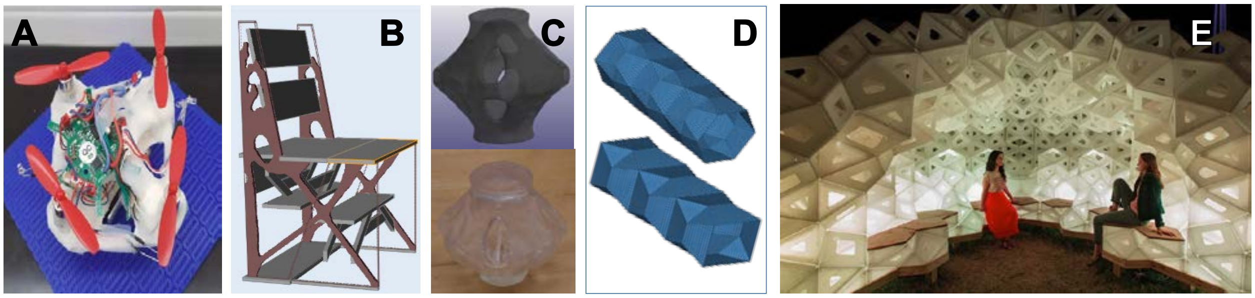

Fig. 4: Examples of final projects for ETA Course 1. (A) Complex quadcopter, (B) Morphing shelf chair, (C) Origami-prefolded crash tubes, (D) 3D energy dissipating compliant mechanism, and (E) Origami-inspired installation at the North Christian Church in Columbus, IN.

4. Optimal Design of Mechatronic Systems (ETA Course 2)

4.1 Objectives and methods

This course is taught by Prof. Andres Tovar and Prof. Sohel Anwar from the Purdue School of Engineering and Technology (Indianapolis) and Prof. Young Suk Lee from the Indiana University Ernestine M. Caclin School of the Arts (South Bend). This course introduces the fundamentals of knowledge transformation from art/design to engineering/technology applications. Different forms of mechatronic systems are discussed relative to engineering and technology applications, including robotic systems, interactive structures, and folding constructions.

This course uses the epistemology of studio practice to acquire embodied knowledge. This facilitates understanding communicative experiences of felt qualities and movements shaping the creative thinking process [12, 13]. Innovative-reasoning processes are taught through the crafting of mechanical structures, while experiencing bodily interactions with the nature of materials and tools. Thus, this course familiarizes a range of design principles and critical studio practice methodologies by working with a range of variable materials.

4.2 Course content

This course integrates mechatronic modeling, simulation, optimal design, and hands-on fabrication of robotic systems (sensors, actuators, electric circuits, embedded controllers), and interactive structures. Course topics start with an introduction to control theory. Specifically, optimal control theory through Matlab and Simulink. After this introduction, approaches to creating interactive mechanical elements are discussed followed by the 3D modeling of art forms. Robotics and artificial intelligence are the last topics discussed. The course evaluation metrics include: (i) Application of art knowledge to problem refinement; (ii) Collaboration to identify constraints and obstacles; (iii) Proposal of multiple designs to solve a problem; (iv) Improve design via optimization; (v) Prototype the system with 3D printing; (vi) Analyze functions for comparison.

4.3 Student projects

In the course projects, students are asked to select one of three general areas: interactive structures, self-assembling structures, and toy robots (walking robots). Students are required to perform a literature review on the project topic, assess the state of the art on the technology, and critique the existing technology. Then, they are expected to propose ideas of improvement in terms of engineering and arts, as well as to model and analyze the proposed improvements. Further, they should apply a design optimization process and also describe a rational for the final design choice. Finally, they should prototype and test a functional design. Examples of final projects are shown in Fig. 5.

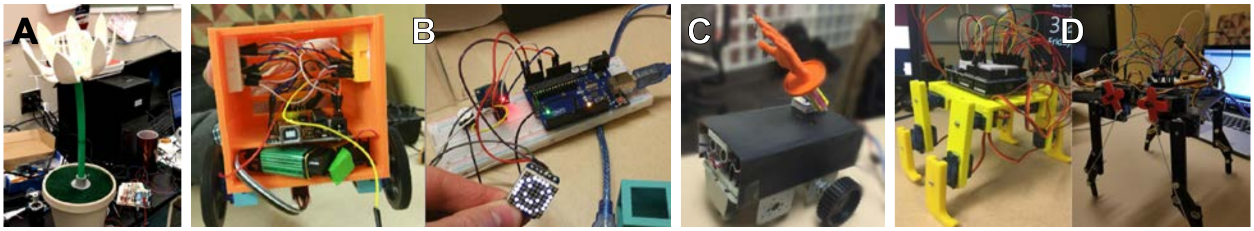

Fig. 5: Examples of final projects for ETA Course 2. (A) Interactive flower, (B) Emotional balancing bot, (C) The helping hand robot, and (D) Four-legged walking robots.

5. Environmental Pollution and Emission Control (ETA Course 3)

5.1 Objectives and methods

This course is taught by Prof. Sohel Anwar (Engineering), Prof. Razi Nalim (Engineering), and Prof. Afshin Izadian (Technology) from the Purdue School of Engineering and Technology (Indianapolis). While there is no instructor from Arts, the pedagogic approach incorporates hands-on, studio-based practices. The course is designed to further promote creativity through immersive experience. The course integrates real-world problem solving into the course curriculum through guest lectures from industry experts. Students learn about environmental pollution sources and the fundamental mechanisms behind their impact on environmental and human health. Furthermore, students learn how automotive emissions can be measured and controlled. In particular, measurement of particulate emission deposited in a diesel particulate filter is studied. Here the ETA students have the opportunity to creatively design sensor components. A number of topics from mechanical and electrical engineering are taught and combined into the course projects, which students accomplished over the semester.

5.2 Course content

The topics of this course can be broken into four sections. The first section covers the sources and mechanisms behind pollution. The second section covers pollution and emission sensing technologies. The third section investigates the effects of pollution on human and environmental health. The last section discusses modeling and design aspects behind healthy control technologies. The course evaluation metrics include: (i) Improve sensor design using the learning environment; (ii) Learn how to analyze data from the industry experts (guest lecturers) and use the feedback to further refine design.

5.3 Student projects

In the course projects, students are involved in the development of a novel technology for soot load measurement, developed for further reduction of particulate emissions from an engine. Students built upon this technology by adapting the design for real-time applications. Students are broken up into groups for this part of the course. The first group investigates (using finite element or similar methods) additional functionality of the sensor data through innovative data fusion methodology. These functionalities include structural failure detection of the particulate filter structure. Another student group develops additional functionalities through experimentation on a hardware-in-loop (HIL) bench. The third student group investigates the application of such techniques to other emission's (e.g. NO_x) sensing and control. After this technology is further developed, the resulting sensing technologies are verified through different methods, including simulation of the model and standardized testing procedures. System validation is carried out through modeling and bench testing in the lab. The final results of each student group are presented to the class and visiting professionals.

6. Evaluations of ETA Courses

Evaluation criteria are used to measure how the ETA courses contribute to students' development of an identity as an "engineer" and as an "artist." The ETA courses are evaluated at four levels: student satisfaction, formative assessment of teaching, student outcomes, and student creativity. Student satisfaction is evaluated for all ETA courses. The latter three levels are evaluated for only ETA course 1, which was offered in spring 2017. Data is not yet available for ETA courses 2 and 3, which were offered in fall 2017.

6.1 Demographics of the students

Demographics of the students are shown in Table 1. For student creativity evaluation, data was collected from the pre-survey for ETA course 1. Out of 20 students, two were female and 18 were male. 19 Students were working towards a master's degree in Mechanical Engineering and one student was working towards a doctoral degree in Mechanical Engineering. The average age of students was 24.0 years (2.5 years standard deviation).Two students reported their ethnicity as White or Caucasian, one as Hispanic or Latino, and 17 as Asian or Pacific Islander. 14 students reported that English was not their first language, 5 reported that English was their first language, and one student did not answer this question.

Table 1: Demographics of the students in the evaluation of student satisfaction and student creativity.

	Enrollment	Student satisfaction survey	Student creativity pre-survey	Student creativity post-survey
ETA course 1	24	15 (62%)	20 (83%)	21 (88%)
ETA course 2	22	11 (50%)	-	-
ETA course 3	17	9 (53%)	-	-

6.2 Evaluation of student satisfaction

The evaluation of student satisfaction contains three criteria: instructional materials, course assignments, and learning. Students are anonymously asked to give a rating on how much they agree on the following three criteria and open-ended statements:

- Material: "Instructional materials helped me learn the subject"
- Assignments: "Course assignments helped me learn the subject"
- Learning: "Overall, I learned a great deal from this class"

Students that participated in the survey gave a rating from 1 to 4 on how much they agree with this statement. A response of "1", "2", "3", and "4" correspond to "Strongly Disagree",

“Disagree”, “Agree”, and “Strongly Agree” agreements respectively. The student evaluation ratings and the averages are summarized in Table 2. The Appendix contains the details of the student evaluation ratings with a comparison chart of the current course evaluations with IUPUI’s mechanical engineering department and program and the overall Purdue School of Engineering & Technology.

Table 2: Student evaluation ratings of the ETA courses. ETA course 1 was offered in spring 2017 and ETA courses 2 and 3 were offered in fall 2017.

	Material	Assignments	Learning	Average
ETA course 1	3.60	3.80	3.53	3.64
ETA course 2	2.91	3.09	2.91	2.97
ETA course 3	2.00	2.33	2.22	2.19

6.3 Formative assessment of teaching

Formative assessment of teaching was reported through a series of classroom observations and a student focus group session conducted towards the end of the semester. These observations were conducted by the Center for Teaching and Learning. Four class sessions were observed with an average attendance of 24 students for ETA course 1. The first two class session involved short lectures followed by in-class activities led by Prof. Tovar and Prof. Wu respectively. The final two class sessions were comprised of student presentations, and peer and instructor feedback. Profs. Tovar and Wu successfully created a hands-on learning environment where students worked on routine in-class activities and a final project that required art and engineering skills and knowledge. 6 out of 24 students chose to work with IU Bloomington students on an origami-inspired art installation and provided the engineering expertise to the art students. Opportunities for peer interaction through collaborative in-class and project work, clear and step-by-step introduction to new software and analysis methods, and a consistent emphasis on the interdisciplinary nature of the course through real-world examples are the key strengths of Profs. Tovar’s and Wu’s instructional methods.

Recommendations for improvement included increased integration of art pedagogy such as opportunities for peer critique, structured design and assessment of collaborative interdisciplinary projects, and a faded scaffolding approach. Data from the student focus group sessions echoed the classroom observation findings. 21 students participated in the student focus group session. Majority of the students expressed satisfaction with the instructors and instructional methods. Students’ recommendation included improved structure and timelines for the final project, more collaborative opportunities with art students, and a less tentative and ad hoc course structure and logistics.

6.4 Evaluation of student outcomes

Student outcomes for ETA course 1 are evaluated through an in-class activities, a midterm project on complex design, a midterm project on origami design, and a final project. Rubrics and are used to track student performance throughout the semester, which included a presentation, a report, and a physical prototype. Student grades are indicated in Table 3. These results suggest that students engaged with the learning strategy and met the ETA 1 course requirements.

Table 3: Student grades for ETA course 1.

	In-class activities (out of 20)	Complex design (out of 20)	Origami design (out of 20)	Final project (out of 40)	Final grade (out of 100)
Minimum	16.91	17.40	15.37	36.80	90.81
Mean (SD)	19.48 (0.71)	18.32 (0.56)	18.16 (1.20)	38.28 (1.09)	94.23 (2.02)
Maximum	20.00	19.40	19.69	40.00	98.09

6.5 Evaluation of student creativity

To evaluate changes in student creativity, two instruments are used: the Reisman Diagnostic Creativity Assessment (RDCA) and the Innovative Behavior Scales, which involve tracking pre and post changes. The creativity instruments contained the following constructs:

- Originality: Confidence in developing original, innovative ideas
- Ideation: Confidence in generating many ideas
- Tolerance of Ambiguity: Comfort with the handling the unknown
- Risk Taking: Adventurous; Brave
- Intrinsic Motivation: Tendency to be motivated based upon an inner drive
- Extrinsic Motivation: Tendency to be motivated by external rewards
- Solution Generation Process: Engaging various potentialities and resisting closure
- Iterative Processing: Willingness to iterate on one’s solution
- Questioning: Tendency to ask lots of questions
- Experimenting/exploring: Tendency to physically or mentally take things apart
- Idea networking: Tendency to engage with diverse others in communicative acts
- Observing: Tendency to observe the surrounding world

Overall, on a 6-point Likert-type scale, where 6 represents strong agreement and 1 represents strong disagreement, the average response to ETA course 1 satisfaction questions is 5.38 (SD = 0.53). The average responses to the engineering identity formation construct (M = 5.25; SD = 0.75) are significantly greater than responses to the artist identity formation construct (M = 4.41, SD = 1.39), t (20) = 3.46, p < .01 (two-tailed). These results suggest that ETA course 1 is much more effective at promoting students’ identification as engineers than artists.

Notably, 5 students who completed the post-survey had collaborated with IU Bloomington Art students on their final project, whereas 16 students did not. Comparing post-survey artist identity formation construct between these two groups of students shows that engineering students who worked with art students reported higher average responses to the artist identity formation construct (M = 5.20; SD = 1.02) than their peers who did not work with art students (M = 4.17; SD = 1.43); although, these differences are not found to be significant.

Students responded to statements formed from the 12 constructs intended to gauge specific innovation/creativity skills or dispositions. Responses were collected on the first day of the class, before students engaged in any course activities, and on the last day of class, immediately following students’ final presentations. Significant changes were found on 6 constructs when comparing responses of the pre and post surveys. In order of magnitude, significant changes were found when comparing pre and post responses using a paired samples t-test. The results are as follows:

- Idea Networking: ($M = .96$; $SD = 0.78$, $t = 5.11$, $p < .01$).
- Questioning: ($M = .78$, $SD = .70$, $t = 4.63$, $p < .01$).
- Tolerance of Ambiguity: ($M = .73$, $SD = .78$, $t = 3.82$, $p < .01$).
- Observing: ($M = .62$, $SD = .68$, $t = 3.75$, $p < .01$).
- Originality: ($M = .45$, $SD = .63$, $t = 3.75$, $p < .01$).
- Ideation: ($M = .41$, $SD = .57$, $t = 2.97$, $p < .01$).

Comparing pre and post responses indicated that students showed increases on nearly every construct. The construct with the highest increase is Idea Networking, followed by Questioning, Tolerance of Ambiguity, Observing, Originality, and Ideation. To help explain these findings, and to identify how this course may be improved in subsequent offerings, the lessons learned when integrating arts into STEM are discussed. We hope that these findings and discussion will motivate other scholars and instructors to explore the impact of art on engineering design learning and provide strategies for improving and evaluating student creativity in such courses.

7. Lessons Learned

The proposed ETA courses for graduate STEM education strive to integrate design pedagogy from the Arts into the engineering and technology curriculum. The goal of this integration is to foster creativity and innovation at the graduate education level. Such interdisciplinary education model is meant to advance U.S. graduate education in STEM and leap ahead in creating new economies of scale through empowerment of graduate students.

Developing an art-integrated engineering (ETA) courses includes fundamental elements in terms of resources, methods, and content. In terms of resources, an ETA course requires the time, tools, and materials to work on physical prototypes to fully utilize studio-based learning. In terms of methods, ETA projects and assignments should clearly identify both STEM and Art components. Finally, in terms of content, ETA lectures should maintain the technical depth and rigor of a graduate-level engineering course.

The effectiveness of an ETA course depends on the quality of the interaction between students and instructors from STEM and Arts disciplines. In the proposed ETA course 1, STEM and Arts students collaborated on a final projects towards the end of the semester. While the post-survey results show that this interaction is not significant in terms of artist identity formation construct, a longer-term interaction may provide new perspectives on design and design methodologies. In addition, student learning experience and overall satisfaction are highly dependent on the quality of the interaction between STEM and Art faculty. This includes syllabus coherence, STEM/Art assignment coordination, and consistent communication from STEM and Art faculty.

It is expected that ETA students are likely to create or advance technologies and products by incorporating experiences from the Arts. ETA students involved in longer-term research, such as a MS thesis or PhD program, are expected to demonstrate increased creativity, particularly if they are involved in engineering design projects. Therefore, ETA course projects, especially the final project, should be flexible and unstructured, while maintaining a clear rubric to assess creative aspects and technical content. The lessons learned from this pilot project can be translated to other STEM graduate curricula. For example, the balanced pedagogical approach used in this pilot program can be adapted to create a graduate curriculum in electronics that integrates aspects of music to promote innovation in musical instruments.

8. Acknowledgments

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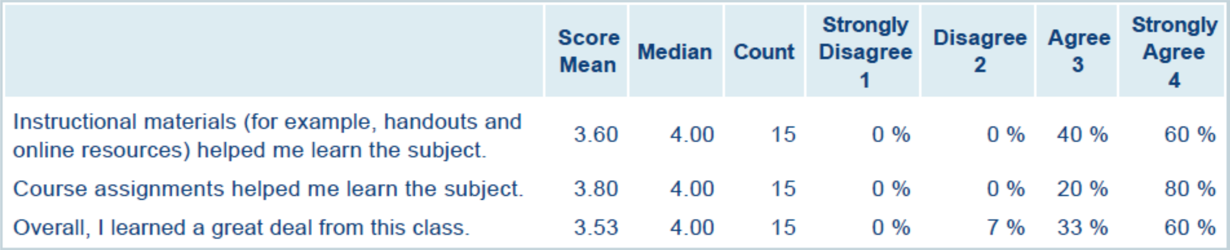
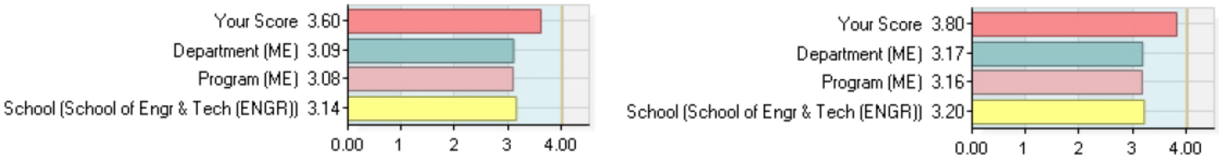
10. Appendix 1: Student Evaluation of ETA Course 1

10.1 Ratings

Table 4: Student Evaluation Ratings for ETA Course 1: Design of Complex and Origami Structures (spring 2017). Project Audience: 24. Responses Received: 15. Response Ratio: 62%.

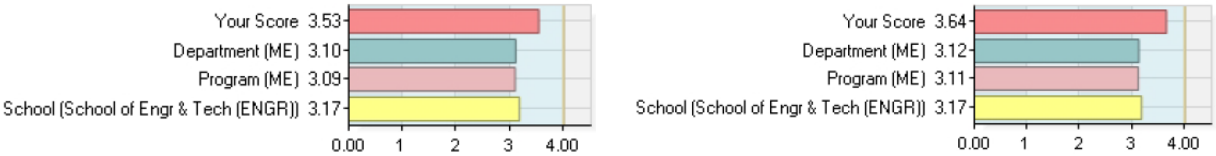


	Score Mean	Median	Count	Strongly Disagree 1	Disagree 2	Agree 3	Strongly Agree 4
Instructional materials (for example, handouts and online resources) helped me learn the subject.	3.60	4.00	15	0 %	0 %	40 %	60 %
Course assignments helped me learn the subject.	3.80	4.00	15	0 %	0 %	20 %	80 %
Overall, I learned a great deal from this class.	3.53	4.00	15	0 %	7 %	33 %	60 %



Instructional materials: 3.60

Course assignments: 3.80



Overall, I learned a great deal: 3.53

Average: 3.64

Fig. 6: ETA course 1 evaluation rating comparison with IUPUI's Mechanical Engineering department, program, and the Purdue School of Engineering & Technology.

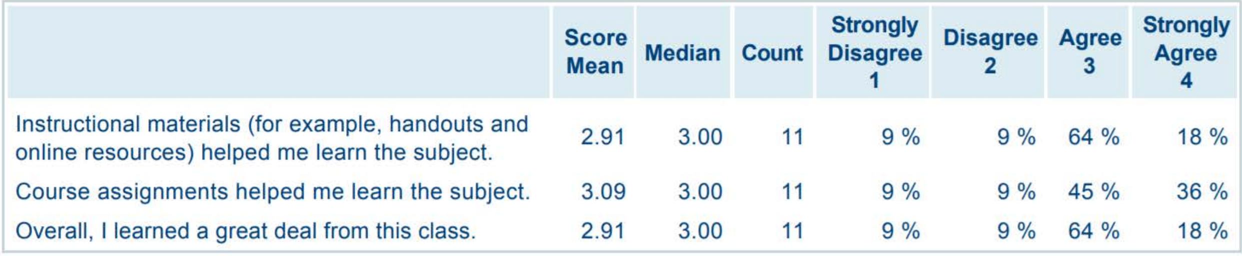
10.2 Student comments

"This course served as a good introduction towards integrating art with design. I enjoyed working with the IU interior design students and helping them with their projects. I will say that the course could be better organized as sometimes it was unclear on what to do for assignments. Overall a good course, which I really enjoyed."

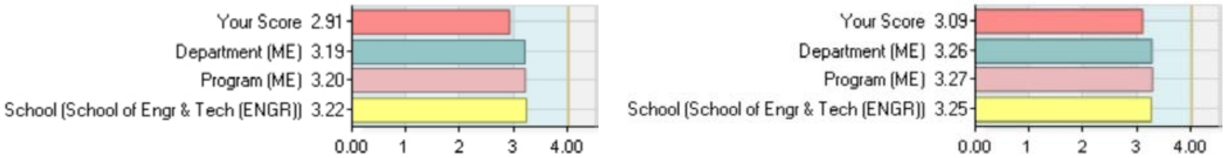
11. Appendix 2: Student Evaluation of ETA Course 2

11.1 Ratings

Table 5: Student Evaluation Ratings for ETA Course 2: Optimal Design of Mechatronic Systems (fall 2017). Project Audience: 22. Responses Received: 11. Response Ratio: 50%.

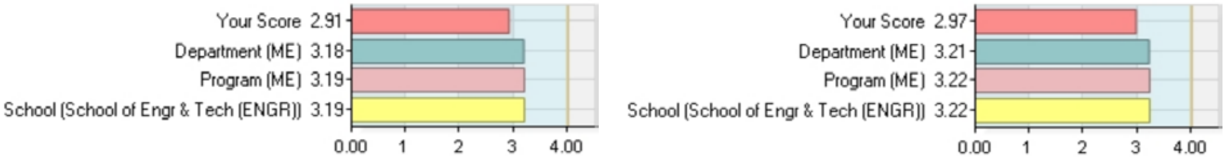


	Score Mean	Median	Count	Strongly Disagree 1	Disagree 2	Agree 3	Strongly Agree 4
Instructional materials (for example, handouts and online resources) helped me learn the subject.	2.91	3.00	11	9 %	9 %	64 %	18 %
Course assignments helped me learn the subject.	3.09	3.00	11	9 %	9 %	45 %	36 %
Overall, I learned a great deal from this class.	2.91	3.00	11	9 %	9 %	64 %	18 %



Instructional materials: 2.91

Course assignments: 3.09



Overall, I learned a great deal: 2.91

Average: 2.97

Fig. 7: ETA course 2 evaluation rating comparison with IUPUI’s Mechanical Engineering department, program, and the Purdue School of Engineering & Technology.

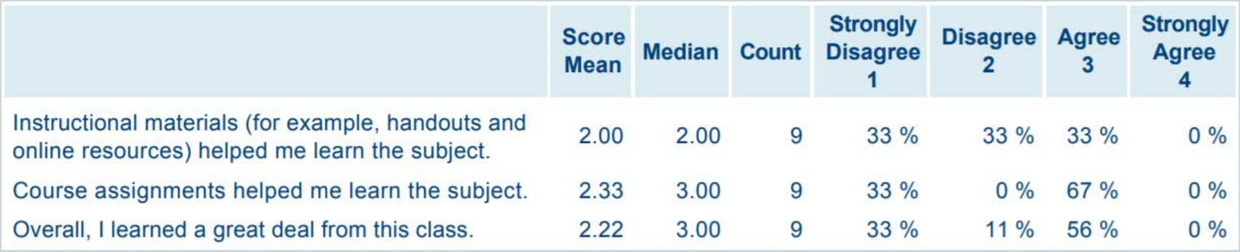
11.2 Student comments

“No clear ideas about the projects…individual sections were better, but had no link to what the other professor taught…insufficient communication between the professors.”

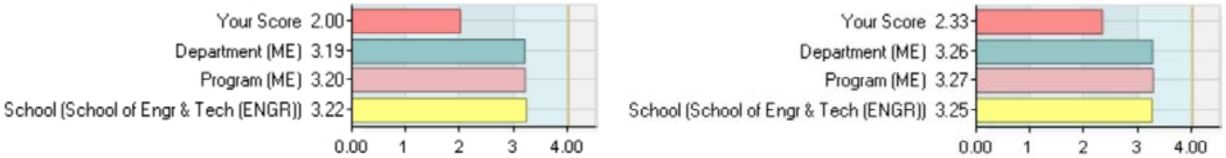
12. Appendix 3: Student Evaluation of ETA Course 3

12.1 Ratings

Table 6: Student Evaluation Ratings for ETA Course 3: Environmental Pollution and Emission Control (fall 2017). Project Audience: 17. Responses Received: 9. Response Ratio: 53%.

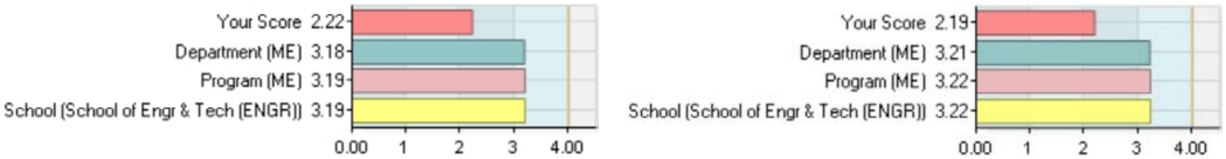


	Score Mean	Median	Count	Strongly Disagree 1	Disagree 2	Agree 3	Strongly Agree 4
Instructional materials (for example, handouts and online resources) helped me learn the subject.	2.00	2.00	9	33 %	33 %	33 %	0 %
Course assignments helped me learn the subject.	2.33	3.00	9	33 %	0 %	67 %	0 %
Overall, I learned a great deal from this class.	2.22	3.00	9	33 %	11 %	56 %	0 %



Instructional materials: 2.00

Course assignments: 2.33



Overall, I learned a great deal: 2.22

Average: 2.19

Fig. 8: ETA course 3 evaluation rating comparison with IUPUI’s Mechanical Engineering department, program, and the Purdue School of Engineering & Technology.

12.2 Student comments

“Three instructors were too much in my opinion. Lack of coordination among them led us to be taught same topic over and over again. We learned many interesting topics. However, having two projects was overwhelming. Time management by the instructor was not sufficient enough. We effectively had only 4 weeks to start and finish our individual project. Replacing a project with a midterm exam would have helped. Thank you.”

“The course was very disorganized with too many changes. It seemed like the professors were never prepared for the upcoming class or to instruct the course in general. Nothing was made in advance; Everything was put together as the course progressed, including assignments, PowerPoints, and especially projects. We were not prepared for the projects either. The lectures did not help with understanding the concepts needed for the projects, and having two projects that are minimally explained is very time consuming.”