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Using Multimedia Immersion to Inspire High School Students to Pursue STEM Careers

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ABSTRACT

Multimedia Immersion (MI) Inspires STEM Learning is an exploratory DRK-12 project for the National Science Foundation (NSF) in the learning strand. Arts and Technology faculty at Stevens Institute of Technology (Stevens) in collaboration with Technology teachers from New Jersey and New York school districts developed, piloted, and evaluated a nine-week STEM-rich multimedia production course for high school students. The MI course is designed to: (1) actively engage teams of students to develop a personally and socially relevant storyline that guides their use of accessible audio and video technologies to create an animated video; and (2) provide guidance and learning experiences in engineering (e.g., criteria, constraints, optimization, tradeoffs), science (e.g. sound, light, energy, mechanics) and multimedia technologies (e.g., computer-based audio production, video editing and visualizations through animatics). Student surveys and an examination of work products, in conjunction with implementation challenges and successes, provide evidence for the feasibility and utility of a high school multimedia course that explicitly addresses science and engineering learning.

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1. Introduction

During summer sessions designed to recruit students to Stevens Institute of Technology from 2010-2016, a two-week curriculum was developed using software to create animations and the requisite soundscape from scratch. Through this experience, a discussion developed on how a full nine-week, 45-session curriculum could be designed, deployed and implemented to schools in districts that supported low income and underrepresented populations in STEM fields. A proposal was submitted to the National Science Foundation, which awarded $500,000 (Award #1720964) in support of this observational research study. The goals outlined in the proposal included: develop a nine-week multimedia curriculum for use in urban high schools and determine if this curriculum can inspire STEM interest; iteratively pilot the curriculum with 10 teachers and 250 students per year; explore student increase in: (a) interest and self-confidence and (b) knowledge of science and engineering for those who experience the curriculum; and measure successes and challenges in various learning environments. A robust program was developed including professional development (PD) sessions for participating high school teachers; purchase, delivery and setup of $1500 of equipment not typically available in high school classrooms; weekly Zoom support meetings; and a Data Collection protocol allowing for seamless collection and analysis. Software tools selected for this study were specifically chosen because they were free and/or free for educational purposes. By using off-the-shelf software products, updates were provided based on operating systems that were unique to each high school. Ultimately, two iterations of a media-based curriculum were developed and implemented in ten schools across the New York and New Jersey region. The student demographic groups represented in the study are inclusive of under-represented populations in STEM careers.

Teachers from participant schools attended professional development sessions on the campus of Stevens Institute of Technology prior to implementing the curriculum. In the first iteration of the PD, four participant teachers went through the course as designed for a two-week summer session. These Development Teachers then spent some weeks creating a lesson plan. A curriculum development team built upon this lesson plan, creating the first iteration of a 45-lesson, nine-week course. During the second iteration, Development Teachers from year one assisted in running the PD session for the teachers in year two. Teachers were introduced to Autodesk's Maya for animation and Avid's Pro Tools and Media Composer for audio and video production respectively.
The sequence of the curriculum in broad overview commenced with a brainstorming session to create a narrative for the animation. This process helped to establish the necessary team dynamic for group work on a creative project and the foundations for development of an efficient and creative workflow. For high school teachers, this was a relatively simple process, but it helped them to consider how the same exchange would happen between students in their own classrooms. From there, the participants were introduced to the software, covering basic functionality. Additionally, participants were taught how to use the required and supplied hardware to support the curriculum, which included: Zoom H4N complete kit with road case, M-Audio - Keystation 49 - MIDI Keyboard, Sennheiser HD 200 PRO Closed-back Monitoring Headphones (8 pairs), Behringer Truth B2030A 6.75" Powered Studio Monitor (pair) and Behringer HA8000 V2 8-Ch Headphone Mixing/Distribution Amplifier.

2. Specific Objectives:

The study was designed with three fundamental and specific objectives as a focus of the research:1) to engage students of under-represented populations in STEM through the use of media production tools in a Creative Design Process, not unlike an Engineering Design Process. By doing so, students learn collaborative team dynamic skills; new skill sets in software and hardware use through directed activities; management of long-term project design and implementation; and how to interlace creative thought processes natural to the arts with the science and technology (i.e. physics wave theory, systems integration and design, software integration between multiple programs) involved to deliver a final product, 2) to show students how lessons learned through the Creative Design Process can translate directly to skill sets and careers incorporating the Engineering Design Process, and 3) to develop a curriculum that can be scaled from a local level to national dissemination in high schools using media arts as a creative educational training technique for STEM-related research, development, and career goals.

As one evaluation measure of the project, students were given before and after surveys to assess their comfort with STEM and the effect the curriculum had on their perceptions of personal success within a STEM framework. The survey was designed to measure students' positive beliefs about engineering and themselves, increased interest and awareness of STEM, and knowledge of the science and engineering design process. From the survey document alone, project leaders were able to measure attitudinal changes in students toward STEM as a result of their participation in the curriculum.

Participant teachers benefited from weekly recorded and shared Zoom meetings, as well as a web-based Q&A portal. Both the meetings and the portal were administered by the PI and expert support team. This ongoing communication provided team building and camaraderie between the teachers, as well as with the program leadership. Through these two mechanisms, challenges in delivering the curriculum were discussed and solutions quickly found. This resulted in better continuity in implementation. Eventually, teachers became experts in the media production field themselves, and shared best practices with each other.

3. Significant Results

The significant findings detailed in this section include those based upon both quantitative and qualitative sources of data. These include:

- Recorded interviews with project teachers by the Lead Researcher.
- Student pre/post attitudinal survey delivered via SurveyMonkey.
- Student Design Logs.
- Recorded weekly teacher/project leadership Zoom meetings; and
- Student-created “Making Of” videos documenting their progress through the curriculum.

3.1 Teacher Interviews with Lead Researcher

A. One hundred (100) percent of the nine (9) teachers interviewed via Zoom stated:

- They would use the curriculum again.
- Students were very engaged in the animation project.
- Students acquired technical and computer skills they would not have done otherwise, which included facility with Maya, Pro Tools, and Media Composer.
- Students were stimulated by the cross-curricular nature of the curriculum, e.g., music/theater students learned more about the physics of light and sound that they would have otherwise, and engineering/technology students learned more about graphic arts, creative writing, and music production than they would have done without the curriculum.
- The curriculum was well-designed, well-constructed, and easy to follow.
- The one-week summer professional development session was essential for teachers to develop the technical skills necessary to teach the curriculum.
- The weekly Zoom meetings with the project leadership were helpful and necessary for sharing information with one another, discussing challenges, proposing solutions, and reporting on implementation progress.
- That they had suggestions and recommendations for the next iteration of the curriculum; these are included in full in the Impact Section of this report.

B. Eighty-nine (89) percent of the teachers interviewed collaborated with other subject area teachers to aid in their implementation of the curriculum. These collaborators included teachers of music, information technology, television production, physics, band, and chorus.

3.2 Student Pre/Post Survey

Over the course of two years, 241 students completed a pre/post attitudinal survey delivered via SurveyMonkey software. The survey was designed to measure students’:

1) Positive beliefs about engineering and themselves; 2) Increased interest and awareness of STEM; and
3) Knowledge of the science and engineering design process.

One of the most telling findings was the final question in the survey. Students were asked to think carefully about their experience with the curriculum and give it a star rating out of five (5), with five being the highest rating. Sixty-seven (67) percent of the students responding to that item ranked the program a combined four and five stars.
From the pre- to the post-survey in 2018-2019, the pilot year of the program, students made significant attitudinal gains for the survey items in Figure 3.

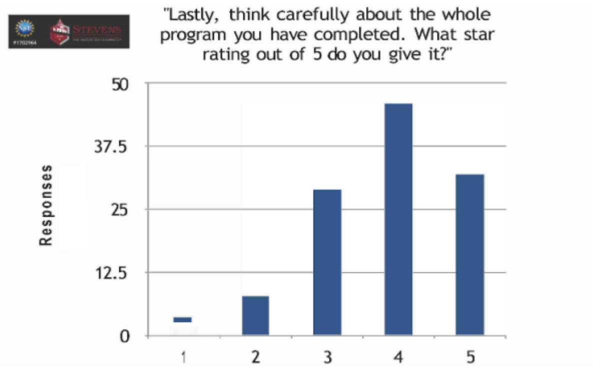

Figure 1. Star Rating Student Assessment of Curriculum

Results were somewhat different for the 2019-2020 cadre of students, as many were not able to complete their animation projects due to the pandemic-related school closures in New Jersey in March 2020.

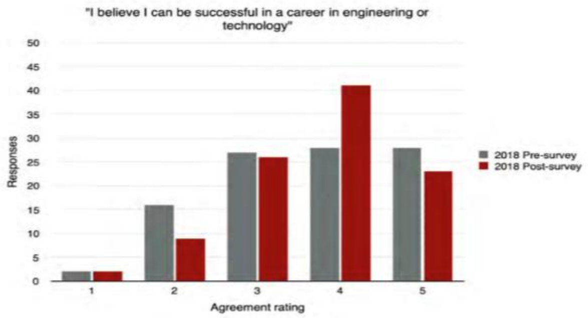

Figure 2. Attitudinal Survey 2018 Implementation

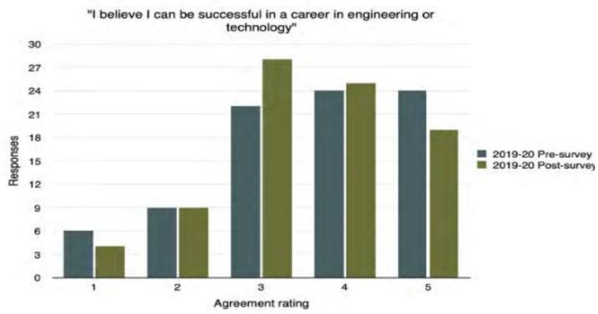

Figure 3. Attitudinal Survey 2019-20 Implementation

It is clear from these results that completing the curriculum, as students did in 2018-2019, results in a greater measurable positive change in students' attitudes toward, and comfort with, STEM.

3.3 Student Design Logs and Science Understanding

Students recorded their progress and responded to questions and prompts in their Design Logs throughout the course of the curriculum. Teachers provided samples of their students' work by uploading them into the Google-supported shared drive. The Lead Researcher and assistants (the Evaluation Team) analysed 135 Design Logs for students' understanding of the physics of sound and the technology of microphones, key STEM content areas for the curriculum. The questions to which students responded in their Logs were Wrap-Ups from:

Module 2, Unit 1: Properties of Sound Waves in the Natural World. Students were asked to define sound, explain how sound waves travel, and describe the role of the ear in detecting sound, and how understanding the science of sound would help them in their animation project.

Module 2, Unit 2: Microphones: Converting Sound Waves to Electrical Energy. Students were asked to explain how a microphone works and its relationship to sound. They also explained how the positioning of a microphone affects how sound is recorded.

Responses were rated High (correct response with appropriate examples and/or illustrations); Medium (correct response, but little or no examples or illustrations); and Low (incomplete or incorrect response; no examples or illustrations). Two independent researchers on the Evaluation Team ranked the same subset of the Logs independently, and then compared their rankings to establish interrater reliability.

For Module 2, Unit 1, 86 responses were rated from five classes. Fifty-five (55) percent of that group rated either Medium or High, displaying an understanding of basic physics concepts of sound.

For Module 2, Unit 2, 49 responses were rated from four classes. Seventy-one (71) percent of that group rated either High or Medium in their understanding of the relationship between sound and microphones.

3.4. Teacher Weekly Zoom Meetings with Project Leadership

Review of the video recordings and 38 transcripts from the weekly Zoom meetings with teachers, the Principal Investigator, Lead Researcher and Research Assistant revealed that there were four distinct and definable stages of curriculum implementation that both the teachers and their students passed through. These phases are defined in Figure 4 and 5: Implementation Phases Visualization illustrates the different amounts of time it took for teachers and their students to move from one phase to another, essentially progressing from novice-level to expert-level in the curriculum. The X Axis in the figures below represents the number of weeks needed to attain the level of expertise necessary for the next phase.

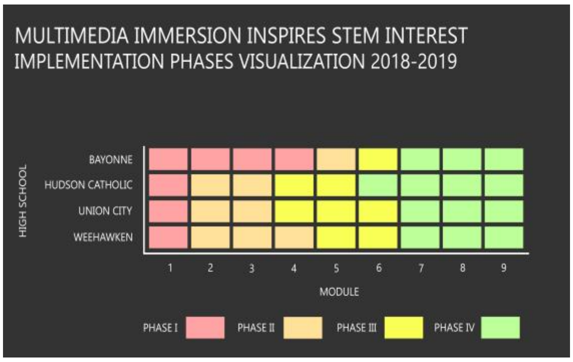

Figure 4. Implementation Phases of 1st Iteration of Curricular Implementation

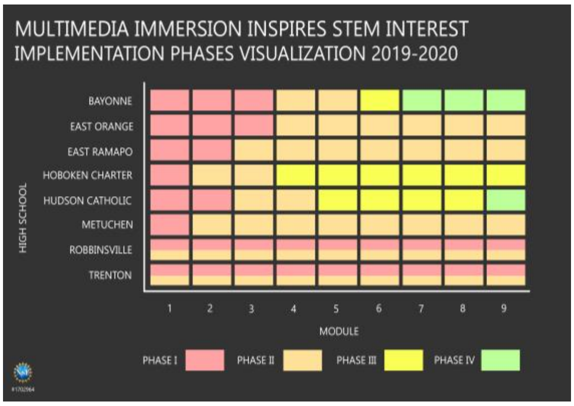

Figure 5. Implementation Phases of 2nd Iteration of Curricular Implementation

In their interviews with the Lead Researcher, the teachers suggested ways of shortening the time it took them to get to Phase IV – expert. Suggestions included: Providing students with partially built assets for the animation so that they do not have to start from scratch; using software available to each school and compatible with the schools' hardware and IT restrictions; and engaging students earlier in the actual animation project, providing guidance as questions arise. Demonstrated in Figure 5, two schools were dramatically impacted by the pandemic and unable to complete the curriculum, therefore never able to achieve a high level of expertise.

3.5. "Making Of" Videos

In some of the classrooms testing the curriculum, students created "Making Of" videos that documented their progress through the creation of the animation. Some of these videos were students recording their own thoughts; while others were done by having a student interviewer talk to groups of his/her classmates periodically throughout the curriculum. The project had access to 50 of these videos. Analysis of the students' comments recorded in these videos supports these statements: Students worked effectively in groups to create the assets they needed to produce the animation; students took on specialist roles (music production, animators, etc.), which drew upon their differing abilities and talents; students consulted with other groups in their class to help solve problems; there was high student engagement throughout the project; and students were able to articulate clearly what they were doing and how it fit into the overall project.

4. Key Outcomes or Other Achievements

The Multimedia Immersion (MI) Inspires STEM Learning produced the following outcomes and achievements:

1. Nine-week integrated STEM curriculum which has been piloted, revised, and field-tested with 13 total high school teachers in northern New Jersey.
2. Cadre of 13 teachers knowledgeable about the curriculum who could serve as future professional development leaders.
3. Tested, revised, and re-tested one-week summer professional development model.
4. Animation examples for future curriculum users developed by project teachers and students.
5. Recordings and transcripts of 40 weekly Zoom meetings with teachers and project leadership, which can serve as a resource for future teachers.
6. Models for organizing student work for the curriculum on Google Classroom.
7. Extensive online collection of student work, which can serve as examples and target papers for future teachers (Student Design Logs, storyboards, animation assets, "Making Of" videos, final animations).
8. Extensive collection of online and print resources to support the curriculum, including sample animations; sample "Making Of" videos; science background on sound; free 3D images and models; information on copyright law; tutorials on the production software; examples of storyboards, scripts, shot lists, cue lists; Q&A Portal content, and explanatory articles on a variety of topics.
9. Comprehensive list of pilot- and field-teacher suggestions and recommendations for the next iteration of the curriculum.
10. Evaluation instruments (surveys, interview questions, data analysis protocols) that can be used/adapted to collect impact data when the curriculum becomes available on a national level.
11. Presentation materials (posters, PowerPoint presentation, photographs, videos, numerical data, testimonials) that can be used to disseminate information about the curriculum to school districts and potential publishers.

5. Training & Professional Development

NSF is particularly interested in what opportunities for training and professional development the project has provided. Professional Development opportunities were specifically targeted to the participant K-12 teachers; more accurately, the high school teachers involved in the study. All participant teachers attended a one-week long PD session on the campus of Stevens Institute of Technology the summer before implementation of the curriculum in their classrooms. The session was run as a micro course of the nine-week curriculum to demonstrate how the Engineering Design Process is almost identical to the Creative Design Process used in media production. Team building skills, time management, introduction to software packages and group/self-evaluation at the end of each day were explored. Teachers also collectively compared notes and strategies through weekly Zoom calls hosted by the PI, providing additional moral support and pedagogical support to each other through the discussion of best practices during implementation of the curriculum.

During all PD sessions on the Stevens campus, undergraduate students of the Music & Technology program in the College of Arts and Letters at Stevens were hired as assistants to help in these ways: manage the software installation on participants' individual laptops; perform technical functions relating to software in the multimedia creation process during the PD sessions; assist the participants in understanding how creative assets are rendered; assist in data management of the many files being generated during the PD sessions; and provide general support to the Development Teachers and Faculty leading the sessions. This experience gave the undergraduate students first-hand experience in tutoring adults in the use of technical systems.

One of the software platforms used in this project is an AVID product called Pro Tools. The project had significant challenges with this Cloud-based program, specifically relating to the creation of individual email accounts for all the classrooms involved. Additionally, many of the participant schools had substantial firewalls limiting student access to the Internet, which had to be resolved to allow the programming to function optimally. AVID customer support ultimately provided dedicated technical support to handle issues as they arose within the classrooms. Since teachers implemented the curriculum at different times across their academic year, this technical support relationship with AVID was active during AY 2019-2020 on an as needed basis.

6. Impacts

NSF requires a series of responses in the final report that directly outline a host of areas in which programmatic impact is measured.

6.1 What impact did the study have on the development of the principal discipline(s) of the project?

The project taught the physics of light and sound wave theory in the context of creating a short-animated video. Students recorded their work in scripted Design Logs and orally reported their progress periodically via "Making Of" videos. The Making Of videos were either conducted by a student interviewer/videographer or consisted of students reporting individually via self-recorded videos. Documenting workflow is a key component of the curriculum.

The curriculum had an impact on the teaching and learning of physics, technology, and engineering concepts in the following ways:

- Science Content Understanding/Application: Students demonstrated, by responding to prompts in the Design Logs and by answering questions during the "Making Of" videos, that they understood the relationships between sound, light, and the production of an animated short that was both visual and included a soundtrack with music.
- Creation of Positive Perceptions of Science, Technology, and Engineering: 241 students over the course of two years completed a pre/post attitudinal survey delivered via SurveyMonkey software. The survey was designed to measure students':
  - Positive beliefs about engineering and themselves.
  - Increased interest and awareness of STEM; and
  - Knowledge of the science and engineering design process.

From the pre- to the post-attitudinal survey in 2018-2019, the pilot year of the program, students made significant gains for these survey items:

- I like activities that use technology.
- I like activities that use science.
- I am good at music.
- I am good at engineering.
- I am good at science.
- I work hard on activities at school that involve engineering.
- I am interested in jobs or careers that include art.
- I am interested in jobs or careers that include technology.
- I think I will have lots of career choices if I learn technology.
- I think I will have lots of career choices if I learn engineering.
- I feel comfortable talking to people who have careers in music.
- I feel comfortable talking to people who have careers in technology.
- I think it will help me in my career if I do well in mathematics.
- I think it will help me in my career if I do well in science.
- I choose activities outside school that involve music.
- I enjoy learning science.

There were significant differences in a second set of survey items that asked students to what extent they agreed or disagreed with these statements:

- I enjoy learning science.
- Science is not one of my strengths. (students disagreed or strongly disagreed with this statement)
- I think learning Math will help me in my daily life.
- I am good at building and fixing things.
- I am interested in what makes machines work.
- Technology provides important tools for designing creative arts projects.

The last point on the list above had the greatest positive difference from the pre- to post-survey for the 2018-2019 group of students.

Results were somewhat different for the 2019-2020 cadre of students, as many were not able to complete their animation projects due to the pandemic-related school closures in New Jersey in March 2020. For that year, there were significant differences for these survey items:

- I think learning science will help me in my daily life.
- I am good at building and fixing things.
- I am interested in what makes machines work.
- I think it will help me in my career if I do well in engineering.
- I need to do well in science to get the career or job I want.
- I feel comfortable talking to people who have careers in technology.
- I feel comfortable talking to people who have careers in mathematics.
- I believe I can be successful in a career in engineering or technology.

For the second set of survey items completed by students in the 2019-2020 cadre, there were two statements with significant differences from the pre- to the post-survey. Students disagreed or strongly disagreed with these statements: Science is more difficult for me than most of my classmates. Math is more difficult for me than most of my classmates.

It is clear from these results that completing the curriculum, as students did in 2018-2019 results in a greater measurable positive change in students' attitudes toward, and comfort with, STEM.

6.2 What is the impact on the development of human resources?

Students participating in the project needed to use both applied science (physics of light and sound) and the Engineering Design Process to create their animated short video. The students were engaged throughout the course of the curriculum in an authentic task: Creating the animation using the same software that professionals use. This had a great impact on students' enthusiasm, according to the teacher interviews. Comments such as "I didn't know I could get a job doing this" were often heard from students.

Both the teachers and students using the curriculum achieved quite definable levels of proficiency over time (Fig. 2 Implementation Phases). Research aspects for teachers involved finding alternative software packages that worked with their schools' infrastructure and firewalls. Later, after the New Jersey schools closed due to the COVID-19 pandemic, students also engaged in researching editing software to complete their projects. Some students became proficient enough to edit their videos on their smartphones.

Through weekly Zoom sessions, teachers received mentorship from the Principal Investigator, as well as from each other. Areas of mentorship included animation software use, possible alternatives, and troubleshooting; time management; student team dynamics; and, after the pandemic began, teaching the curriculum online. Such peer mentorship was possible due to the team building and bonding that occurred between the PI and the teachers at the summer professional development sessions preceding each implementation year.

6.3 What was the impact on teaching and educational experiences?

Teachers who were interviewed by the Lead Researcher reported that their students were galvanized by having a project goal (the final animation); using authentic, professional-grade software to create the assets and the final animation; working in teams with specialist roles; and being able to relate the STEM content taught in the course to a practical goal.

During post-implementation interviews, teachers mentioned consultation and collaboration with other faculty in their high school in related subjects, i.e., Physics, Music-Band, Television Production, and Information Technology staff.
Teachers also provided substantive recommendations to project leadership on methods of improvement for course delivery, increasing content accessibility to the students and additional ancillary materials, like training videos, to improve pedagogical support.

6.4 What is the impact on society beyond science and technology?

The curriculum was designed, not only to excite students about STEM through immersion in a multimedia project, but to provide them with authentic, transferable job skills. These included the ability to: Use professional animation software tools to create assets and a complete animation; understand how modelling can be accomplished with this software; work collaboratively in a team to produce a product; take on a specialist role within a team to produce a product; tell an animated story that involved using STEM concepts, art, creative writing, and music; communicate effectively both within and between teams in their classroom; think creatively to solve technical (software) problems; and for some students, the team leaders, to manage a project to completion.
The last item on the list required interpersonal skills to get other team members to do their jobs; a sense of time management; and a clear vision of the final product.

7. Conclusion

It is clear from the results that the majority of students participating in this study were engaged by the technology in a creative way. They followed the precepts of a standardized Engineering Design Cycle, while employing the concepts of a Creative Design Cycle practiced by professionals in content creation and media production within the sphere of the Entertainment Industry. Through that practice, students were able to envision themselves participating in some form of a STEM career, be it in visual production, audio production, workflow management, or team leadership. For all elements, students were introduced to and guided through the process within an educational framework and with all the excitement of personal content creation and interpersonal interaction towards a team goal.

8. References

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8.1 References of Educational Standards Used in Curriculum

International Society for Technology in Education (ITSE) Standards used in curriculum design:

Standard 1.a. & b. & c.
Standard 2.c.
Standard 3.a. & b. & c. & d.
Standard 4.a. & b. & c. & d.
Standard 6.a. & b. & c. & d.

Next Generation Science Standards (NGSS) Standards used in curriculum Design:

Disciplinary Core Idea (DCI) Standards used in curriculum design:

ETS1.A Defining and delimiting engineering problems
ETS1.B Developing Possible Solutions
ETS1.C Optimizing the Design Solution
HS-PS4.A: Wave properties
PS4.B Electromagnetic Radiation
PS4.C Information Technologies and Instrumentation

Science and Engineering Practices (SEP) Standards used in curriculum design:
Asking questions, Developing and using models.
Planning and carrying out investigations
Analyzing and interpreting data
Designing Solutions, Engaging in argument from evidence,
Communicating information

Core Curriculum Content (CCC) Standards New Jersey used in curriculum design:

Patterns, Cause and Effect
Patterns, Energy and Matter
Structure and Function