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Using Science Fiction Prototyping to Decrease the Decline of Interest in STEM Topics at the High School Level

Mary DE LEPE [1], William OLMSTEAD, Connor RUSSELL, Lizbeth CAZAREZ and Lloyd AUSTIN

Abstract. In order to address the lack of student interest in STEM subjects and the dwindling number of students pursuing STEM careers, the Creative Science Foundation (CSF) has developed an easy to deploy educational strategy. This strategy, effectively titled Science Fiction Prototyping, utilizes science fiction stories and material to "explore the possible implications of research and technology on humans, societies, and the world." It is also possible that these prototypes can be used to increase STEM motivation in students. The researchers will first perform a meta-analysis and literature review to determine the present outlook of STEM curriculum, student interest in STEM careers, and student enrollment in STEM careers after graduation. Other parts of the research project include a pilot study to explore the feasibility of using science fiction prototypes within a high school environment to increase student interest and attraction to STEM related careers.

Keywords. Science Fiction Prototyping, STEM, Science, Technology, Engineering, Mathematics

1. Introduction

In recent years, high school student interest in Science, Technology, Engineering, and Mathematics disciplines has declined. This study was conducted in an attempt to determine the cause of the decline and the validity of Science Fiction Prototyping as a strategy for motivating and increasing student interest in STEM topics. This is a follow-up to previous studies conducted by Professor Vic Callaghan, Director of the Creative Science Foundation and Professor Emeritus of Computer Science at Essex University in Colchester, United Kingdom, and Brian David Johnson, a futurist at Intel Corporation, whose future casting, the process of using ethnographic field studies, technology research, trend data, and Science Fiction to provide Intel with a pragmatic vision of consumers and computing, made him a pioneer in development of artificial intelligence, robotics, and Science Fiction Prototyping.

After the research team reviewed existing literature and hosted a small Science Fiction Prototyping (SFP) workshop, the research team found that while SFP can be a fun activity, SFP did not affect student's interest or motivation towards STEM disciplines. Results were limited due to time constraints and a lack of diversity in the

[1] Corresponding Author.

samples. However, the findings highlighted appropriate methods to test the validity of SFP.

2. Impact of the Literature Review

A review of existing research reveals that the diminishing interest in Science, Technology, Engineering, and Mathematics (STEM) disciplines can be attributed to numerous environmental, educational, cultural, and societal barriers. Students are also not pushed to connect everyday technologies, like mobile phones, computers, and other innovations, to STEM disciplines. Without an understanding of how STEM disciplines influence our electronically interwoven society, students become users of technology rather than innovators.

Numerous barriers exist that impede the creative thought processes of students. The high school level of science literacy is declining in the United States, which now ranks below the world average in producing STEM graduates [7]. One study claims that the problem began with the implementation of the No Child Left Behind policy, as the policy reduced the science curriculum and the lessoned the importance of science related test scores [1].

More barriers to student interest in STEM are the student's environments. Their socioeconomic background, race and ethnicity, gender and parents' academic level all heavily influence interest in STEM careers [8], [9], [5]. Low socioeconomic levels prevent students from being able to tap into resources that wealthier students have readily available for learning [9]. Parents' personal educational achievements also correlate highly with a child likeliness to be encouraged and challenged throughout their life to explore STEM topics.

Gender, race and ethnicity challenges have the greatest impact on STEM interest and take-up. This is because certain cultures have practices that discourage education. For example, minority women are less encouraged to pursue STEM topics. Both the scientific community and culture often ostracize women that pursue STEM fields [8]. Low-income communities have fewer resources available and teachers who are qualified to teach STEM subjects. Teachers in low-income communities are required to teach science and mathematics, subjects in which they are not subject matter experts [5].

Science Fiction Prototyping (SFP) is one strategy proposed as a possible solution to the lack of contemplation and motivation shown by students in regards to pursuing STEM careers [3], [4]. SFP is a learning activity where fact and imagination are coupled to create a story of how an innovation put to use in a future setting would affect the people of that time socially and economically [3], [4]. The student is encouraged to imagine how the people would interact with the new technology, what problems would the technology solve, and what new problems could it [3], [4].

The biggest idea behind SFP is that students should be able to critically think about the interaction between society and emerging technologies. Emphasis should be placed on the use of science to provide testing for possible scenarios [3], [4], [6].

3. Contextual Factors

There are several factors that impacted the design and implementation of this study, the biggest being time. When the research team progressed to the point of data collection, local area schools were on spring break, so connecting with teachers and convincing them to allow researchers to affect their instructional time proved a challenge. It would have been preferable to have the pre-survey administered days prior to the prototype presentation. Due to time constrains our entire population was a small sample size with little diversity.

4. Methodology

4.1. Research Design

The research team developed a pre and post survey to analyze the students' experience, interest, and motivation towards STEM topics. The pre-survey asked questions that categorized students previous experience with and current interest in STEM. It also asked students to rate their satisfaction and enjoyment of STEM activities and clubs. The primary goal of the pre-survey was to understand current inhibitions towards STEM and develop a baseline that could be used in comparison with the post survey. After the pre survey was distributed, a member of the research team led an in-class presentation and activity. Immediately after the in-class presentation and activity, the post survey was distributed. The post survey asked similarly worded questions to the pre survey in order to easily quantify a decrease or increase in interest and motivation of STEM. Compared to the pre survey, the post survey had more Liket questions that asked students to rate their satisfaction, interest, and motivation towards STEM. The primary goal of the post survey was to expand upon the baseline set through the pre survey to gauge any change after the STEM activity. The students were asked to write their first name and the date on each page of the pre and post surveys so the research team would be able to compare the results.

4.2. Participants

Our audience was comprised of two high school classrooms of Earth Science, one of 28 students, and the other of 26 students, giving a total of 54. The frequency of boys and girl was basically even, since as the class sampled had a total of 28 boys and 26 girls. All the students come from similar socioeconomic backgrounds, ranging from low to middle class, most of them, not having much experience with STEM classes, except for their shared Earth Science class, and a few varied mathematics classes such as Algebra and Trigonometry. Something that was different was the age range, the classes mostly comprised of 14 year olds (64.8%) and 15 year olds (35.2%), though there is no evidence yet of this being significant in the study.

A pre-survey was administered on paper at the start of each class session directly after a very brief introduction of the researcher and purpose. The teacher helped facilitate distribution and collection of the survey, as well as respond to student questions about how to address survey questions. Students were asked to mark their pre-surveys with a small icon, drawing, or other mark that would also be added to the post-survey. This strategy allowed for matching of pre and post-surveys without identifying individual students, and proved to be very effective.

4.3. Instruments

To that end, a workshop was put together that:

- Introduced Brian David Johnson and Vic Callaghan, and how they use prototypes
- Introduced prototype concept by providing an overview of prototype examples:
  - Presented premise of Nebulous Mechanisms.
  - Held a class discussion about Jurassic Park, the science it presented, and how the story explored the possible impact through the narrative.
  - Showed a video prototype (A Day In the Life of Glass) to deepen understanding.
- Showed examples of other ways prototypes are used.
- Had students engage in a class brainstorm exploring a prototype idea.
- Navigated to the Creative Science Foundation website and described the T-Fiction process and the competition opportunities.
- Got students into groups to write their own T-Fiction samples and share the resulting stories with the class.

The post-survey was administered and collected directly after the session during the same class period.

4.4. Data Collection and Analysis

After the pre and post surveys were answered and collected, the quantitative information from questions 1 through 7 on the pre survey, and questions 4 to 7, where documented in an Excel sheet for further comparison. With the aid of the attachment application Analyse-it, the research team was able to analyze the data obtained, and make more sense of the mindset of the students surveyed during the activity.

5. Findings

As previously stated in the instruments section, the research team created two surveys. The first survey, a pre survey, was distributed prior to the Science Fiction Prototyping (SFP) activity, while the second survey, a post survey, was distributed after the SFP activity to effectiveness on SFP increasing the audience's interest in STEM.

Of the pre and post surveys, nine questions were quantitative and their means and standard deviations are displayed in this table where the students were asked to rate each category from 1-6 (whenever the standard deviation is bigger than 1, it means the students' opinion varied a great deal).

Table 1. Descriptive Analysis of Survey Responses

Survey Question for pre and post survey	Mean Pre Survey	Mean Post Survey	Standard Deviation Pre Survey	Standard Deviation Post Survey
Current interest in required STEM classes	3.7	1.1	4.0	0.9
Current interest in required STEM electives	3.7	1.3	4.3	1.1
Current interest in STEM Clubs	3.6	1.5	4.1	1.4
Future interest in Required STEM classes	4.0	1.0	4.2	0.9
Future interest in STEM Electives	3.8	1.4	4.4	1.0
Future interest in STEM Clubs	3.8	1.4	4.1	1.3
Enjoyment in Current Required STEM classes	3.9	1.1	4.0	0.9
Enjoyment in Current STEM electives	4.0	1.4	4.1	1.2
Enjoyment in Current STEM Clubs	4.0	1.6	4.1	1.3

$N = 54$

From the pre to the post survey, most of the means increased, albeit very slightly, when in most cases at the pre survey the standard deviation was more than 1 (except for Future interest in Required STEM classes), the research team observed a slight decline in the post survey standard deviation, showing the opinion of the students varied less once they went through the activity.

Aside from observing the variations of opinion between students (for which the team has yet to find a correlation for their way of thinking about STEM previous to the activity), the main objective was to measure student's reactions towards STEM once the Science Fiction Prototype was administered. T tests (with α=0.05) were conducted to compare the mean rating differences on the above survey questions. If there was such a p-value less than α=0.05, then there is evidence of change in STEM attitudes after the activity.

Table 2. Paired T test Results of the Nine Quantitative Responses

Survey Question for pre and post survey	p-values for pre and post survey	T value for pre and post survey	DF (Degree of Freedom) for pre and post survey
Current interest in Required STEM classes	0.0410	2.09	53
Current interest in STEM Electives	0.0010	3.50	53
Current interest in STEM Clubs	0.0092	2.70	53
Future interest in Required STEM classes	0.1919	1.32	53
Future interest in STEM Electives	0.0005	3.71	53
Future interest in STEM	0.0945	1.70	53

Clubs			
Enjoyment in Current Required STEM classes	0.3316	0.98	53
Enjoyment in Current STEM electives	0.6162	0.50	53
Enjoyment in Current STEM Clubs	0.2827	1.09	53

As Table 2 shows, the most significant change occurred in the current interest in STEM questions (0.0010, in Green), which shows that the activity was a fun and motivating option for STEM education at the high school level. Although, it was not motivating enough for future endeavors in Required STEM classes and Clubs, it did seem to inspire the students to look for fun STEM Electives as a future option (0.0005, in Red). Still their level of enjoyment of STEM in general did not seem to increase, quite the opposite, it seems the students are still predisposed to loath STEM education.

It is evident through the student's disappointment and lack of interest in pursuing future STEM classes that the activity did not last long enough. The research team can surmise that Science Fiction Prototyping is a good way to inspire high school students to enjoy STEM classes if applied from early on and for longer periods than the 40 minutes allotted for our test experiment.

Although this study does not delve too deeply on the idiosyncrasies of SFP itself, it gives a small glimpse of the audience and the obstacles it will run against in the hopes of motivating students to pursue STEM through SFP, and can set the groundwork for further studies. Since this is the first time SFP has been tested at the high school level, the research team considers the results to be as expected, since it's accepted that SFP alone will not eradicate STEM antipathy, yet it could be a useful tool to shake the monotony of lectures and standardized testing.

Even though, not precisely quantitative, pre survey questions 8 through 11, also gave a glimpse of what the mindset of the students was before the activity. Most of the students did not enjoy STEM, or just went along because they either liked their teacher, or their friends were in the class. They tended to complain that the class was either too difficult or boring or even had a hard time finding relevance to the subject. After all this being asked if they had plans for college, came as no surprise that a great deal of them were not sure or not decided to continue furthering their education. Moreover, if a major in college was suggested, it usually was not a STEM-related career.

After the activity however, the post survey proved that the students enjoyed the activity, felt at the time motivated by it, and regretted the lack of time to develop their own prototypes.

6. Conclusion

It will be important in future research to include the following:

6.1. Work with teachers prior to engaging with the students.

Engaging with the teachers in order to help them fully understand the goals and process of the research will ensure that the class is prepped and ready for researchers to come in and get started without having to lay significant groundwork. It also may encourage teachers to grant researchers more class time for investigation and study. Teachers know and understand their students, so it will behoove researchers to enlist their support, as they can propose suggestions or changes to the planned methodology that will elicit more effective or valuable data. For example, after the first presentation, the teacher involved in this study provided context and information on what the students needed that greatly improved student response in the second presentation. Although all of the students in this project were in ninth grade, future student samples should span the grade levels. Teacher input would be necessary to ensure grade-level appropriateness of presentation content.

6.2. Perform focus groups for data collection.

When given the opportunity to speak freely about their opinions toward STEM, the student participants expressed their feelings more comprehensively than the survey would allow. When students struggled to articulate an idea, others would chime in to help complete thoughts.

It should be noted that when the students were verbally questioned about engaging in the prototyping activity, the response was overwhelmingly positive. They said they wished they had more time to come up with prototype ideas and time to develop the stories. When asked by the facilitator if they had a choice to take science fiction prototyping as a class, the students gave a resounding, “Yes!” The student participants also spoke about how they would be more apt to like STEM classes if they were to incorporate prototyping, because it would make the class content more relevant to them.

6.3. Utilize current and emerging technologies to engage the learner in the prototyping methodology.

As the study suggests, future iterations of Science Fiction Prototyping (SFP) workshops could be greatly improved by utilizing current and emerging intelligent environment technologies. By utilizing intelligent technologies students would be more engaged with SFP activities and methodology. Activities promoted by the SFP methodology, including T-fiction where students write short stories small enough to fit within a series of tweets (called T-fiction), could be enhanced through intelligent uses of mobile devices. Mobile devices would allow students to easily share their T-fiction stories with other students locally and globally. Mobile devices would also allow students to participate in global contests on the Creative Science Foundation’s (CSF) website.

Two additional intelligent technologies that could enhance Science Fiction Prototyping (SFP) workshops are augmented reality and virtual reality. With rapid prototyping models and easy to use software, students could design, build, and share SFP prototypes with other students on a local and global scale. With augmented technology, students could augment everyday objects with videos, pictures, text, animations, and web links. Virtual reality would allow students to become completely immersed in different worlds.

6.4. Future implications and significance of the findings.

The findings show that SFP could be a good activity to get students interested in STEM, perhaps not long term yet; however it is a good instrument to use against the boredom acquired in the everyday lecture classroom. The research team surmises that a longer

SFP activity, that goes on for days, instead of one hour, would have a higher impact on the students towards STEM, and it should be the next step in research to validate the need for SFP in high school classes.

Since this was the first time SFP has been introduced to the high school level, the research team did not anticipate a significant change in the students' mindset about STEM; however, the team was pleasantly surprised to see the students asking for more, even if they were not entirely convinced of pursuing a STEM class, much less a career, after the activity. The team predicts, that the continuation and better planning of SFP added on a more often basis to STEM high school classes will definitely have an impact on more students liking STEM and changing their schemas. The research team thinks that a reason for the students to reject STEM is due in great part to having developed early in life a predisposition to hate STEM topics. One class will not change their minds. Moreover, repetitive fun activities, such as SFP, will help students change their previous schemas, and create a new love for STEM.

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