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Storytelling with Machines: Innovative Approach of Developing Creative Mindset and Teaching About Mechanisms Through Stories

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Storytelling with Machines: An innovative approach to foster a creative mindset and to learn about mechanisms through stories

Abstract

The historical ancestors of computers and robots have interesting stories to tell. From abacuses to tea-serving karakuri puppets, "automata" have long been used as tools for explaining scientific principles and for amusing entertainment. To tap into the use of automata for explaining scientific principles, an undergraduate-technical elective course was developed that explored the engineering principles of mechanisms in an innovative way: by adopting automata for creative storytelling. The details of this course are described in this paper. The objective of this course was to teach students about mechanical elements with the context of storytelling. Students learned about the basic elements of mechanical systems while emphasizing the underlying physical principles. Students also developed an understanding of the working principles of elements such as linkages, cams, and gears, which generate and convey mechanical motion. In addition to studying these physical elements, the students investigated the mechanics of storytelling, and they explored the historical and creative relationship between automation and narrative. Through hands-on projects, students designed and fabricated basic automata that give life to stories of their own design. From the project deliverables and student reflections, the author finds that incorporating storytelling and automaton creation had three major impacts on student learning. First, it allowed students to create connections between elements of storytelling and engineering and provided a new perspective to approach engineering problems. Second, it allowed students to think out-of-the box and fostered their creativity. Finally, this pedagogical approach also had broader impact on students' attitudes towards their professional career.

Introduction and Motivation

Creativity is listed as one of the top attributes of the engineers in 2020 [1]. In the context of engineering, creativity means invention, innovation and thinking outside the box to solve the diverse and complex problems of the 21st century. A typical engineering curriculum tends to focus heavily on technical subjects such as mathematics, physics, and discipline-specific material [2] . Most of the student credit hours are spent in completing curricular requirements. Various creative subjects such as arts, music, and theatre are only present in vestigial form [2] and are not explored by engineering students to the fullest due to lack of time, opportunity or motivation.

Exposing the engineering students to creative arts and allowing them to explore it has a potential for significant benefits. The works of Leonardo da Vinci are one of the most famous examples of innovation resulting from the integration of arts and engineering. Leonardo da Vinci was a painter, sculptor, scientist, engineer, architect, anatomist and has made significant contributions and discoveries in each of these fields. In fact, his interest in a variety of fields and the ability to connect the knowledge from different fields is what led to many of his inventions [3]. Educators have investigated several approaches of integrating art and engineering in an educational setting. This has either been done through interdisciplinary course enrolling a combination of art and engineering students [4, 5, 6, 7] or by incorporating modules or projects into existing engineering or art courses [8, 9, 10, 11, 12] or labs [13].

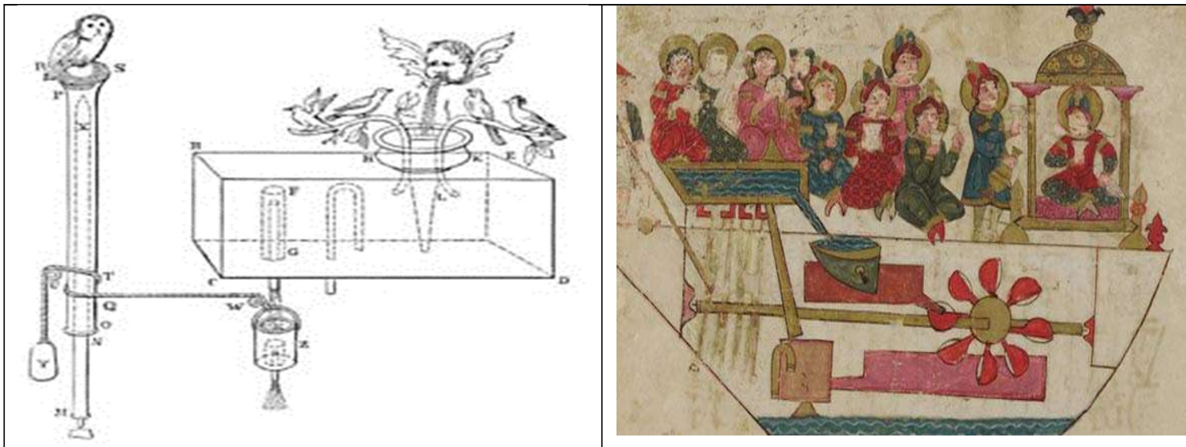
Often, these approaches have been adopted in design type classes where an element of creativity is already present and is enhanced through incorporation of art. *Storytelling with machines* is unique in its approach in that it is not inherently a design class but rather a technical mechanisms class in the context of mechanical engineering. Traditionally, a class on mechanisms tends to be heavily mathematical and analytical with little scope for creativity. Thus, to encourage a creative mindset and provide students with a different lens of looking at mechanisms, the elective *Storytelling with machines* was developed by leveraging the elements of storytelling and automaton building. The goal was to study the impact of such incorporation. To that end, this exploratory research begins to answer the research question (RQ):

RQ – What is the impact of incorporating storytelling and automaton creation on the students' learning in a mechanisms design class?

Literature Review- Storytelling and automata in context of engineering

Storytelling is an ancient art and is often the portrayal of real or fictionalized experiences [14]. There are various types of storytelling such as oral storytelling, written storytelling, visual storytelling, and digital storytelling [15]. Storytelling has been used in engineering in many ways. Stories have shown to support learning and cognitive development [16]. Some examples include using storytelling as a tool to stimulate students' interest and passion in engineering design class [17], using generative storytelling in interaction design class to foster communication among engineering students [18], and using digital storytelling to help students address the complexities of design problems [19]. Researchers have also used storytelling as a tool to develop a theory of culturally contextualized engineering design curricula and assessment tools for Navajo middle school students [20, 21]. In this work, the researchers used stories of Navajo engineers and scientists to introduce engineering design concepts to middle school students. In the context of this class, storytelling is used as a tool to allow the students to showcase their learning about various mechanisms. Thus, the students were building the machines (automaton) to tell a story.

The word automaton is derived from Greek and means "acting of one's own will" [22]. An automaton is a mechanical device build to represent a human or an animal and gives an illusion of acting by their own power [22]. Originally developed with the purpose of entertaining people, these automata became the predecessor of modern-day robots and computers. The first recorded automata appeared in Egypt in second or third century BC developed by Greek mathematicians and inventors [23]. These early automata used basic mechanical elements as well as complex principles of pneumatics for their automata. Some of the very early automata were developed by a mathematician Hero of Alexandria. Other well-known automata developed over the history include the Al-Jazari automatons of 12^{th} and 13^{th} century (example -automatic wine dispenser, a soap and towel dispenser, orchestra operated by force of water [24]), the digesting duck of Vaucanson in 17^{th} century, the great Turkish chess player in 18^{th} century, Pierre Jaques-Droz automaton in 18^{th} century and many more [23]. Figure *1* shows some example automata from the past.



(a) (b)

Figure 1 Sketches of example automaton from the past (a) Hero's wash basin automata *[22]*, (b) Al-Jazari's orchestra operated by force of water

These automata originally developed for entertaining the public often became tools for educating about various mechanisms and physical laws [23]. Storytelling with machine leverages this idea of using the automata as a tool to allow students to explore, design and build mechanisms with a more creative context.

The remainder of this paper discusses the development of this course and findings from the impact of incorporating storytelling and automaton building in a mechanisms design class.

Course Overview

Storytelling with machines course was taught as an elective in a department where a singular Bachelor of Science in engineering (BSE) ABET accredited degree is offered. The undergraduate focused teaching-institution is located in the mid-Atlantic region of the United States, with a predominantly white student population hailing from the Commonwealths of Virginia and Pennsylvania and States of New Jersey, Maryland, and New York.

Learning Objectives

The following learning objectives were established for students:

At the end of successful completion of this course, the students should be able to:

- Understand the principles and workings of basic mechanical elements such as linkages, gears, and cams.
- Select appropriate mechanisms for desired motions
- Execute steps of the design process such as requirements gathering, concept generations, concept selection and prototyping
- Demonstrate technical and creative skills in design and fabrication of mechanisms using tools such as Computer Aided Design (CAD), laser cutting, and prototype techniques.

- Recognize key storytelling structures and methods.

Course Format and Approach

This class was offered in the Fall 2020 semester. The class met for a 16-week semester, as a 3-credit course and was offered as an elective in the engineering curriculum. The class met twice a week on Tuesdays and Thursdays for 75 minutes per class period. Due to COVID-19, the class only met in person for the first week and then transitioned to online instruction. After going virtual, the topics of the class were presented in modules using the institution's learning management system (LMS). The class time was used for various activities to allow for understanding of the topics (see Table *1*).

This institution allows students from variety of majors to sign up for certain technical electives. Thus, while this technical elective was offered for engineering students, students from majors other than engineering could sign up for the class. A total of seven students enrolled in the class including four students with engineering major, two students with biotechnology major and one student with industrial major. Of the seven students, four were male and three were female.

The department of engineering at this particular university is non-discipline specific. Thus, technical electives are offered in a variety of engineering topics based on the expertise of the faculty member. For example, one faculty member with civil engineering background offers a technical elective on structural analysis, while another faculty member at the same department with computer science background offers a technical elective on Design for Internet of Things. The faculty member teaching this course has mechanical engineering background and thus, the focus of the class was primarily on mechanisms within context of mechanical engineering.

Topics covered in the class included theory of mechanical elements such as linkages, gears and cams, elements of storytelling and automaton building. These topics with major class assignments are listed in Table 1. Typically, the topics of mechanisms and story or automaton were covered in alternate weeks. Three major mechanisms were covered in the class including linkages, gears, and cams.

Fairytales were used to contextualize the instruction around storytelling elements. The instruction included introducing various genres of fairytales, elements of a fairy story and character development. Fairytales were selected due to the familiarity of these stories. The materials used to teach the concepts of storytelling were curated by the author using a variety of online resources [25, 26, 27] as well as reference books [28, 29, 30] . It may be noted that while fairy tales were used to contextualize in class, the students were not limited to using fairy tales for their projects.

The concept of the connections between storytelling, automaton and mechanisms was established in the first two weeks of the class through various activities. This was done to provide a context for the class. One of the first activities was writing a story about an automaton. For this activity, the students were shown a short animation of an automaton and asked to write a story about it thus allowing them to connect automaton and storytelling.

Table 1 Class topics with major assignments

Week	Mechanism Topics	Story/Automaton Topics
1-2	Introduction to class, Basic physics, Introduction to mechanisms	Introduction to fairytales – what are fairy tales, genres, automaton basics
3	Linkages -what are linkages, types of linkages -four bar, slider crank, straight line, special mechanisms	Elements of story -context, arc, characters, conflict, moral, audience and narrator -reverse engineering story into elements
3-4	Mini Project 1 – Linkage Automaton	
5	Cams – What are cams, types of cams, types of followers, follower motions, displacement diagram, disk cam profile	Character development – what is a character, types of characters, functions and evolution over time, character relationships in story.
6		Mood board development – What is mood board? Elements of mood board, how to develop character mood boards
6-7	Mini Project 2 – Cam Automaton	
8	Gears – What are gears, types of gears, spur gear terminology, velocity ratio, spur gear selection, gear trains	
8-9	Mini Project 3 – Gear Automaton	
10		Automaton Artists – Introduction to prominent automaton artist, review of the unique features of their work, inspirations for final project
11-15	Final Project	

Another activity was toy dissection [31]. For this activity, each student in the class was given a small wind-up toy and a mini tool set to take the toy apart. In order to spark their curiosities about mechanisms, before taking the toy apart, the students were asked to play with the toy for few minutes and try to imagine the mechanism that would make the toy move in a certain way. For example, if a monkey flipped after winding it, what mechanism would make it flip? The students were asked to draw a sketch of the mechanism. After that, the students dissected the toy and studied the mechanism inside the toys. This activity allowed students to appreciate the complexity of mechanisms in seemingly simple toys. This activity also allowed them to create connections between mechanisms and movements. This is evident from the quotes in the reflection submitted as part of the assignment.

"I leaned how complicated the design was. I learned that it takes many different parts and mechanisms to make a simple movement."

"There was at least 20+ components that made this simple toy function."

"Singular parts can cause multiple motions".

"There are complicated processes that cause simple motions".

In addition to these activities at the beginning of the semester, the students were given reflection assignment with each major assignment to continue reflecting on and building the connections. Throughout the semester, the students were assigned three mini projects and one final project. The details of these assignments are discussed next.

<u>Major Class Projects</u>

The purpose of the class projects was multifold. The primary goal was to allow students to explore the design and synthesis of various mechanisms with the context of building an automaton for a scene from selected story. Another goal was also to gradually increase the complexity of the projects throughout the semester to allow students to incrementally build their knowledge and expertise. Throughout the semester the students were assigned three mini projects and one final project. At the core, the goal of each project was to build an automaton to depict a scene from a story. At the beginning of the first mini project, the students explored various fairy tales and selected one for their project. It may be noted that students were not restricted to using fairy tales and could use other stories for their project.

Mini project 1

The goal of the mini project 1 was to explore linkages in context of their selected story. The students were required to design and build a simple automaton using only linkages showcasing a scene or character from the story. Once the story was selected, the students were asked to identify the movements either from a scene or a character that they would like to create an automaton for. They were required to identify input and output motions and were only allowed to use linkages to achieve those movements. Examples of such movements would be waving of wand, raising of the hat, going around in circles etc.

Deliverables for the first mini project included update check-in, reflection, and a presentation to the class with demonstration of the automaton.

Mini project 2

The goal of mini project 2 was to explore cams and design and build a simple automaton depicting a scene or a character from their story. For the second mini project, the students had to modify one of the characters from the original story and re-write the story with the modified character. The students had to apply the principles of character development in story to modify one character and update their story accordingly. For this project, the students were required to have at least two moving elements featuring at least two different types of cams and were only allowed to use cams for accomplishing input and output motions.

Deliverables for mini project 2 included character development and writing the modified story, project presentation with demonstration of the automaton and reflection.

Mini project 3

The goal of mini project 3 was to explore gears and build simple automaton using only gears. For this project, the students could use any theme they liked for their automaton. This was done to allow for creative freedom with the theme of the automaton and broaden the range of their exploration beyond the selected story. Their automaton was required to have at least 4 gears with at least 2 gears of different sizes. This was done to add sufficient complexity to the project.

The deliverables for mini project 3 included a gear selection memo, project presentation with demonstration of the automaton and reflection.

Final project

For the final projects, the students were asked to create a more complex automaton including at least two of the three different elements from linkages, cams, and gears. Additionally, the automaton must have at least three moving elements.

The first task for the final project was to select a story individually and then work with their team member to combine the individual stories. To combine the stories, the students could modify characters, scenes, include new elements, discard elements from the original story. They were then asked to write the new story.

After the new story was written, the teams worked on storyboarding different scenes that had potential to be automated, created mood boards for the characters and scenes for the automaton. Each member of the team was required to create their own automaton while making sure that the various elements of the story are cohesive between different automaton. Their final automaton had to fulfil following requirements:

- Dimensions
  - Minimum – 5” X 5” X 5”
  - Maximum – 10” X 10” X 10”
- The automaton must have at least two different elements from linkages, cams, gears
- The automaton must have at least three moving characters in the scene.

<u>Adjustments due to COVID-19</u>

One of the foci of this class was learning various hands-on skills such as prototyping, 3D printing, laser cutting. Due to the pandemic, the classes moved virtual, so it posed challenge for the making aspect of the class. For the first project, the students were encouraged to build their prototypes using household materials such as cardboard, popsicle sticks, glue, wood scraps and scrap paper. For all future projects the instructor created a basic prototyping kit for all students. This kit included materials such as foam board, wooden dowels, gear set crafting set, paper fasteners, and tools such as hot glue gun and precision knife. In addition to the materials, the students could also attend virtual workshops for laser cutting and 3D printing offered by the library at this institute.

Another adjustment was made to the final team project. Instead of having to deliver one automaton build collective by the student team, the tasks were distributed between teams and individual to allow for collaboration in a virtual environment. Thus, the students worked in teams virtually to combine story, create mood boards, and determine the theme of the automaton. After this, everyone could create a different automaton as long as the themes and elements of story were consistent across the teams. This allowed the team to collaborate on certain aspects of the final project while accommodating for the fact that the members were at different locations and thus had freedom to build their own designs.

Student performance -Examples of student work

As part of mini project deliverables, the students had to make a presentation of their process along with the demo of their final project.

Example of student work as part of mini project 1 (linkage automaton) is shown in Figure 2 and Figure 3. For their project, this student selected the story of Paul Bunyan [32] . For their automaton, they selected the scene where Paul Bunyan -the giant is cutting down the trees by swinging his axe. The normal lumberjacks are also shown cutting down trees to contrast the size of the giant. The student started the process by sketching out the input and output motions and linkages that would allow them to achieve those motions. After the initial sketch, they developed preliminary prototype using foam board to test out the motions and made corrections as needed. Figure 3 shows a more complete automaton for the linkage project.

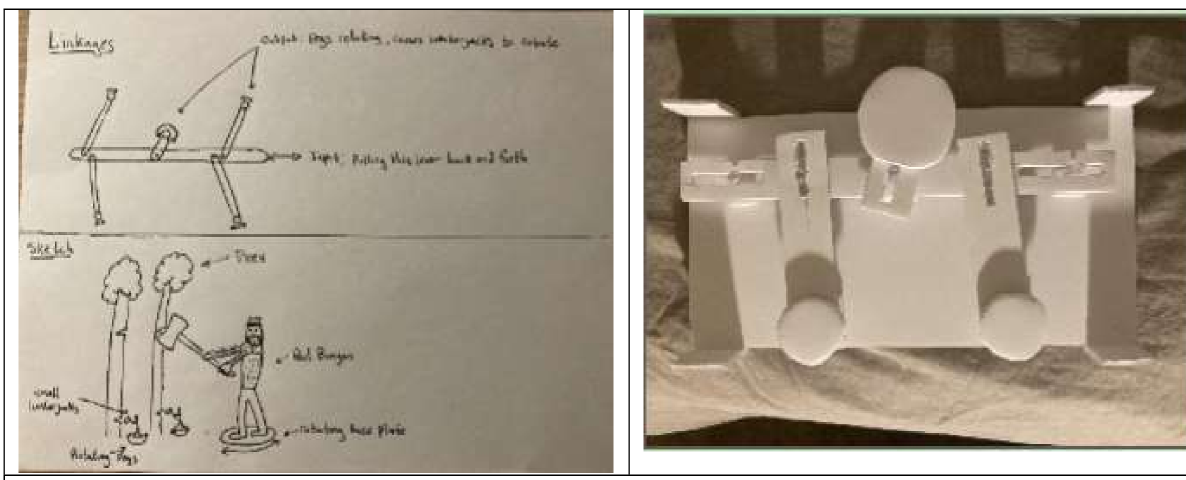


Figure 2 Example of student work for mini project 1 linkage automaton

Figure 3 Completed automaton for linkage automaton

It may be noted after going virtual, the students were required to use the materials they could easily access around them to complete the project. Most students only had access to material like cardboard, paper scraps, glue and scissors. Therefore, the final outcomes of the first mini project were not refined.

Example of student work for the second mini project (cam automaton) is shown in Figure 4.

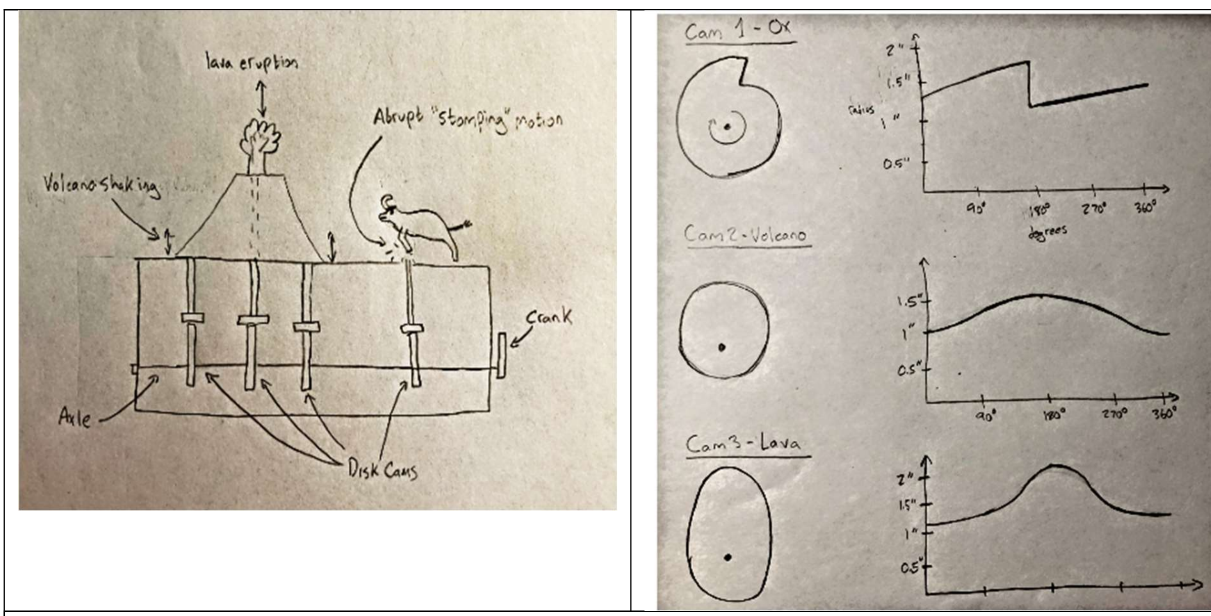


Figure 4 Sketches and Cam Displacement for mini project 2 (Cam Automaton)

Recall that for the second mini project, the students had to select one character from their original story, modify the character and rewrite the story. Their automaton should showcase the scene including the modified character. In the example shown here, the student modified the character of Babe the Blue Ox. Instead of the calm character, the modified character was short-tempered, would avoid humans and was destructive in nature. For their second project, the student selected the scene where the volcano erupts due to the destructive activities of the ox. Figure 4 shows the concept sketch of the automaton and the cam displacement diagram. Figure 5 shows the completed automaton. Here the snail cam causes the ox to have stomping motion and the three other cams cause the volcano to shake and the lava to erupt. The automaton is driven through a hand crank. The colors of the automaton represent the angry nature of the ox.

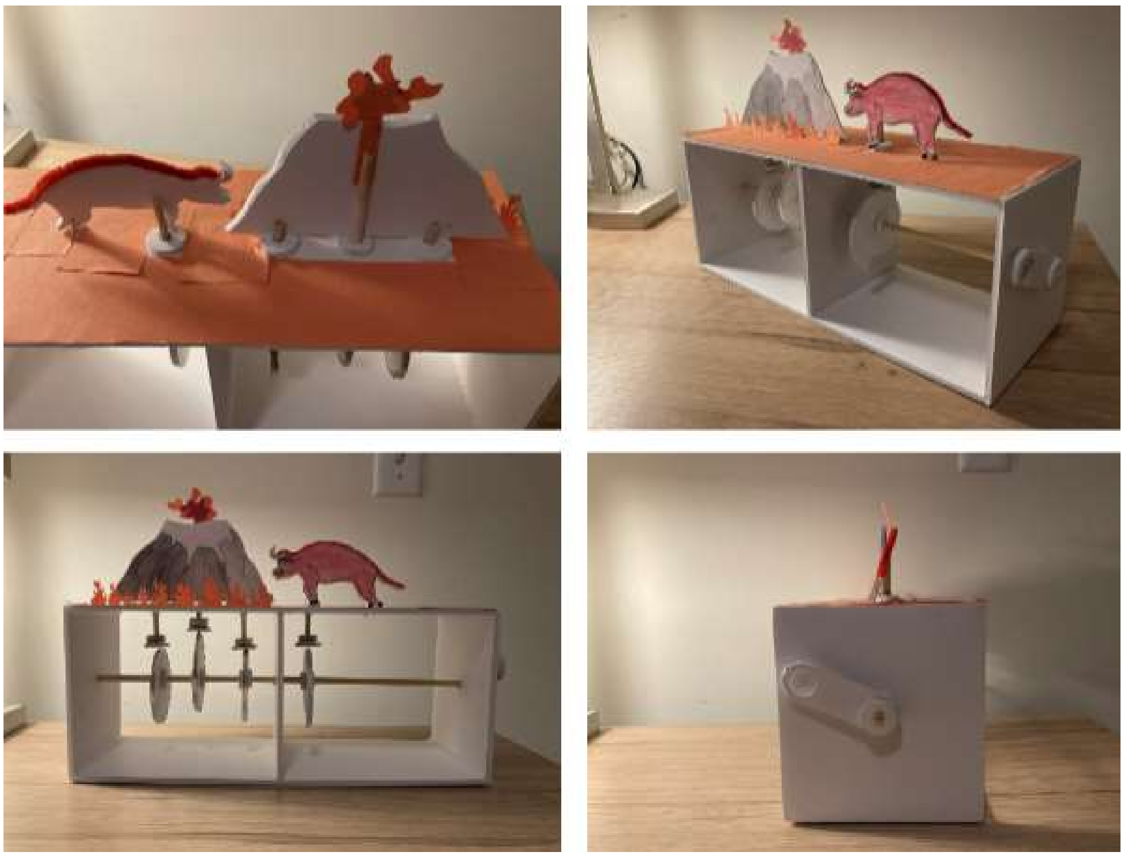


Figure 5 Completed automaton for cam automaton

For mini project 3 (gear automaton), the students were free to select any theme they liked to provide for creative freedom and exploration of possibilities. This led to the portrayal of some interesting themes by the students as shown in Figure 6.

In Figure 6, the image on the left is self-portrait by a student. Due to COVID-19, classes moved virtual and so this student is forced to spend hours in front of the computer. Their automaton depicts them sitting at the desk in swivel chair, in front of a moving computer screen. A different student created the gear automaton to show how school makes them feel. They created moving gears showing the "gears turning in the head" as they complete various courses in the curriculum.

(a) (b)

Figure 6 Example projects for mini project 3 (gear automaton). ((a) – self-portrait; (b) – how school makes me feel)

Figure 7 and Figure 8 show example automaton for one of the final projects. This automaton depicts a scene from the combined stories – *It's the great Pumpkin, Charlie Brown,* and *Doctor Know-All.* The scene depicts Dr. Know-All pointing to the three guilty culprits of the prank.

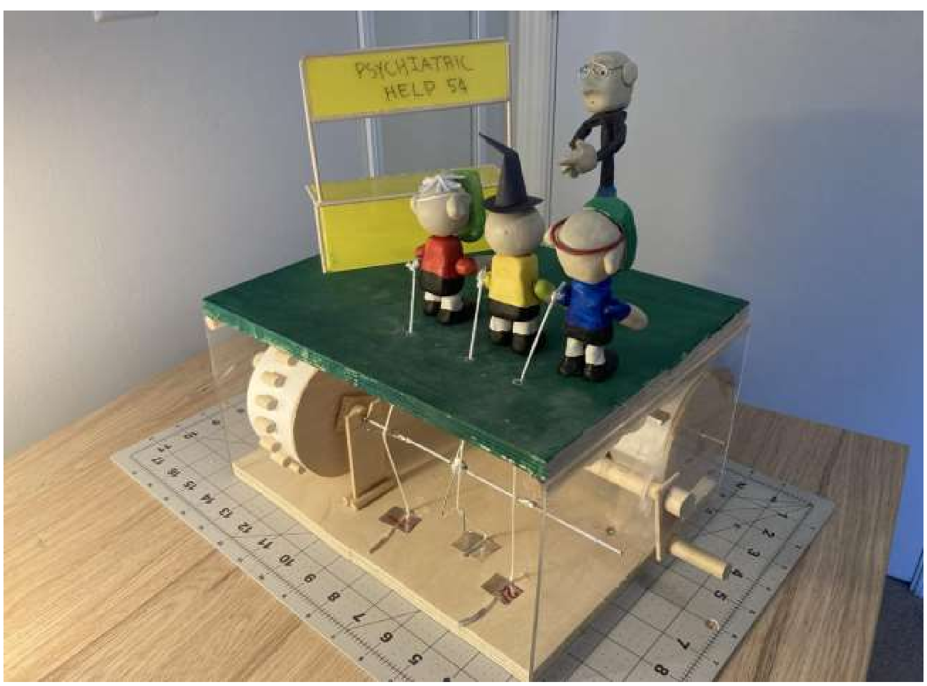


Figure 7 Example automaton from the final project

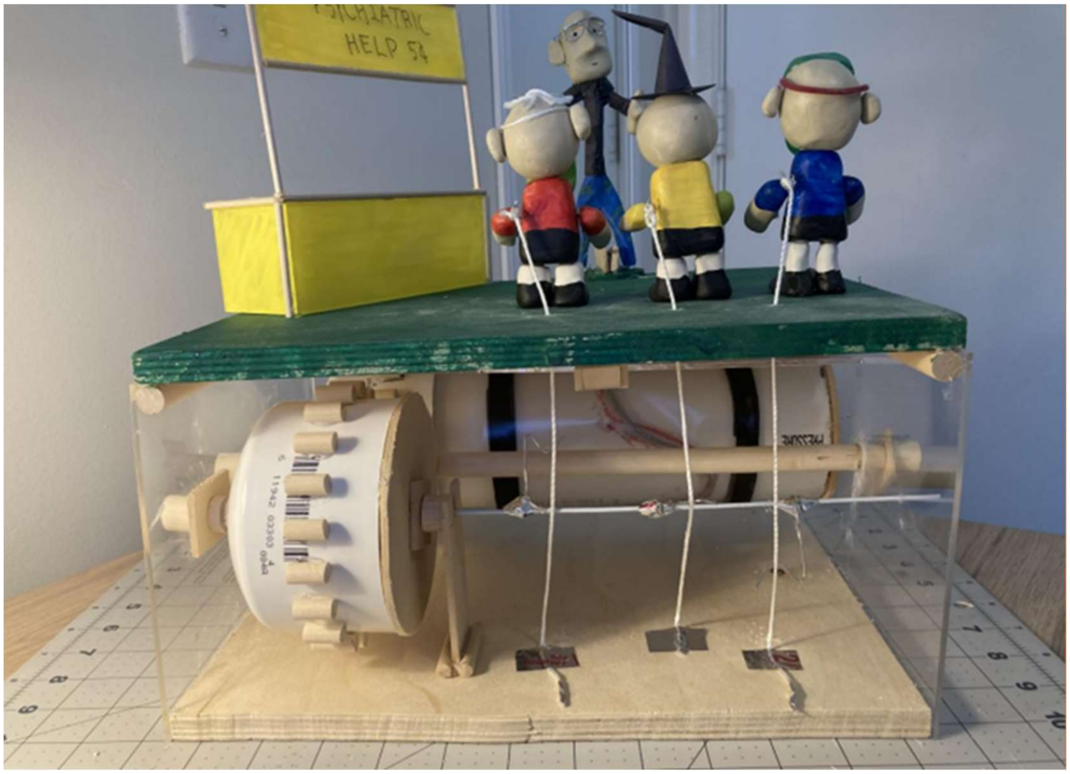


Figure 8 Example automaton for the final project

Figure 9 shows the sketches of the “underground” mechanisms. These are the mechanisms that make the automaton work. The input is a single crank that drives the drum cam and gears. Through the follower of the drum cam, the back and forth motion is transmitted to the character of Dr. Know-All. Note that this student decided to use magnet and steel cable to make the follower precisely follow the motion of the path on the drum cam. In initial ideation phase, the student has sketched out three cams that would be used to transmit motion to the characters of the guilty culprits as can be seen in Figure 9. However, in the final design, the student decided to use strings and wires to create pulley mechanism to transmit this motion.

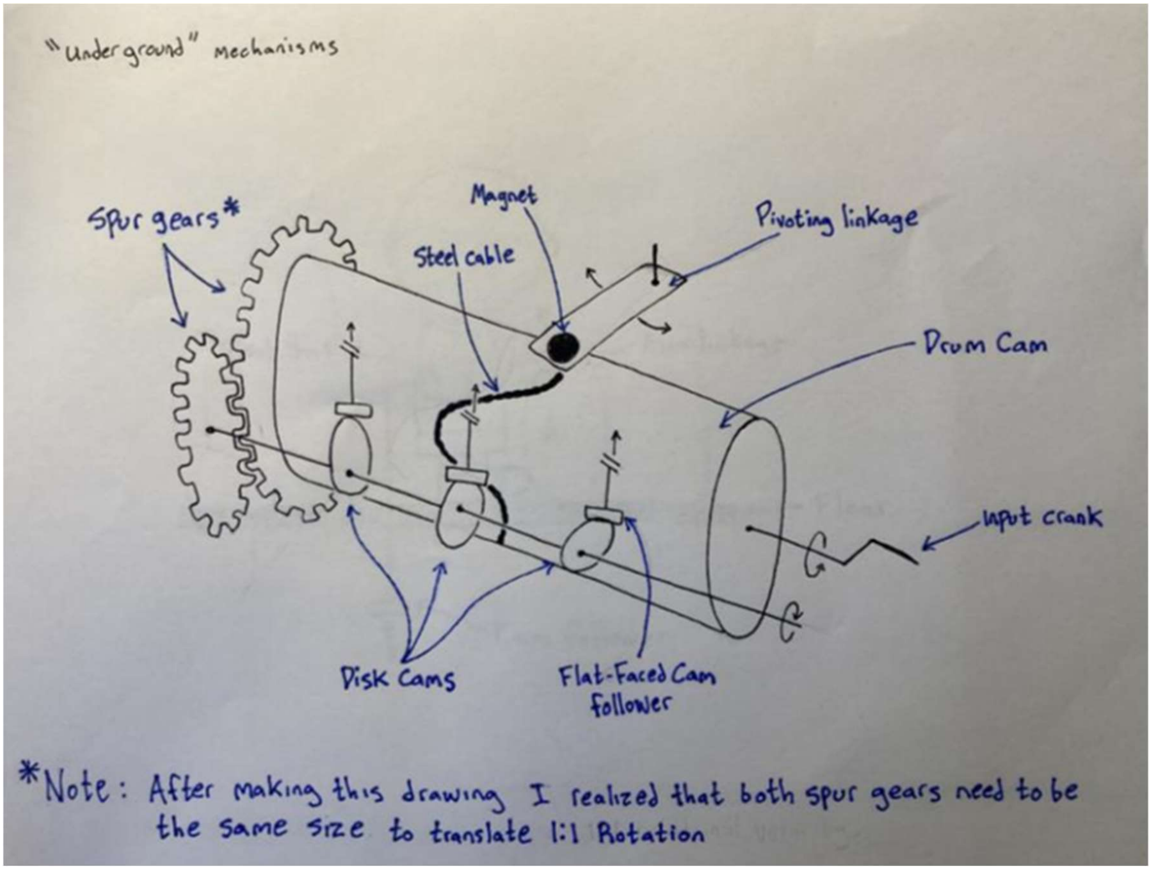


Figure 9 "Underground" mechanisms for the automaton

For this project, the characters were created out of clay and wire and the mechanisms were made from wires, wood, PVC and scrap plastic.

The author would like to point out that since this course was taught virtually during the COVID-19 pandemic, several limitations were imposed on the course. One of the major limitations was the lack of access to maker spaces, fabrication studios and other on-campus resources that would allow the students to fully explore their creativity. Thus, for this pilot version of the course, creativity was not formally assessed. Rather open-ended reflection responses were used to gain insights into the impact of incorporating storytelling and automaton creation on students' learning. Open-ended reflection responses were grouped into themes using pattern matching and these themes are presented in the results section. The author has added an example of rubric used for mini project 2 in Appendix 1 Rubric for Mini Project 2 Cam Automaton Presentation to provide details of the criteria used for grading student work.

Results - Impact of incorporating storytelling and automaton creation in mechanisms design class students' learning

One of the goals for this class was to explore the impact of incorporating storytelling and automaton creation on students' learning in a mechanism design class. As such, students were asked to submit reflections at the end of each project. Following are some example prompts given to the students for reflection:

1) Draw a concept map that shows the connections you have made between engineering and storytelling.

2) What does "Storytelling with Machines" mean for you personally beyond the class?

3) What were your top 3 learnings from this class? Why?

4) What was the most challenging aspect of the class?

5) How will you apply what you learned in this class in your career?

These reflections prompted the students to think about the connections they were able to make between storytelling and engineering, reflect on the challenges and successes, and lessons learnt through the process of building their projects. The impact of incorporating storytelling and automaton building as identified through student reflections is following:

1) This approach allowed students to build interesting connections between storytelling and engineering providing new lens for approaching engineering problems.
2) This approach helped students' creativity by allowing them to think outside the box.
3) This approach allowed for broader impact on students' attitudes towards lifelong learning and career.

Each of these impacts is explained in the following sub-sections.

Connections between storytelling and engineering

At the end of each class project, students were prompted to reflect on the connections they were able to make between storytelling and engineering. These connections were not explicitly taught in the class but were implicit through various class activities and projects. Figure 10 illustrates a mind map created by a student showing the connections they were able to make between storytelling and engineering. This mind map was developed as part of reflection for the final project. The components of storytelling as identified by the student include characters, timeline, visuals, moral/theme, and planning. The components of engineering include stakeholders, documentation, design, tools, and building. The student was able to create interesting connections between storytelling and engineering. For example, characters in a story are like the stakeholders for engineering problem.

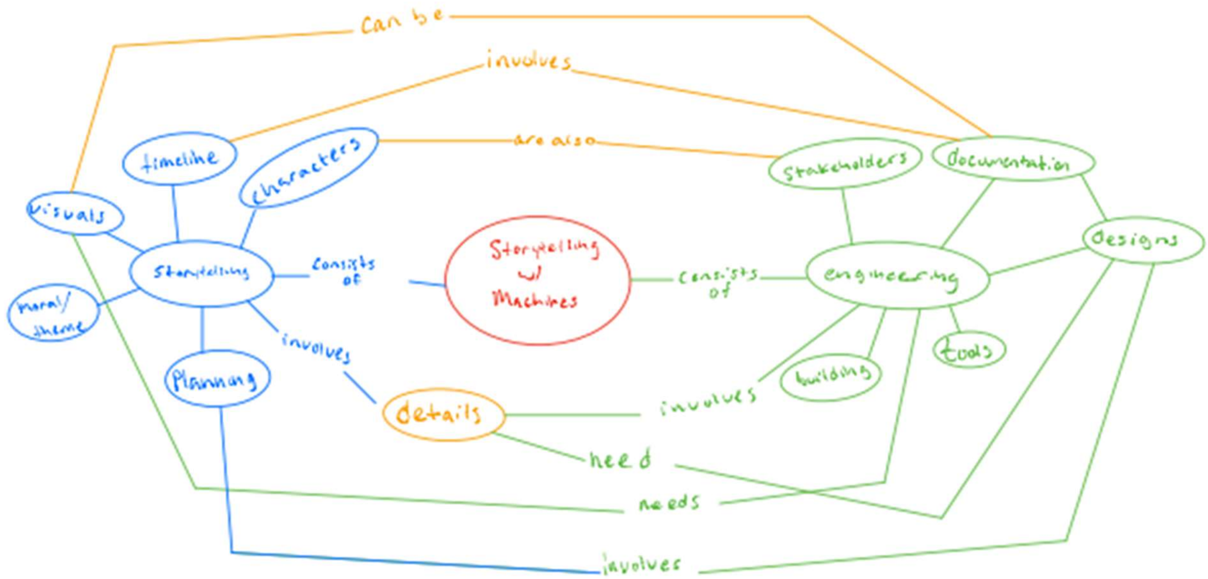


Figure 10 Connections between Storytelling and Engineering as identified by a student

Similar connections were made by most other students in the class as evident by following quotes from various student reflections:

"I have been telling stories with machines throughout all of engineering. This is something I did not realize until I took this class. This is important to realize because any problem can be looked at as a story. Sometimes problems need to be looked at from a new perspective in order to find creative solutions".

"From this class, I learned that storytelling is important in any kind of project to engage the audience and make them more interested in your product without boring them. Also, I learned that I can apply storytelling to basically everything and not just machines".

"The process used in creating a story is almost identical to that used by engineers when completing a project".

"Also I realized the importance of having a story for your designs. Whether it be a blown out fairy tale or just a simple theme, stories give designs more richness overall making your designs more attractive than designs without stories".

<u>Impact on creativity</u>

In a typical engineering project, students are often tasked with addressing the needs of stakeholders and finding a solution to solve a problem. While this training is important for engineering students, it often fails to provide opportunities for exercising creative thinking and exploration. In Storytelling with Machines class, the students were not designing or building to solve for a specific problem but rather to use their projects as a tool for learning about mechanisms and explore their creativity. This allowed the students to think out-of-the box and be more creative. This is evident from the following quotes from students' reflection.

"Lastly, the more useful lesson I learned from the class was the ability to look beyond the box. I never found myself to be a super creative person; I never really have the opportunity for free ideas from only my peanut gallery. Being able to freely express in your own creative ways is beneficial for confidence and future opportunities."

"A good way to explore and discover new ideas is to have fun and experiment. In this class, we didn't attempt to tackle any serious engineering problems and just tried to have fun with our projects. This made me feel more comfortable trying out more outside-the-box ideas. Sometimes in an engineering setting, people limit themselves by taking things too seriously."

Broader impact on career

This class also had broader impact on students' attitudes towards their career. This impact ranged from having the attitude of fun and creativity towards engineering problems to viewing engineering problems as stories. The broader impact that this class had on students' attitudes towards their career is evident in the following quotes from the student reflections:

"I will use what I learned in the class in my future to create more meaning and add a touch of humanity to lifeless objects."

"As I have previously stated, I will apply the learning of this class to my career by finding ways to view each problem as a story. The stakeholders become characters, the scene becomes the constraints and so on. I think it is important to step back and view problems this way because it provides an easy way for you to organize all of the details of the project into a roadmap. I think this class was the perfect transition to learn how to view engineering from different perspectives. We are always taught new ways to view and approach problems, and now I am at an advantage because of this class."

"The biggest take away from this class I will apply to my career is not to give up if you fail a couple of times. It took me a long time in this course to realize this but failing is a good thing. You learn something from it each time and eventually all that knowledge will lead to success. I will always fail in life. But it is how you get up after failure that defines you. And people always say that, but I never applied that to my personal life until this class."

"Later in my career, I will always try to have fun with my work and apply my creative ideas whenever it is appropriate. Keeping this mindset will aid my problem-solving ability and help to make my work more entertaining."

Conclusion and future work

This paper presents the development of a technical elective course titled Storytelling with machines. This course was developed with the intent of teaching students about the theory and principles of mechanical elements such as linkages, cams, and gears, with the context of storytelling and automaton building. Throughout the course, the students worked on various hands-on projects allowing them to explore the mechanical elements and design and build automata to depict scenes from stories. The reflections submitted by the students show that this approach of incorporating storytelling and automaton building in a mechanisms class had three major impacts.

- First, it allowed the students to draw interesting connections between storytelling and engineering.
- Second, it fostered a mindset of creativity through exploration of stories and mechanisms.
- Finally, this approach will have broader impact on students' careers by allowing them to develop attitudes of having fun and using different lens to look at engineering problems.

The findings of this research indicate that it would be beneficial to the students to incorporate the elements of storytelling and automaton building in technical engineering classes. This can be done through mini projects by allowing students to explore technical content in the context of stories and making. For example, in an electronics class, students can explore the concepts of electronics in context of stories and making. They can be assigned mini projects to design and build animated scenes from stories using electronic hardware and software components. This can provide students with a new lens to explore the concepts of electronics in context of storytelling.

Since this was the first time teaching this course, the instructor focused efforts on developing the content and designing projects to allow creative exploration of mechanisms. Some limitations were also imposed on the class because of being virtual due to COVID-19. Specifically, the virtual environment significantly limited the hands-on aspect of building and using a variety of prototyping methods for the projects. Therefore, it is possible that the students were not fully able to explore their own creativity. The author hopes that this limitation will be addressed in future offerings of this class post COVID-19. The future work from this research will also entail a more systematic approach to measuring the improvement in creativity throughout the course.

References

[1] The Engineer of 2020: Visions of Engineering in the New Century, National Academy of Engineering, 2004.

[2] D. M. Beams, K. Gullings and C. E. Ross, "Seeking New Perspectives: Engineers Experiencing Design through Creative Arts," in *American Society of Engineering Education's 123rd Annual Conference and Exposition*, New Orleans, 2016.

[3] W. Isaacson, Leonardo da Vinci, New York: Simon & Schuster, 2018.

[4] R. T. Bailey and B. Friebele, "3D Design in Art and Engineering: An Interdisciplinary Experiment," in *American Society of Engineering Education* , Virtual Conference, 2020.

[5] P. Caratozzolo and A. A. Delgado, "Improving Creative Thinking in Engineering Students through Art Appreciation," in *American Society of Engineering Education 126th Annual Conference and Exposition*, Tampa, 2019.

[6] J. Mirth and A. Findley, "Enduring Design: Examining the Relationship Between Art, Engineering, and Creativity," in *ASEE Zone III Conference*, Gulf Southwest-Midwest0North Midwest Sections, 2015.

[7] V. Schoner, R. Gorbet, B. Taylor and G. Spencer, "Usinig Cross-Disciplinary Collaboration to Encourage Transformative Learning," in *37th ASEE/IEEE Frontiers in Education Conference* , Milwaukee, 2007.

[8] C. Wigal, "Art for All Design Collaboration," in *Proceedings of the ASEE 2018 First Year Engineering Experience Conference*, Glassboro NJ, 2018.

[9] B. Benson and M. Burnett, "Convergence - an engineering and arts education project that brings together faculty and students of different disciplines and nationalities," in *Proceedings of the 2018 ASEE Zone IV Conference*, Boulder CO, 2018.

[10] N. Kathryn, "The Engineering in the Museum: Helping Engineering Students Experience Technology as Art," in *Proceedings of the ASEE 1996 Annual Conference and Exposition*, Washington DC, 1996.

[11] A. Rose and V. Grash, "Interaction of Engineering Technology and Fine Arts Through Instructor Collaboration," in *Proceedings of the ASEE 2005 Annual Conference and Exposition*, Portland OR, 2005.

[12] L. Yu and F. Abarca, "ElectrizArte, combining engineering and arts," in *Proceedings of the 2012 Interdisciplinary Engineering Design Education Conference*, 2012.

[13] S. Burkett and C. Snead, "Picasso's Clarinet : When Art and Engineering Collide," in *ASEE Annual Conference and Exposition*, Austin, 2009.

[14] M. Eskandari, B. Karanian and V. M. Taajamaa, "Tell/Make/Engage: Design Methods Course Introduces Storytelling Based Learning," in *ASEE Annual Conference and Exposition*, Seattle, 2015.

[15] "Masterclass," 8 November 2020. [Online]. Available: https://www.masterclass.com/articles/a-guide-to-storytelling#4-types-of-storytelling. [Accessed 3 March 2021].

[16] R. Adams, C. Allendoefer, T. R. Smith, D. Socha, D. Williams and K. Yasuhara, "Storytelling in Engineering Education," in *ASEE Annual Conference and Exposition*, Honululu, 2007.

[17] I. A. Olwi, "Storytelling as an Effective Mean for Stimulating Students' Passion in Engineering Classes," in *ASEE International Forum*, Indianapolis, 2014.

[18] B. Karanian, A. J. Suria and J. Summers, "Car Storytelling and Interaction Design," in *ASEE Annual Conference and Exposition*, Seattle, 2015.

[19] T. Ball, L. Beckett and M. Isaacson, "Formulating the Problem: Digital Storytelling and the Development of Engineering Process Skills," in *IEEE Frontiers in Education Conference (FIE)*, El Paso, 2015.

[20] S. S. Jordan, K. White, I. K. Anderson, C. Betoney, T. J. D. Pangan and C. H. Foster, "Culturally-relevant Engineering Design Curriculum for the Navajo Nation," in *American Society of Engineering Education Annual Conference and Exposition*, Columbus, 2017.

[21] S. S. Jordan, C. H. Foster, I. K. Anderson, C. A. Betoney and T. J. Pangan, "Learning from the experiences of Navajo engineers: Looking toward the development of culturally responsive engineering curriculum," *Journal of Engineering Education,* vol. 108, no. 3, pp. 355-376, 2019.

[22] "MAD Museum The History of Automaton," [Online]. Available: https://themadmuseum.co.uk/history-of-automata/.

[23] R. Peppe, Automata and Mechanical Toys, Marlborough Wiltshire: The Crowood Press Ltd, 2002.

[24] A. Soth, "The Marvelous Automata of Antiquity," *JSTOR Daily,* 7 June 2018.

[25] K. M. Weiland, "Helping writers become authors," [Online]. Available: https://www.helpingwritersbecomeauthors.com/.

[26] "The StoryTeller Academy," [Online]. Available: https://www.storytelleracademy.com/blog.

[27] "Self-Publishing School," [Online]. Available: https://self-publishingschool.com/.

[28] S. Slayton, Lessons from Grimm: How to write a fairy tale (Lessons from Grimm Series Book 1), Amaretto Press, 2020.

[29] M. Warner, Once Upon a Time: A Short History of Fairy Tale, Oxford University Press, 2016.

[30] M. Warner, Fairy Tale: A very short introduction, Oxford University Press, 2018.

[31] S. Finger, "Rapid Design through Virtual and Physical Prototyping," 2010. [Online]. Available: https://www.cs.cmu.edu/~rapidproto/activities/toydissection.html.

[32] [Online]. Available: https://en.wikipedia.org/wiki/Paul_Bunyan.

Appendix 1 Rubric for Mini Project 2 Cam Automaton Presentation

Mini Project 2 Cams Rubric

Criteria	Ratings			Pts
This criterion is linked to a Learning Outcome Overview of Modified Story	**2 pts** **Full Marks** Clear overview of story including plot and main characters.	**1 pts** **Partial Marks** Overview of the story either missing clear explanation of the plot or the main characters.	**0 pts** **No Marks** Overview of the story not provided.	2 pts
This criterion is linked to a Learning Outcome Rationale for selecting scene/character	**1 pts** **Full Marks** Rationale for selecting particular scene/character for the automaton is clearly explained.	**0 pts** **No Marks** Rationale is missing.		1 pts
This criterion is linked to a Learning Outcome Sketch of new character	**1 pts** **Full Marks** Clear and annotated sketch of the new character is provided.	**0 pts** **No Marks** Sketch is missing or is not clear or annotated.		1 pts
This criterion is linked to a Learning Outcome Sketch of final automaton	**1 pts** **Full Marks** Clear and annotated sketch of the automaton is provided. The various parts such as characters, linkages, movements are clearly labeled.	**0 pts** **No Marks** Sketch is missing or is not clear or annotated.		1 pts

Mini Project 2 Cams Rubric		
Criteria	**Ratings**	**Pts**
This criterion is linked to a Learning Outcome Displacement diagram of cams	**2 pts** **Full Marks** Clear and labeled Displacement diagram of both cams is provided. / **1 pts** **Partial Marks** Either displacement diagram of one cam is missing or is not clear or labeled. / **0 pts** **No Marks** Displacement diagram is not provided.	2 pts
This criterion is linked to a Learning Outcome Prototyping process	**3 pts** **Full Marks** Prototyping process is clearly explained with pictures of the steps taken towards final prototype. / **1 pts** **Partial Marks** Either the prototyping process is not clearly explained, or the pictures of the steps taken towards final prototype are missing. / **0 pts** **No Marks** Prototyping process is missing.	3 pts
This criterion is linked to a Learning Outcome Lessons learnt	**2 pts** **Full Marks** Clear demonstration of lessons learnt including challenges and victories. / **0 pts** **No Marks** Lessons learnt are not discussed.	2 pts
This criterion is linked to a Learning Outcome Automaton Demo	**3 pts** **Full Marks** During the demo, the input and output motion are clearly explained. The automaton works as intended. / **2 pts** **Partial Marks** During the demo, the input and output motion are not clearly explained. The automaton does not fully work as intended. / **0 pts** **No Marks** During the demo, the input and output motion not explained. The automaton does not work.	3 pts
Total Points: 15		