2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #39317

Creating Creative Educational Opportunities among Engineering and Arts Students

abdullah ibrahim, Texas A&M University at Qatar
Roudha Saif Al-Khaldi, Texas A&M University, Qatar
Doaa Elamin Emam
Dr. Yasser M. Al Hamidi, Texas A&M University, Qatar

Dr. Al-Hamidi holds a Ph. D. degree in Mechatronics from the University of Bourgogne Franche-Comté (UBFC), France, and currently working as the Mechanical Engineering Laboratories Manager at Texas A&M University at Qatar. He joined Texas A&M University at Qatar in 2007 coming from University of Sharjah. Dr. Al-Hamidi had been appointed as a visiting lecturer in 2018 to teach design related courses in the mechanical engineering program. He specializes in product design, instrumentation, controls, and automation. Dr. Al-Hamidi founded the Engineering Enrichment Program in 2016, which is currently one of the Center for Teaching and Learning pillars. He received three Transformative Engineering Education grants related to multidisciplinary education in 2018, 2021 and 2022. In 2021 Dr. Al-Hamidi received the Dean's Achievement Award to recognize his contribution to the campus within that year. In 2015 he received the Association of Former Students AFS Distinguished Achievement Award as a recognition for his commitment, performance and positive impact on Aggie students. And in 2010, he received the STAR award as a recognition for his outstanding service and achievement at Texas A&M at Qatar.

Prof. Marwan Khraisheh, Texas A&M University, Qatar

Professor and Chair of the Mechanical Engineering Program at Texas A&M University at Qatar.

Creating Creative Educational Opportunities Among Engineering and Arts Students.

Abdullah Ibrahim[1], Roudha Al-Khaldi[1], Doaa Emam[2], Dr. Yasser-Al Hamidi[1], and Dr. Marwan Khraisheh[1]

[1] Texas A and M University at Qatar
[2] Virginia Commonwealth University at Qatar

Abstract:

This paper aims at introducing new multidisciplinary activities between students from the Engineering and Arts majors. It sheds the light on how engineering students can be prepared to become ‘outside the box thinkers’ by interacting and working on common projects with students from the arts and design majors. The collaborative efforts revolved around the aspects of “design thinking”, an innovative and broad project based educational model that uses a systematic approach towards problem solving. With traditional engineering education, students are accustomed to breaking down theoretical problems and solving them using standard procedures. Although such a way of teaching instils analytical and methodological thinking, but it is not enough to prepare students to be creative in solving future problems. Research shows that engineers who practice one of the visual arts develop enhanced observational capabilities, which help them to be more effective and innovative. Taking it a step further, the design thinking process has proven to be phenomenally successful in the past, in that it better prepares students to face the challenges of the industrial world, by instilling qualities such as empathy, teamwork and adaptability. By collaborating with students from artistical backgrounds, engineering students can benefit from the creative thinking of art majors. This engineering-art connection also works in the opposite direction. Art students would simultaneously gain vision on how to bring their ideas to life more realistically. Through collaboration with engineering students, they would acquire systematic thinking and planning. In addition, they would learn scientific and engineering facts about their designs that would help them grow as artists themselves.

The above premises make an excellent ground to build several activities that can be used for the education and training of engineering and arts students. These activities required students to establish some shared resources beforehand which are tailored to teach other majors about their own major without diving deeper but instead focusing on creating the connections to see the overall picture. Over the course of one semester students from all majors were able to collect solid material in the form of PowerPoint presentations to share and explain to other majors. They also brainstormed different project ideas to develop constructive collaboration and synergy among themselves and produced two ideas which they executed and constructed successfully. The thought process behind the brainstorming and execution of these ideas relied heavily on the design thinking model and the stages of this model. The first project was to build a giant physical sculpture of a water bottle and a lung hanged from the top side inside the bottle. The drive behind the design relates back to the source of life, air, and human lungs, confined within a cage of plastic waste. The design gives the recycled waste a humanitarian aspect, connecting our lives to what we consume and harm the environment with. The second design is for a kinetic arts installation, and it is still a work under progress. This paper will show in detail both projects and how they helped in improving students thinking skills while employing the stages and steps set down by the general design thinking ladder/framework.

Introduction

Art has been a representation of man's creativity since prehistoric times, from petroglyphs and pictographs to the creation of Mona Lisa. Engineering and engineering solutions have been used to improve life since the same prehistoric time frame, from the creation of the first wheel to the water wheel and the watermill. It can be said, then, that art and engineering are fundamentally and inherently connected. Bran Ferren explained this connection in his TED talk in 2014 [1]. Through his experience Bran realized that art without engineering is nothing, and engineering without art is meaningless. This conclusion was supported by countless experimental research conducted in the last few decades, including a paper submitted in the journal of consulting psychology [2]. The paper included the result of an experimental test ran with 105 students from the fields of both art and engineering. The experiment was conducted under the pretext of measuring the independence of judgment given its positive relationship with creativity, and to analyse the dream and dream recalling tendencies of the 2 groups of students. The report states that the ability to recall dreams was the greatest among art students and least among engineering students, and that dream imaginativeness and dream recalling numbers positively correlated with the tests for creativity. This suggests that creativity, despite being an innate quality, does depend on the type of education a person is given.

The research results in [3] state that students who experience art and STEM together, are associated with positive qualities such as increased critical thinking and deeper-learning abilities, problem solving, higher teamwork and other qualities that are not only necessary for being successful engineers or artists, but also for being the consummate citizen who is vital for a successful society. Moreover, much of the positive qualities that this multifaceted approach leads to are the exact qualities that employers are looking for. This is quite significant as the aggregate unemployment rate among engineering graduates in western countries is almost 13% [4], and a staggering 62.3% and 42.8% among Fine art and Design graduates respectively [5]. These numbers do not just disincentivise students from pursuing their desired majors and their passions but also suggest a need for an immediate change to improve disciplinary education, if not completely returning to an integrative multidisciplinary approach.

The vitality of multidisciplinary education is therefore evident. However, the approach towards this collaborative education is just as important. The way a topic is introduced to a student and the way that topic is applied varies highly with respect to the type of educational model being followed. Project based learning, for example gives students the ability to reflect upon their learnings and leads to a general increase in self-motivation and self-efficacy. UBD or understanding by design models help students in relating what they learn in a course to the real world, and thus deepening their understanding. But given the limitations of these and other models, there is always some important piece of experience or learning that is left out. For that very reason, design thinking is one of the most renowned educational models. The model incorporates not only the self-motivation and reflection of project-based learning, and the real-life association of concepts as seen in UBD models, but goes a step further and grants students the freedom of exploration to truly expand their horizons, incorporating self-learning and entrepreneurial learning. [7] Design thinking stands out from similar educational models as in it, there is not a specific topic, or a specific question that students are to answer. Rather, the advisor/instructor/facilitator gives the team of students a broad scope, and the team is then to define a problem that they will tackle within this scope. [6] Design thinking has 4 main stages of learning: Discovery, Ideation, Experimentation, and evolution. The discovery stage is what you might call the “what is it” stage, where the students undergo comprehensive literature review and expert consultations to identify problems that they could tackle within the established scope of the project. Once this problem has been identified is when the Ideation stage begins. Ideation is the “what if” stage where students brainstorm potential solutions to the identified problem/problem statement, throw around ideas and eventually use constructive criticism to enhance and improve their ideas/solutions. The solutions are constantly refined and reiterated, until narrow range of viable solutions can be identified. Once a solution is decided and agreed upon through a collaborative effort, the experimentation stage begins where the proposed solution is tested and important questions about its functionality and practicality are answered. Next is the evolution stage, where the results of the previous experimentation are used to improve and work on the proposed solution and redesign it to the point where it is considered “good enough” for the purposes of an academic project. Once the project has reached the “good enough” point, or it is suitable and meets the needs established in the scope of the problem and the project, the solution is then ready to be deployed and marketed. Our strategy, therefore, is founded on the ideas of design thinking, which emphasizes teamwork, empathy, experimentation, and iteration as key components of the design process. Design Thinking can be an effective instructional strategy for interdisciplinary projects requiring creativity and innovation, according to earlier studies.

Design thinking and multidisciplinary education quite simply complement one another and have been proven to be most successful when applied together. For example, Cracow university of technology’s staff of the faculty of Architecture (FA) attempted to do this in 1980 by introducing classes into the engineering curriculum which made students aware of the achievements of contemporary artists and gave them a glimpse of the global artistic and cultural progress/development to make their students more aware of the surrounding world [7]. In recent years, many educational institutions such as Rice University, have offered their students the opportunity to opt for courses that can lead to the intersection of art and engineering. Rice students enrolled in any field of engineering can also enrol in contemporary art and design courses. The well renowned university even offers a course called, Intersections in Art and Science (FWIS 182), of which the name speaks for itself. Rice students have formed a club called Rice: Art and Engineering, the purpose of which is to give students a platform to “discuss the ways in which these two fields overlap and brainstorm new ways of intertwining these two disciplines [8]. Harvard school of engineering decided to develop their curriculum by integrating liberal arts concepts within it, the decision proved incredibly fruitful. The courses offered in this curriculum not only emphasize the importance of user and economic factors which are key parts of the design thinking process (empathy), but also grant exposure to technical skills such as performance measurement and quantitative analysis/simulation [9].

Motivation

An artist's vision would be pointless without the presence of structural engineering solutions that could bring these visions into existence. Famous artists in the past including but not limited to, Leonardo da Vinci and Picasso were not only considered talented artists and known for their creativity, but also for the machineries they engineered along with their artwork. In fact, it can be said that art and engineering go hand in hand, and much of the technological and artistic wonders that we see in front of us in the 21st century are the pin ultimate combination of these two fields. The problem however arises primarily in today's education system; In general, engineers acquire little to no arts instruction. Universities' engineering departments hardly ever provide classes in art history, architecture, or the appreciation of beauty. Within university faculties, this is essentially unique. To their detriment, this left-side brain bias in engineering (and some science courses) results in graduates who are not "whole brain thinkers" and leads to engineers who lack creativity. Coincidentally, many art students due to the lack of engineering courses in their respective education facilities, lack the ability to bring their creative and artistic visions to life. This was the main problem that we wanted to target with our multidisciplinary approach/collaboration between arts and engineering. Students from varying majors, such as architectural design, fashion design, mechanical engineering and electrical engineering came together to combine their abilities and realize how they can benefit from the association of their skills. Our goal is to emphasize the importance of both humanizing engineering studies i.e., training students to think across a range of disciplines and to leverage their exposure to diverse methodologies, and, at the same time, enhancing the systematic and scientific teachings of art courses. Moreover, on a much larger scale, we aim to introduce multidisciplinary education system in Qatar like what many of these globally acknowledged universities are praised for.

This study, and the collaboration between the two universities is just the beginning of a long journey. The first project that the students undertook is not dissimilar from a course which is part of the master's degree education at the NTNU, Trondheim, Norway [10]. The students were urged to use their creative abilities which helped them develop greater teamwork and problem-solving capabilities. This is the intended result that our collaboration between art and STEM students aims to bring about, and by using design thinking as the basis of our approach, the positive impact of this multidisciplinary educative experience will provide the fundamentals and basis needed to produce graduates who are outside the box thinkers and much more well prepared to tackle real world problems. This project's instructional strategy is founded on the ideas of design thinking, which have been proven to be successful in encouraging cooperation and innovation among students from various academic fields [11]. In the referenced paper, successfully proven strategies relative to the collaboration of art and technology are discussed, along with the results and outcomes of these strategies. Another article [13] published in Harvard Business review acknowledges the uniqueness of the application of design thinking for problem solving, focusing on empathy, experimentation, and collaboration. This is just one of several articles that avows the benefit of design thinking. However, despite several similar studies, and despite design thinking's ever-increasing implementation in various educational settings to boost collaboration and innovation among students, there is little to no research/evidence on the usefulness of this model when paired with an interdisciplinary educational model. Our study aims to fill in this gap and show the impact of such an approach, and it efficacy in a multidisciplinary scope.

The step taken by VCU-Q (Virginia Commonwealth University-Qatar) and TAMU-Q (Texas A&M University at Qatar) is a continuation to previous efforts towards implementing design thinking approach in a multidisciplinary context. The instructional strategy for multidisciplinary projects involving engineering and arts students is presented in this study. The strategy attempts to encourage innovation, collaboration, and creativity among students from various academic fields. We discuss a project where engineering and art students collaborated to construct interactive art displays to illustrate the efficacy of this strategy. In the following sections, we take you through the methodology and processes employed in the collaboration projects, with every section briefly going over the steps taken in each stage of the design thinking process. Section 1 talks about the discovery stage. Section 2 talks about the ideation/brainstorming process, and the succeeding sections will talk in brief about the practical work/building process for each individual project, which encompasses the experimentation and evolution stages. The results of our efforts are highlighted in the succeeding sections.

Methodology and process

The project involved 3 teams (a mechanical engineering team, an electrical engineering team, and a diverse team from the arts and design major), working together to create interactive art installations that serves or represents a greater message. Each team consisted of a minimum of 4 and up to 6 members. The initiative was not a compulsory course, but rather, an extra circular activity between two of the most well renowned engineering and arts universities in Qatar in which the participants all volunteered for the collaborative effort. The project spanned over a period of 12 weeks. The instructor served as a facilitator and provided guidance and feedback to the teams throughout the project and made sure that the teams followed the design thinking ladder [12]. The teams' efforts are broken down in the next few sections respective to each stage of the design thinking process.

1. Discovery: Taking a multidisciplinary approach towards problem solving

The first step in this process, was for the students to share what they learned from their respective disciplines and familiarize each other with their languages. The exploration efforts began by the Art and design students sharing concepts from their majors that they thought would incite interest in the engineering students. They started by elaborating on their frame of thought when coming up with any conceptual design and followed with explanations of core concepts. These concepts included the explanation of, and the difference between the terms "art" and "design". They discussed the freedom and unrestricted nature of art which allowed it to represent various viewpoints, questions, and dilemmas, versus the restricted nature of a design and the necessity of it serving a specific purpose while operating under certain constraints and requirements. Their explanations were followed by the conclusion that "a good design always has some aspect of art behind it". In other words, a good design is also always a good piece of art. After VCU's presentation on the fundamentals of art and design, the engineering teams were now tasked with presenting and explaining core engineering aspects. Their main objective was to share concepts, terminologies, and methodologies that could be applied in tandem with and would complement the artistic design process discussed by VCU. These specific concepts were chosen whilst keeping in mind the broader scope that the teams were working under, i.e., sustainability.

With this, the mechanical engineering team was up first. Since they had gained an understanding of how the art students' minds worked and their creative tendencies, the team decided to focus on concepts that would resonate with the VCU team. The two chosen areas of focus- given the immense potential for diverse applications for both- were Truss structures and Additive manufacturing. After brief explanations on the technicalities of truss structures and their different applications around the world, the team suggested the use of a unique software, "TrussFab" for any possible designs. TrussFab is a rendering tool that can convert any 3D mesh into a structure of differently sized trusses made entirely of plastic water bottles. The suggestion was well received as it had great acumen relative to the theme of sustainability while also being like other design software used by the VCU students in the past. This was a vital exchange between the teams, as it established the foundations necessary to allow the Arts team to lead the designing process effectively once the ideation stage began. The other core concept emphasized by the Mechanical team was additive manufacturing. Along with the use of TrussFab, the team suggested implementation of 3D printing, and justified this suggestion by presenting the benefits of additive manufacturing over traditional/conventional methods of manufacturing. This idea was also well received as it opened the doors to the use of recycled plastics and other waste material (shredded to make printable filaments) and could thusly facilitate adherence to the theme of sustainability. Apart from a general sense of direction to focus their designing efforts towards, the mechanical teams' suggestions also helped art students gain a wider perspective; Given the ability of additive manufacturing techniques to bring complex geometry to life without much labour, the art students recognized the limitless design potential of such technology, and the positive impact it could have on the way they approached their own majors.

The foundations for the approach that the teams would take towards this collaborative project were established from these two presentations. A general sense of direction was gained from the exploration of applicable methodologies. The teams had already started coming up with possible ideas and problems to tackle, and the electrical engineering team set about to ensure the successful execution of any possible proposals. To allow unrestrained design capability, the electrical team aimed to focus first on the possibility of dynamic designs. For this, they introduced the other teams to the concept of actuators and their uses in dynamic structures. The team elaborated on the basics of an actuators' functionality and its core components, followed by the segregation and application of different types of actuators. Upon the conclusion of the actuator's topic, the students discussed the various aspects of lighting; something significantly related to the aesthetics of most designs. Various lighting methods and their real-world applications were discussed, giving the other teams a clearer understanding of how certain design aspects are achieved. The informational session was followed by a brief question and answer session. The interactive session tested the other teams' understanding of the different actuator types, their applications, and other details shared in the presentation.

The open communication between the teams during this brief session led to a tremendous increase in team chemistry and synergy, while also ensuring that all members understood and comprehended the information given to them

By discovering common ground between themselves, and towards the end of the discovery stage, the 3 teams were armed and ready to work together. Through discovery and exploration, they fully understood the weight/complexities behind the problem they would tackle; the idea of a “design/artwork” that included “various engineering aspects” and was tailored around the theme of “Sustainability”. Although these initial team meetings and exchange of knowledge acted primarily as the discovery stage of the design thinking ladder [12], they also served as the beginning of the ideation stage (centred around brainstorming for a viable solution to a chosen problem). The initial team interactions set the foundations for meaningful and successful brainstorming by acquainting each team with the language of the other, and these foundations were manifested fully in the next stage.

2. Ideation and brainstorming

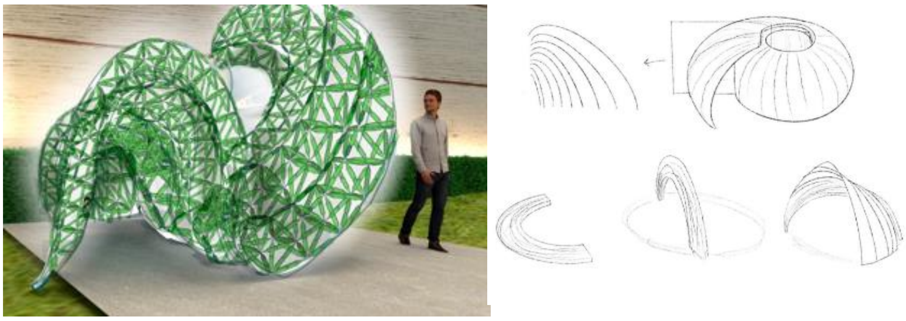
Following the team presentations, VCUQ students used their visual representation skills to convey ideas, translating the language of design into elements that can be transformed with engineering: such as multi-dimensional design proposals. Using hand sketches, digital illustrations, and rendering software, VCUQ team created digital mock-ups for project ideas, taking inspiration from forms in their surroundings, culture, science, Arabic calligraphy, the human body, and Earth. The team was successfully able to adapt the thoughts into digital mock-ups by using Graphic Design skills. Due to the large number of proposed ideas the teams decided to pursue two separate projects- each with different team leaders, ideas, and conceptual foundations.

2.1. Project 1

The intention in the first project was to mimic a real-life scenario where arts and design students propose an art installation idea, and the engineering students to realize it into reality. The teams decided that for the first project, their chosen theme would be sustainability, in particular the current issues surrounding recycling and plastic pollution. With this scope in mind, VCUQ headed the brainstorming efforts which were the key part of the ideation stage. The VCUQ teams’ efforts showcased artistic thinking by combining art with the human body, and plastic pollution. They used the language of art, graphic designing, and interior designing to shed light on issues relative to the chosen theme/scope. VCUQ designed several different digital prototypes, and the 3 main ideas that were shortlisted were as follows:

I. Melting glaciers: This structure represented a wave constructed using clear plastic bottles conveying the idea of melting of glaciers that is expedited by the presence of microplastics in the water. This concept art was a representation of a global threat, i.e., global warming.

II. Kinetic shell: This concept art represented marine life combined with the aspect of the harmful effects of pollution on the environment and human life. The shell’s design was to be kinetic and would open up/ retract (with the use of actuators) to represent the human brain. Both the designs are shown below in Figure 1 parts A and B



(A)Melting glacier *(B) Kinetic shell*

Figure 1: Design ideas

III. Lungs trapped in plastic bottles: This was the concept art that stood out the most to all team members; kinetic lungs hanging inside a large model of a plastic bottle. The proposed design can be seen in Figure 2. This seemingly simplistic concept was quite unique with respect to the message the art students wanted this design to convey. For proper functioning of the lungs, humans need a clean and constant intake of oxygen. However, inhaling the microplastics in the environment damages the lung tissues limiting the lungs' ability to exchange oxygen into the bloodstream. This can lead to several life-threatening diseases such as cancer, asthma, hypertension. This grave message was exactly what the VCUQ students wanted the design to convey via the entrapment of lungs within the plastic bottle. The lungs were chosen to be the kinetic part of this model, and to simulate the aspect of breathing/contracting lungs, the arts team suggested that linear actuators be used in the hanging lungs model.

In the end, it was decided that the third concept would be the one that would be worked on as the first/primary project. A point of interest to note was how VCU students made models/renders of their concept art using truss structures. Similarly, it should be noted how they reflected on, and then suggested areas for the incorporation of actuators. This was a sign that the initial stage of this collaboration project was a success; the art students had adopted the language and the way of thinking that the engineering presentations tried to get through to them. They were now not only creating concept arts for projects, but also thinking of bringing these concepts to fruition in a more systematic and scientific manner.

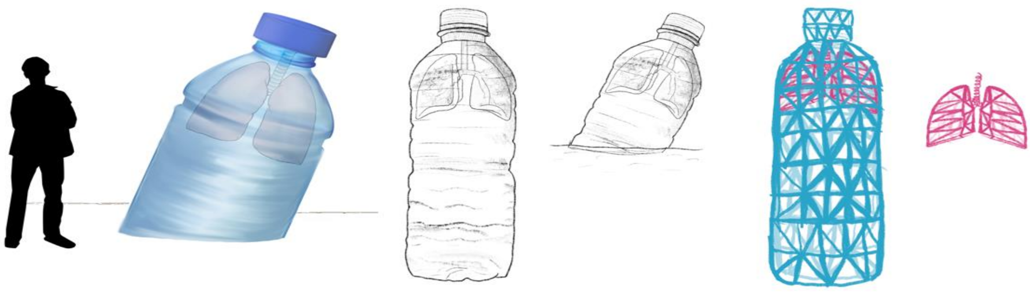


Figure 2: Chosen design idea

2.2. Project 2

For the second project, the teams wanted to mimic another real-life scenario where the workflow goes in an opposite direction. In such workflow the engineering teams propose and partially execute an idea and then ask art and design students to make it looks more aesthetic and appealing. For that, engineering teams brainstormed many ideas revolved around using different types of actuators having in mind ending up with kinetic art installation that can be handed over to the art and design students to put their own artistical touches on. Some of these ideas are:

I. Moving art pieces showing beautiful mathematical functions with 3D experience using tiny actuators.
II. Dynamic wall comprised of linear actuators which move thin panels to create interesting designs.
III. Interactive sand art using a magnetic ball lying on top of a pile of sand which moves to create different designs.
IV. Origami interactive art which moves when it detects motion.

The origami idea was the champion amount all ideas which engineering students came up with, as they felt it requires collaboration and work among different disciplines within engineering majors, and it can be transformed by art and design students into many different emotional and energetic art installations.

Taking inspiration from the Japanese paper-folding art form of origami, VCUQ students proposed three different designs for the second project. Each design proposal focused on taking inspiration from nature and aimed to represent the symbiosis of the art team's creativity and the engineering team's technical knowledge. Inspired by Louis H. Sullivans famous quote "forms follow functions" [14], the arts students employed what they had learned about servo motors from the electrical team, and proposed designs consisting of several units "cells". The kinetic functionality of each cell unit would be utilized to represent various shapes and forms pertaining to origami. The proposed forms/designs took the mechanism of the unit cells' components into consideration ("following the function"), whilst maintaining the original inspiration from nature, plants, and Sealife. There were 3 main iterations of such unit cells that were proposed:

I. Wings of Nature: The first design proposal titled shown in figure 3, is a direct inspiration from the wings of birds and butterflies as well as the organic beating of these wings. The models basic sculpture uses paper with a blue dye to mimic the Monarch butterflies' famous wings. The beating of these wings creates a harmonic blend of energy within nature which is represented by delicate layers of paper (applications of origami). In the individual cell units, the paper wings would be attached using moving rods. The ebb and flow created by the rods' movement would be reminiscent of the beating of wings. The proposal suggested a plate of one hundred such cells, creating an ocean of kinetic energy to depict the harmonious beauty of nature.

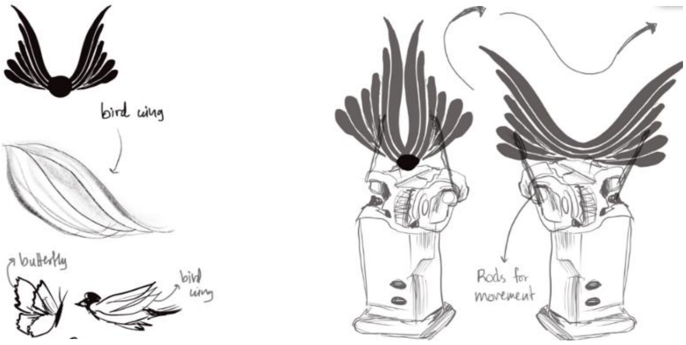


Figure 3: Wings of Nature

II. Blooming Energy: The second design proposed, can be seen in Figure 4. This design took inspiration from flowers, and more specifically, the natural process of buds blooming into flowers. The final design would transform from a closed flower bud into an open flower Recycled paper with natural dye would be used to represent the petals of the flowers. The kinetic movement of these petals would arise from moving rods, similar to the first proposal. This design reflected both, transformation, and flow of energy, within nature.

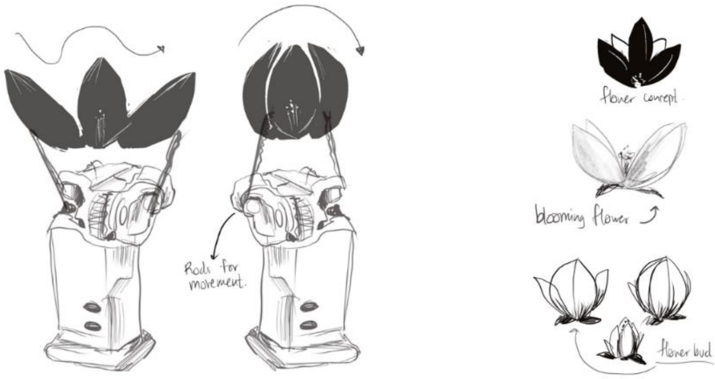


Figure 4: Blooming Energy

III. Clams and pearls: The third design proposal shown in Figure 5, took inspiration from the deep-rooted history of pearl diving in Qatar (a culturally significant profession and the main source of the nation's income before the discovery of oil). As a representation of sea life and the ocean, kinetic clam shells containing 3D printed pearls were the suggested unit cell design.

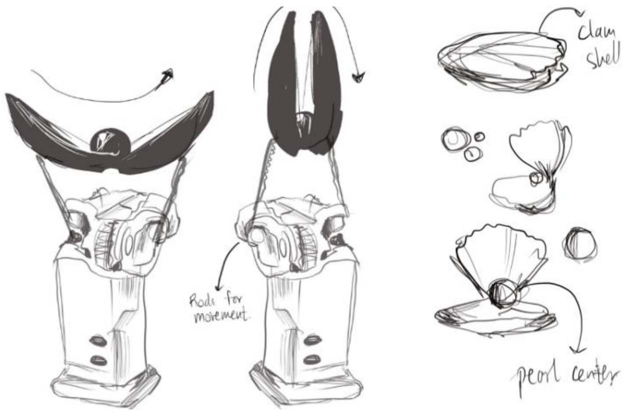


Figure 5: Clam and Pearls

Since the first design, ‘Wings of Nature’, was a relatively more generic representation of nature than the other two, it was chosen as the primary design for Project 2. Due to the designs being quite facile and simplistic, the teams aimed to make a large-scale installation which would incorporate up to a thirty of the similarly designed unit cells.

3. Experimentation and evolution:

3.1. Project 1

Once the initial designs were finalized and selected from the ideas put forth by the art and design students, the engineering teams gave their suggestions on how best to execute the ideas and initiate the physical building process. For experimentation, the mechanical engineering team was at the head of the first project; a physical sculpture of a water bottle with a pair of human lungs trapped within. The team decided that the frame of the sculpture for the first model would be made entirely from truss structures. The reason for this choice was based on the strength and reliability of trusses whilst being structurally simplistic and easy to build. Given the large height (3 meters) of the to-scale bottle model (a scale of 1 x 10 was chosen), structural stability was essential. Moreover, since the assigned scope of this project was sustainability, the teams aimed to construct the frame of the model entirely from recycled plastic water bottles. These were the initial conditions that the teams kept in mind before starting the building/designing process. The steps taken to get towards the final product are highlighted below, along with challenges faced by the students and the solutions they employed while facing these challenges.

The TrussFab extension allows the conversion of any CAD model created in Sketchup, into a mesh made only of fixed-length plastic bottles acting as joint members. Therefore, using the two software’s (Sketchup and TrussFab) as the primary design platforms was the ideal approach to meet the design/project requirements. The extension had preinstalled CAD models of single joint members made of specific bottle sizes, with the option to edit the bottle size according to the user preference. Since the pre-set bottle lengths were not available in Qatar, the students chose the most readily available/widely used bottle brands to set the size of the joint members. To allow for a more design freedom, while also maintaining structural homogeneity, only two different bottle sizes were chosen: The first bottle size was the 30.5 cm long 1.5 Litre Doha water bottle, and the second were the smaller 500 ml water bottles of Al-Rayyan that were only 15 cm in length. The combined length of two of each of these bottles would make one member.

For the final design of the basic sculpture, the base of the model was a hexagon. 5 identical layers on top of one another, followed by two smaller layers, each connected with equilateral triangles made up the shape of the water bottle and its’ cap. Sketch Ups’ scaling feature was used to reshape the top two layers to represent the curvature and the cap of the plastic bottle. The final rendering made by the students is shown in Figure 5. The next step was to convert this initial render into a bottled mesh using TrussFab. The first few iterations of the bottled mesh had some glaring flaws and required several edits and changes.

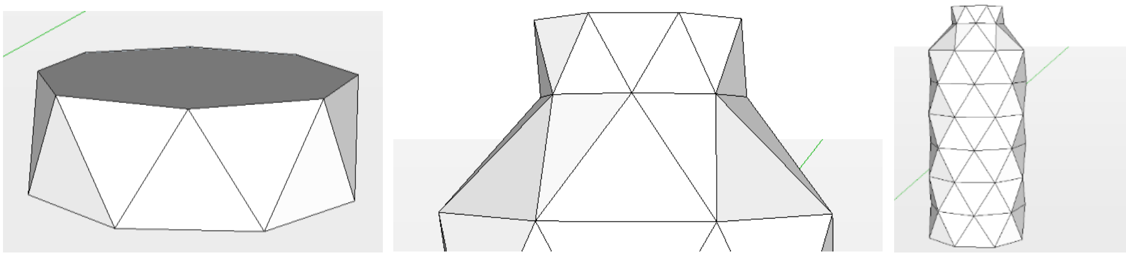


Figure 5: pre-meshed render

The next render had several interior trusses added to its lower most layers to improve structural integrity. To validate the new design, the mechanical team used SAP2000 to analyze and estimate the largest forces acting on each member. The stress analysis results of applying a point load of 5 Kg's to the point where students aimed to hang the lung structure, i.e. the top layer's centre, are shown in Figure 6 below. Part A represents the final meshed design. Parts B represents the estimated axial forces that each member experienced, and parts C and D represent the moments in each axis about every joint. The largest axial force was 48 N, the largest shear force was 8 N, the largest moment was 2N and the largest torque was .15 Nm. To confirm the deformation estimation given to us by the software, students decided to run some manual tests as well. Tensile testing of the bottle members and the 3D printed connectors (elaborated on below) was done with referance to the results from the structural analysis. There was none/minimum deformation of members at the given loads.

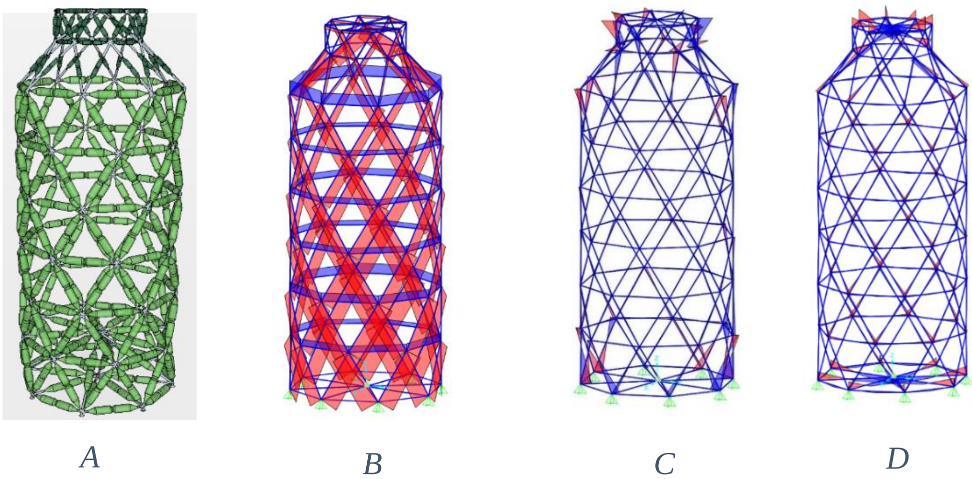


Figure 6: Meshed design and load analysis diagrams

Once the design was finalized, the next step was to generate the 3D printed plastic connectors and pods that would connect the bottle members together. Many of the connectors that were generated by the software, especially the ones at the top most layers, where the members were diagonal instead of completey vertical, were interjoined. This prevented students from attaching the C-Cuffs (used to hold the bottle members in place) to the connector and the bottles. To solve this problem, students decided to increase the length of the connectors in this specific layer by using smaller bottle members instead of the big ones. Visual representation of this specific flaw can be seen in figure 7, along with the edited CAD design to overcome this flaw as well as the final printed part.

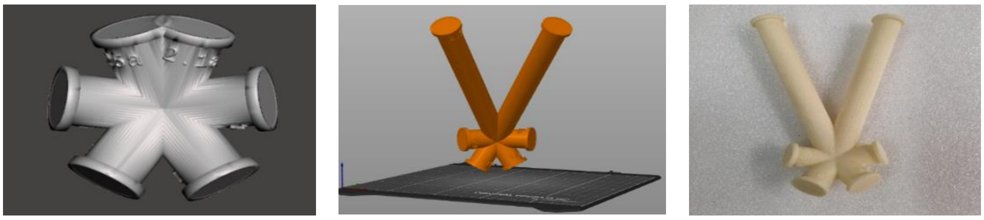


Figure 7: Faulty Interjoined connector versus the modified result

Once all the connectors were checked, the next step was to make sure that all connectors would individually fit in one of the available desktop 3D printers. 50 of the 75 connectors fit easily in the printer bed of the selected printers. However, for the 25 that did not fit, the students had to come up with an appropriate solution. An example of such a connector can be seen in Figure 8, which shows an unprintable connector with large diagonals. Next to it, a modified version of this CAD design can be seen which was split into layers using meshMixer to make it fit within the printer plate. The respective final printed parts can also be seen.

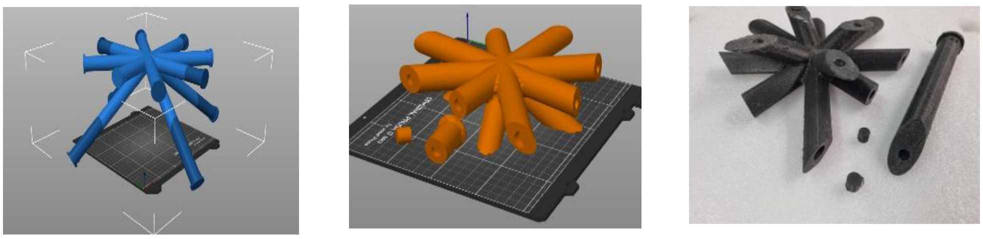


Figure 8: Unprintable Base connector and its modified/printed version.

Before initiating printing, the team of students directed their efforts towards mass collecting recycled water bottles for both shredding and member creation. The shredded material would then be extruded to make a printable filament. This step was vital as the objective was to use recycled plastic for 3D printing, given that the project was a representation of sustainability. Almost two thousand plastic water bottles were collected by the students which were then cleaned thoroughly, first with water and then with acetone. After the acetone clean, each bottle was then rewashed, dried, and set aside for shredding. Before simply shredding the bottles however, the teams also worked with direct filament maker machines that are shown in figure 9. As a team activity, they set the machine up/put the machine together using blueprints. Once the machine was functional, it was used to convert cleaned bottles into ready-to-use filament. Unfortunately, this process took longer than simply shredding the bottles, Hence, due to time constaraints, shredding was choosen as the primary method of bottle to filament conversion.

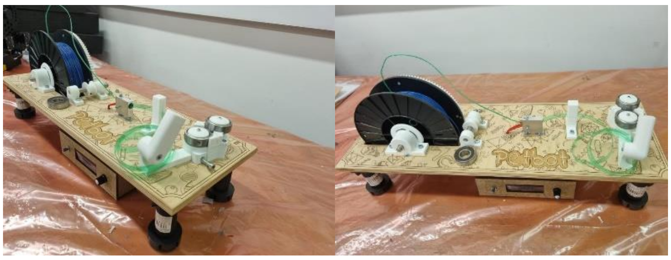


Figure 9 Filament maker machines set up by students

Once shredded, the material was then put through an extruder and the created filament was used to make the connectors. A key step was confirming the adequate printing parameters for the shredded recycled PET filament, as this information was not readily available on the internet.

For this purpose, before printing entire connectors/models, small shapes were printed using the shredded filament. Once printed, they were checked for their brittleness and structural stability. The initial parts proved to be quite fragile and the connectors parts broke down when the smallest of forces was applied to them- even during post processing steps of taking off the support material. The engineering team then decided to increase the infill value of the printed parts, and reprint the test parts. On the second attempt, the printed parts were much more robust and durable, although not as durable as parts printed from ABS plastic. The varying part quality proved to be one of the limitations of this project. With these parameters, the students started setting up jobs for printing the actual connectors, starting from the base layer. Once the parts were printed, the students set about manually removing the support structures, and building the model up layer by layer. The final products' height was adjusted to compensate for time constraints, and the result was a mirror reflection of the original idea as shown in figure 10 below.

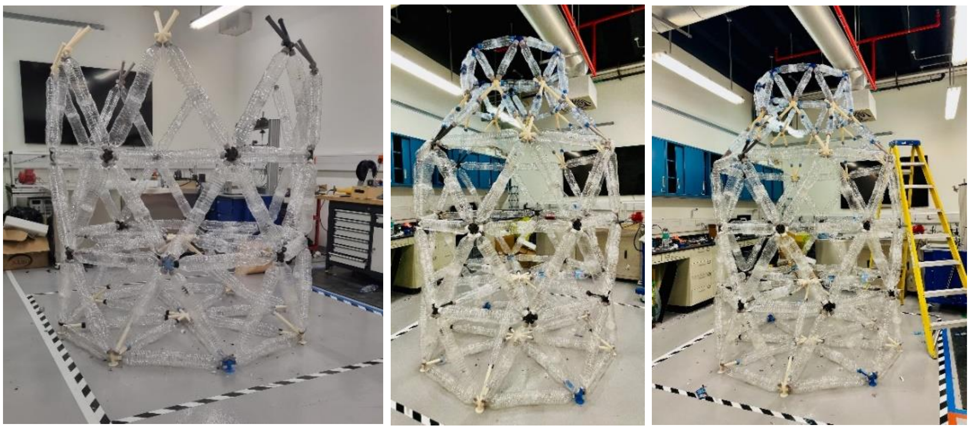


Figure 10: Project 1 final sculpture

3.2. Project 2

The second project aimed to bring together the best of both worlds- the creativity and technical knowledge design students and engineering students, respectively. Building upon the proposed ideas of the engineering team, the chosen design ideas incorporated the use of a variety of electronic equipment (Servo motors, sensors, and microcontrollers) along with 3D printing equipment to create personalized and adjusted gears to control the movement of the origami design. The mechanical engineering team assisted the electrical team by leading the 3D-printing efforts. The significance of the ideation stage is reflected in the brainstorming efforts of this second project, as the teams not only had to work in a more limited scope but were also facing time constraints.

To bring the project to life, the team first had to determine the operating system. They decided to use servo motors with feedback to create a blooming motion for the origami paper, which would be attached to the 3D-printed gears. Ultrasonic sensors were also incorporated to detect motion in front of the design and trigger the movement of the origami. Electronic equipment such as servomotors with feedback, Arduino boards, ultrasonic sensors, and raspberry pi boards were ordered. These electronic components were necessary to create the motion and ensure that the origami pieces are moving in the right direction.

Before the team started working with the electronic equipment however, 3D designs had to be printed. The required 3D parts for the unit were available online. The mechanical engineering team printed one set of gears to test them out with the available electronic equipment. Mechanical engineering team went through different iterations of design to improve the motion mechanism as shown in Figure 11. The final design was of a great improvement compared to the initial design which they downloaded from the internet. Final design is show in Figure 11 to the right. Figure 12 shows different designs 3D printed using FDM and SLS printers for testing.

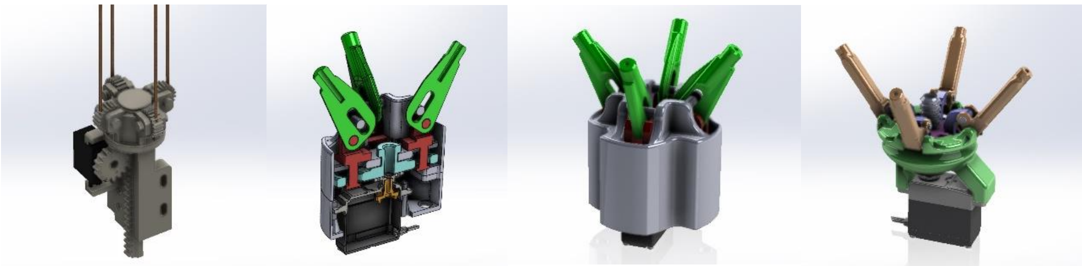


Figure 11: Different design iterations for the origami mechanisms, final to the right

Figure 12: 3D printing of different design iterations of the origami, final to the right

While the gears were being printed, the electrical team tested different codes to move one servo motor by detecting motion that was 6cm away from the sensor. The sensor's role was crucial as it allowed the servo motor to respond to any motion detected. Multiple codes were tested until a relevant simple code worked perfectly. The code was also adjusted and tested to test four different sensors with four different motors on one Arduino board. This was necessary to ensure that the motion was consistent throughout the piece. One unit was created, and to test the blooming mechanism, sticks were added to the top gears, and one origami test swan was glued to the sticks, as shown in Figure 13. Once the sensor detected motion, the servo would work, and then move the gears, which would lead to the sticks moving the piece of paper. The origami swan would bloom as the servo motor's movement caused the gears to turn. The basic cell was fully tested, and test was successful.

The teams worked tirelessly to bring the project to completion, constantly refining and perfecting the design to ensure that it was both aesthetically pleasing and technically sound. The result was a project that was both beautiful and functional, displaying the team's dedication to the integration of electrical components with art and design. The final product was supposed to be like what is shown in Figure 14, an array of 30 cells fixed on a support structure, but by the submission due date this was unfortunately not done.

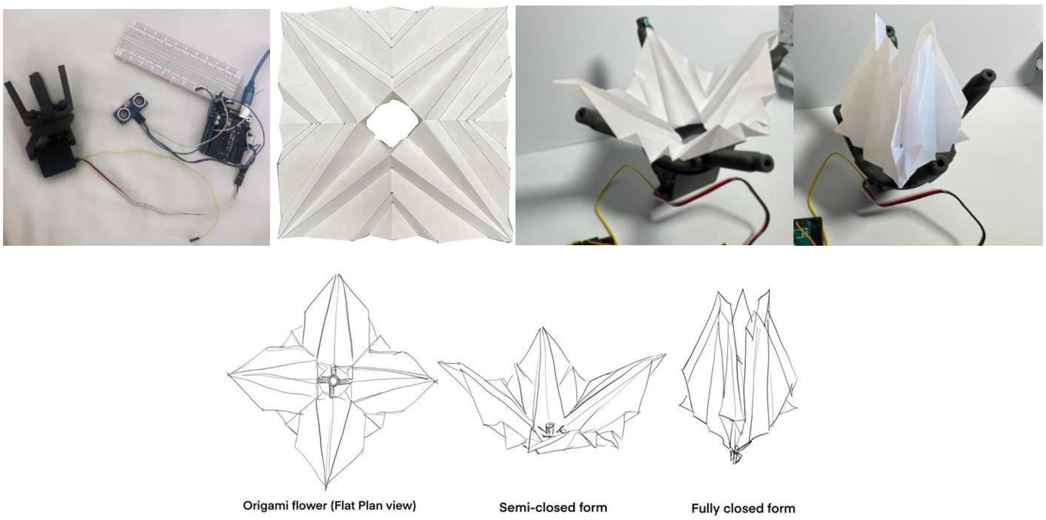


Figure 13: Control electronics to the left, and the origami prototype to the right

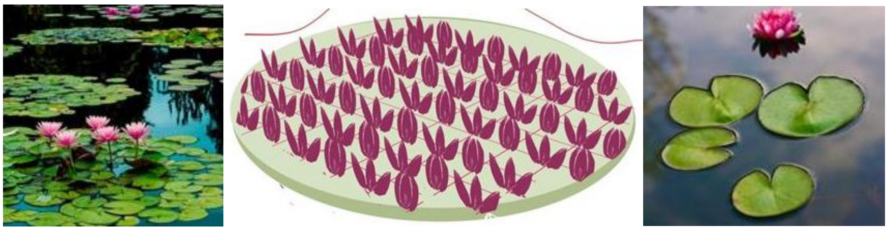


Figure 14: Project two final product CAD model

Results and analysis

The finalization of the two art installations brought about an end to the collaborative project. The question on hand now was whether our efforts were successful in cultivating engineering students who are "out of the box thinkers", and technologically well-versed artists. The key factors that played a role in evaluating the efficacy of our pedagogical approach were as follows.

1. Participants ability to work in interdisciplinary teams.
2. Participants ability to innovate and execute ideas.
3. Participants ability to iterate their proposed solutions.
4. Participants ability to effectively communicate.

To assess the extent to which students benefited from the learning outcomes, we conducted a survey at the conclusion of the study. The survey was given to every student who had participated, and it included both open and close ended questions. To get quantifiable information about the students' perceptions of their learning outcomes, teamwork, and general satisfaction with the project, the closed-ended questions were employed. On the other hand, open-ended questions were used to gather qualitative information on the experiences, difficulties, and recommendations for improvement by the pupils. Using statistics and content analysis, the survey results were analysed, and certain conclusions drawn. The results can be seen below in figure 15.

The success of the multidisciplinary collaboration in both projects can be attributed to the use of design thinking as a framework, where students developed a systematic approach for each project that followed the stages of design thinking. This resulted in a satisfactory outcome within the time constraints of the academic collaboration. The students thrived in the environment of sharing ideas, tasks, and giving peer reviews. This contributed greatly to the successful application of design thinking. Survey results show that the interdisciplinary approach used in the projects highly promoted cross-disciplinary collaboration and fostered creativity. Most students reported that the projects helped them develop new skills and knowledge beyond their disciplinary expertise. The students rated the development of teamwork an average value of 4.5 out of 5, showing that they believed they could function well as a diverse team. The development of the students' ability to successfully convey their ideas across disciplines, i.e., their ability to effectively communicate with other majors was indicated by the average communication development rating of 4.25 out of 5. The average rating for development of time management was 4 out of 5, indicating that the student’s ability to effectively manage their time and meet the project deadlines was positively impacted. The most noticeable of all of these scores was the high score that participants gave to the development of their creativity. Both art students and Engineering students gave positive feedback with respect to an improvement in innovation and creativity especially whilst problem solving. This spoke to the success of the two main aspects of this project/s; a multidisciplinary collaboration that integrated the strengths of an engineering-based education with that of an Arts based education, and the use of design thinking to produce outside the box thinkers. Despite a positive participant feedback, there were some areas where the collaborative project scored low. The development of hands-on skills is one such example. It had an average rating of 3.5 out of 5, with the lowest ratings coming from the Art and design team members who answered the survey questions. This can be easily explained, as the purpose of this multidisciplinary project was to combine the skillsets of both art and engineering students- bringing together the best of both worlds. With this in mind, the Arts team was mostly responsible for ideation and design of ideas, while the engineering teams led the majority of the practical implementation of the brainstormed ideas. Similarly, the survey results showed that the average rating for instructor support and guidance was 2.5 out of 5. This low score, can be attributed to the nature of design thinking pedagogy where instructor acts as a facilitator and leave students on their own to explore the whole scope of design and encourage them to work together collaboratively. In the open-ended questions, the students showed a high level of satisfaction with the selected projects and recommended that similar projects be incorporated into future curricula.

Conclusion

This paper presents collaborative work between students from the Engineering and Arts majors, revolving around implementing design thinking in a multidisciplinary context. Initially, students from each major established a solid background about each other's majors. The activity spanned over 12 weeks, during which students carried out two projects to simulate real-life scenarios. The survey results support the effectiveness of the approach used. For future efforts and implementations of a similar pedagogical framework, the authors aim to incorporate feedback loops to gather insights from participants. They also plan to conduct a comparative study to better understand the effectiveness of the implemented approach in a more reliable way than surveys. The authors are also planning to expand the scope of such multidisciplinary efforts to other fields (beyond art and engineering) or contexts (beyond sustainability), where design thinking and multidisciplinary approaches could be beneficial. This could involve exploring new areas of application, such as healthcare.

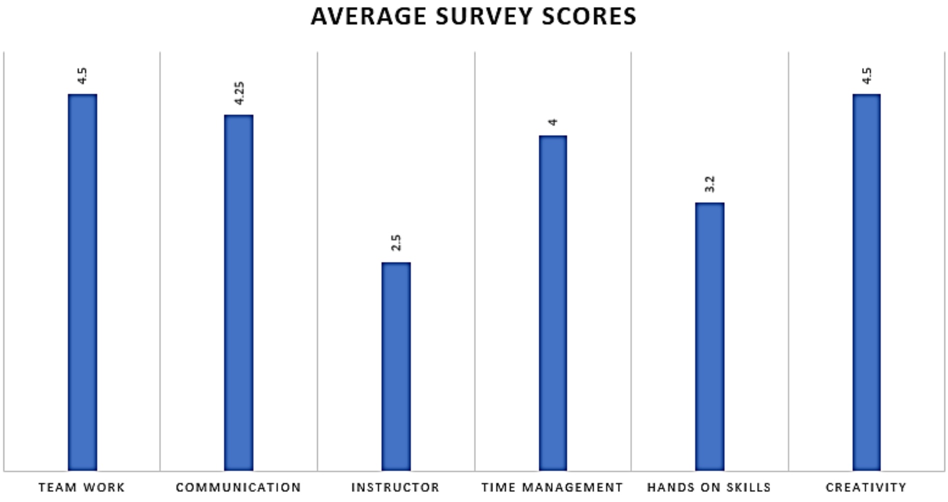


Figure 15: Survey Results

References

[1] https://www.ted.com/talks/bran_ferren_to_create_for_the_ages_let_s_combine_art_and_engineering?language=en

[2] N Schechter, G R Schmeidler, M Staal, "Dream reports and creative tendencies in students of the arts, sciences, and engineering.", https://psycnet.apa.org/record/1966-00104-001

[3] David skorton and Ashley Bear, "The integration of humanities and art with siences, engineering and medicine: Branches from the same tree", The National Academies Press.
Available on Google Books: https://books.google.com.qa/books?hl=en&lr=&id=JQGKDwAAQBAJ&oi=fnd&pg=PR1&dq=engineering+and+art+students&ots=I5vbvB7zJ2&sig=EPXcsdKEm_YXFNghcvmGKt09v7Q&redir_esc=y#v=onepage&q=engineering%20and%20art%20students&f=false

[4] Helen Atkinson & Martin Pennington, "Unemployment of engineering graduates: The key issues", December 2012 https://www.researchgate.net/publication/275107194_Unemployment_of_engineering_graduates_The_key_issues

[5] Miriam Firth, Elli Whitefoot: "What do creative arts graduates do?" December 2022 https://luminate.prospects.ac.uk/what-do-creative-arts-graduates-do

[6] Design Thinking, Teaching strategies, Iowa State University, https://www.celt.iastate.edu/instructional-strategies/teaching-strategies/design-thinking/
[7] Galena Pisoni, Marcella Hoogeboom, "Investigating effective dynamics of virtual student teams through analysis of Trello boards", 2019 17th International Conference on Emerging eLearning Technologies and Applications (ICETA), pp.639-643, 2019 https://ieeexplore.ieee.org/document/8476051
[8] Maria J. Żychowska, "Humanisation of engineering studies", Available online: World Transactions on Engineering and Technology Education, Vol.17, No.3, 2019: http://www.wiete.com.au/journals/WTE&TE/Pages/Vol.17,%20No.3%20(2019)/06-Zychowska-M.pdf
[9] Beth Altringer and Fawwaz Habba, "EMBEDDING DESIGN THINKING IN A
MULTIDISCIPLINARY ENGINEERING CURRICULUM", VentureWell 2015: https://venturewell.org/open2015/wp-content/uploads/2013/10/ALTRINGER.pdf
[10] https://riceartandengineering.wordpress.com
[11] Biswas, Amitava. (2008). Managing art? technology research collaborations. Int. J. Arts and Technology Int. J. Arts and Technology. 1. 66-89. 10.1504/IJART.2008.019883.
[12] L. Jaccheri and G. Sindre, "Software Engineering Students meet Interdisciplinary Project work and Art," *2007 11th International Conference Information Visualization (IV '07)*, Zurich, Switzerland, 2007, pp. 925-934, doi: 10.1109/IV.2007.102. https://ieeexplore.ieee.org/abstract/document/4272089?casa_token=DfnzntUqrOIAAAAA:0Aexe44slmiMhIGIO62u7_AgWL6eppiZLsfWzjwYehMJ4ghi31Jk_B9ithMvCRQefRtijAb4
[13] Why Design Thinking Works. Harvard Business Review, 96(6), 72-79. https://hbr.org/2018/09/why-design-thinking-works
[14] Cara Wrigley and Kara Straker, "Design Thinking pedagogy: the Educational Design Ladder", Innovations in Education and Teaching International
Volume 54, 2017 - Issue 4, Pages 374-385
https://www.tandfonline.com/doi/full/10.1080/14703297.2015.1108214
[15] Jacki Craven, 'The Meaning of 'Form Follows Function', Humanities, ThoughtCo
https://www.thoughtco.com/form-follows-function-17723