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Using Comics to Promote Student Interest in the Breadth and Depth of Chemical Engineering

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Abstract

To encourage students to pursue chemical engineering at undergraduate and graduate level engineering programs, the motivations behind student involvement and success in this field must be examined and adapted to accordingly. In this study, an educational comic has been created and distributed to university students to investigate whether career prospects impact student motivation in pursuit of chemical engineering on an institutional level. This comic was then distributed to students beginning their first undergraduate year at Northeastern University and who had not yet definitively declared their major.

This comic dismantles two key misconceptions that may discourage students from pursuing chemical engineering: limited scope of industrial opportunities and restrictive skill sets relating exclusively to chemistry and math. To overcome these misconceptions, the comic demonstrates a student questioning their career interests and learning about the fluidity of chemical engineering work in various industrial contexts. This educational tool delves into industries such as oil and gas, material science, drug discovery, sustainable energy, environmental preservation, agriculture, and food science. Through the inclusion of these industries, the comic provides a clear but thorough introduction into the breadth of environmental, social, and scientific impact that chemical engineers can have. The comic also emphasizes the diversity of knowledge bases and skill sets chemical engineers use to combat the fallacy that their work is exclusively based on chemistry or math.

For a baseline, students were instructed to complete the Felder Soloman Learning Style survey to assess their preference for visual or verbal learning tools. Further survey questions assessed the impact of the comic to boost student engagement, comprehension, and retention of learning materials. Some students were also personally interviewed to gain a more holistic evaluation of their attitude and understanding towards pursuing chemical engineering as a career.

The results of this study indicate greater student interest in pursuing chemical engineering and showcase the power of expanding educational tools to better showcase the possibilities that await graduates.

I. Introduction

Encouraging the next generation of chemical engineers begins with adjusting teaching methods in the classroom to accommodate student learning styles. One teaching method proven effective is comics, where panels of animations are coupled with informative text. Though commonly perceived in an entertainment setting, comics provide an effective alternative to traditional teaching methods such as textbooks or lectures[1]. In this study, comics have been specifically used to demystify the field of chemical engineering and introduce the many opportunities it presents to students and professionals alike.

1.1 Chemical Engineering Enrollment

The perception of chemical engineering curriculums in national undergraduate programs, as well as of existing post-graduate opportunities, are often restrictive in nature. Students often

exclusively list “chemistry” and “mathematics” as topics focused on by chemical engineering programs, neglecting more integral concepts such as conservation principles, fluid mechanics, or process control[2]. The general perception of chemical engineering as a field is also usually contained to petroleum and oil refining, or chemical manufacturing. These assumptions made about the educational and professional experiences of a chemical engineer are limited and often discourage students in high school or college from pursuing chemical engineering. Students who feel they are less inclined to chemistry and math will similarly be less inclined to pursue chemical engineering. Students who are also less interested in the oil or chemical manufacturing industry will consequently be less interested in pursuing a career where these are the only perceivable fields that they can work in.

These findings are reflected in waning undergraduate and graduate enrollment in chemical, petroleum, and chemical-related engineering. Year-to-year medium percent change in freshman enrollment in this major had been steadily declining since 2018 in 96 institutions, with a markable 10.4% decrease in 2020[3]. In their 2021 Graduate Enrollment Census, The National Science Foundation found that chemical engineering had the smallest 1-year growth of 1.4% in 2020-21, and the large 5-year decline of 29.1% in 2017-21 among other engineering disciplines[4]. These statistics demonstrate a national declining trend in pursuing chemical engineering, and educators should prioritize developing more effective methods of recruitment to the field.

1.2 Comics as Educational Tools

To help provide a means of overcoming these obstacles in recruiting students to chemical engineering, this paper will describe the development and dissemination of a comic that explains the breadth and depth of chemical engineering opportunities in a clear and engaging way. Comics have gained popularity in recent years for their effectiveness as educational tools, but have a long history with many examples of their educational effectiveness in a variety of subjects[5,6,7]. Dating back to a 1944 study where an educational comic was distributed to 2,500 students in various grades, evidence indicates that students up to 18 years old enjoy reading the content in this comic[8].

Students explained the comics were easy to read and found their narratives entertaining, sentiments that have remained constant among students even today.

When compared to infographics to express data-driven information, one study by Wang et al. found that participants had a greater level of understanding, engagement, and enjoyment reading comics[9]. Participants scored higher in questionnaires assessing their comprehension of the content in comics as opposed to infographics or illustrated texts. Participants who had read comics were able to recall 55 percent of its contents, as opposed to 43 and 41 that had read infographic and illustrated texts. Generally, participants appreciated the organization of the comic's structure as improving memory and condensing complex information. This qualitative and quantitative evaluation of comics as an effective education tool demonstrates the basis for its use in this study.

The foundation of the study described in this paper is also built upon several previous analyses by our research group, including some preliminary analysis aimed at K-12 students. One comic was developed in alignment with Next Generation Science Standards aimed to explain the use of voltaic cells in a simple way through the development of a comic detailing the science behind voltaic cells and its practical applications[10]. This study was distributed to 11 K-12 students and its results demonstrated that while 80 percent of students enjoyed reading the comic, there was varied engagement with the contents and most retained little to no information conveyed.

In another study[1], two comics titled "Data Analysis" and "Uncertainty" were distributed to a Transport I Laboratory course where the comic's contents had already been introduced in class and were being supported by the comic's contents. Student feedback was gathered through student self-assessment on a 1-5 Likert scale, which indicated that 94 percent of students were more confident in the comic's contents after reading it, and the average grade of students in the course increased from 83.0 ± 1.6 to 86.2 ± 1.2. This self-assessment combined with course performance demonstrated the effectiveness of comics in educational contexts for student understanding.

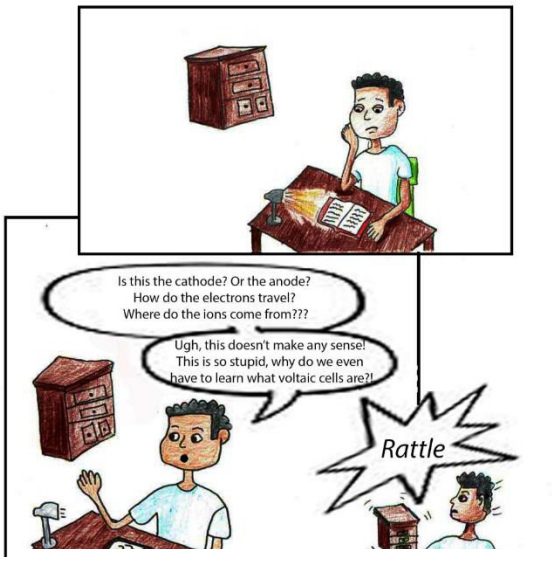

Figure 1: Example Page from "The Use of Comics to Educate K-12 Students on Voltaic Cells"

The findings from these studies suggested educational comics are effective at developing student understanding, improving academic performance, and strengthening confidence in course material. However, the benefits derived from the integration of comics in classrooms is reliant on the foundational knowledge readers must have before reading the comics. To extract the full range of advantages that comics provide students, they must have a baseline of knowledge that allows them to effectively follow the comic's narrative and comprehend its contents. These findings were incorporated in the following methodology chosen to evaluate student understanding in the breadth and depth of chemical engineering opportunities.

II. Methods

2.1 *Comic Development*

A new comic was developed, following a young student guided by a professional chemical engineer through the opportunities available to them in different industries. These fields include chemical manufacturing, material science, drug delivery, energy sources, environmental preservation, agriculture, and food science. The comic employs conversational language to provide simple but thorough introductions to the fields discussed. The illustrations also utilize cartoon-style animations to appeal to younger age groups and maintain the accessibility of the comic's contents. Figure 2 below displays several pages from the comic for reference.

Figure 2: Example Pages from "The Wide World of Chemical Engineering" comic.[11]

2.1.1 External Contributions

The comic's script were written and revised by undergraduate student Ira Hysi and Chemical Engineering Teaching Professor Luke Landherr. The comic was also professionally illustrated by Northeastern chemical engineering alum Monica Keszler. Illustrations were further guided by the input of the American Institute of Chemical Engineering (AIChE) K-12 Foundation in ensuring safety measures such as specific personal protective equipment (PPE) were properly displayed throughout the comic.

2.1.2 Character Diversity

Data from the Census Bureau indicates that diversity in the chemical engineering community continues to be limited despite progress towards diversity, equity, and inclusion. In 2021, approximately 72% of chemical engineers were white-identifying and 20% were female-identifying[12]. These statistics demonstrate the heterogeneous identities comprising the chemical engineering workforce, limiting the range of perspectives and innovation various industries have access to. This comic was specifically developed with the intention of highlighting the importance of diversity in chemical engineering, by first categorizing each industry in contrasting colors. The visual spectrum displayed emphasizes the spectrum of identities welcome and needed in the

chemical engineering community. The homogeneity of characters presented throughout the comic was also incorporated to encourage students of various backgrounds and identities to pursue chemical engineering. This includes the African American main character, who racially identifies with a minority of chemical engineers.

2.2 Local & Digital Distribution

The comic was distributed to approximately 200 students enrolled in the Introduction to Engineering Course at Northeastern University for first-year undergraduate students in engineering. For purposes of formative assessment to determine to whom the comic could be disseminated to in future studies, the comic was also distributed digitally via LinkedIn to reach a broader audience for use by other chemical engineering educational institutions. In the four months since the comic was initially shared through this resource, approximately 250,000 viewers have seen the post containing the comic, 1,585 viewers have liked the post and 281 have reposted it for further distribution.

2.3 Institutional Distribution

The comic has also been distributed as a recruiting resource to other institutions like Michigan Technical University, University of Buffalo, and University of Washington to effectively introduce and explain the realm of chemical engineering to prospective students. University of Washington has hosted the comic on their official departmental site for chemical engineering to encourage students to join the department[13]. This demonstrates the merit of this comic as seen by institutional leaders to motivate student enrollment, and proves the impact of this comic as a cross-institutional recruitment resource for chemical engineering.

2.4 Assessment Methods

2.4.1 Felder Soloman Learning Style Index

Students receiving the comic were instructed to complete an on-line questionnaire based on the Index of Learning Styles developed and validated by Richard M. Felder and Barbara A. Soloman[14]. This questionnaire uses a series of 44 questions to ask students to self-assess their learning style based on four primary scales: active-reflective, sensing-intuitive, visual-verbal, and sequential-global. Students are then better able to determine where their preferences lie on each spectrum, suggesting what approaches to learning they may benefit from the most. Previous engagement with this survey has shown the positive reception of visual tools by students in STEM and its effectiveness in STEM education. This evaluation is made to understand student learning preferences when considering the integration of a comic as a tool in classrooms. Given the nature of comics as visual tools presenting a narrative in a sequential format, student self-assessments on the visual-verbal and sequential-global scales have been prioritized in this study. The survey presented a better understanding of what are considered effective learning tools for students in undergraduate engineering programs.

2.4.2 Comic Comprehension

Students were also asked to complete a survey after reading the comic to evaluate their understanding of its contents and their reception of comics as a learning tool. More specifically students were asked to elaborate on the aspects of the comic that did or did not appeal to them, whether the comic clarified the roles of chemical engineers, and if they would recommend comics as a learning tool in other circumstances. These questions were asked either in open-ended form

or on a Likert scale of 1-4. For comprehension, a level of 1 indicates little to no understanding and 4 indicates near or complete mastery. For agreement, a level of 1 indicates the student would not recommend the comic at all and a level of 4 indicates the student would highly recommend the comic. This survey demonstrated the effectiveness of the comic for the purpose of educating and encouraging student engagement in chemical engineering.

III. Results & Analysis

The results of this study are based on limited feedback from 7 students in the Introduction to Engineering course, despite it being seen or utilized by 200 students. This restriction can be attributed to the non-incentivized approach taken in distributing the comic and collecting student feedback as students voluntarily analyzed the comic's effectiveness. Many students in the course may also have been deterred from the comic's contents if they were not chemical engineering majors. Generally, students were also likely experiencing potential survey fatigue from other coursework which discouraged their participation in this study.

3.1 Felder-Soloman Index of Learning Style

The results from the Felder-Soloman Learning Style survey demonstrate that the participants of the study prefer learning through visual and/or sequential tools as opposed to global and verbal. Within these two scales existed a range of 1, 3, 5, 7, 9 and 11, where participants self-assessed their preference for visual tools between level 3-7, and their preference for sequential tools between 1-7. Figure 3 below displays the breakdown of participant preferences on the two scales. A key determinant of a learning tool's functionality is its alignment with its users' learning style. Assessing participant learning styles indicates that students of this study learn more effectively with visual tools that are presented in chronological order. These preferences suggest that the proposed comic may be more successful in conveying information to this study's participants than other learning tools.

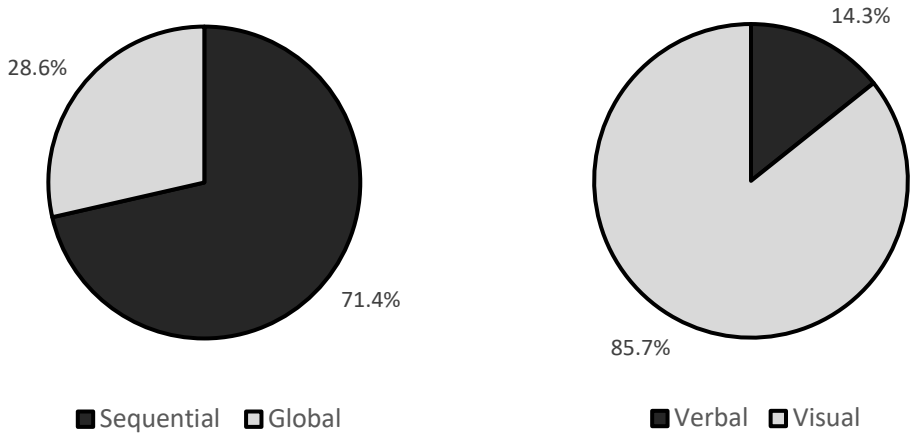

Figure 3: Results of Index of Learning Style Survey (N = 7)

3.2 Comic Comprehension

Students who read the comic were asked to evaluate its value as a learning tool in multiple ways. Based solely on its ability to transfer knowledge and improve understanding, the comic was found to increase confidence in conveying and working with its content. Students who did not feel confident in the comic's material or were not familiar with its subject matter found that the comic improved their understanding to be moderately or extremely high. When asked for their subjective feedback on the positive aspects of the comic that appealed to them, participants noted several formatting and content elements that the comic employed. Participants appreciated the concise and digestible language, as well as the comic's creative visual components and inclusion of chemical engineering fields they had not immediately thought of.

Specifically, students said they thought the comic:

- "was very visual and creative"
- "laid out several different fields, some I would say didn't pop straight into my head when I thought of chemical engineering but made sense."
- "provided information on the subject in a concise easy to understand manner"

While it should be noted that all participants had intended to pursue chemical engineering in their undergraduate studies, the comic still improved participant understanding in the variety of opportunities available to them postgrad. Participants also greatly resonated with the environmental and social impacts emphasized throughout the comic. Specifically, students said the following appealed to them:

- "The man's goal of making a difference while enjoying science and math"
- "I felt as though I was apart of the demographic that the comic was appealing to as I am chemical engineering but still deciding what I would like to do with Chemical Engineering."

When finally asked whether students would recommend comics as a learning tool in future iterations of the Introduction of Engineering course or as a tool in other learning circumstances, all students moderately to highly agreed. Here it has been demonstrated that the student reception of comics as learning tools is largely positive. Student comprehension of the comic and their recommendation of it as a learning tool could be traced back to their alignment with visual and sequential learning styles. Students in this investigate were more attuned to visual and sequential learning styles, which was reflected in their evaluation of the comic's ability to improve comprehension and resonate with their interests and experiences. The participant consensus to include comics in other learning environments, along with the course that they received this comic, further emphasizes the effectiveness of educational comics. Figures 4 and 5 illustrate the comic's effect on comprehension and participant agreement toward the use of comics as useful educational resources. These results demonstrate the impact that comics can have in boosting student understanding of chemical engineering opportunities and engagement with the field.

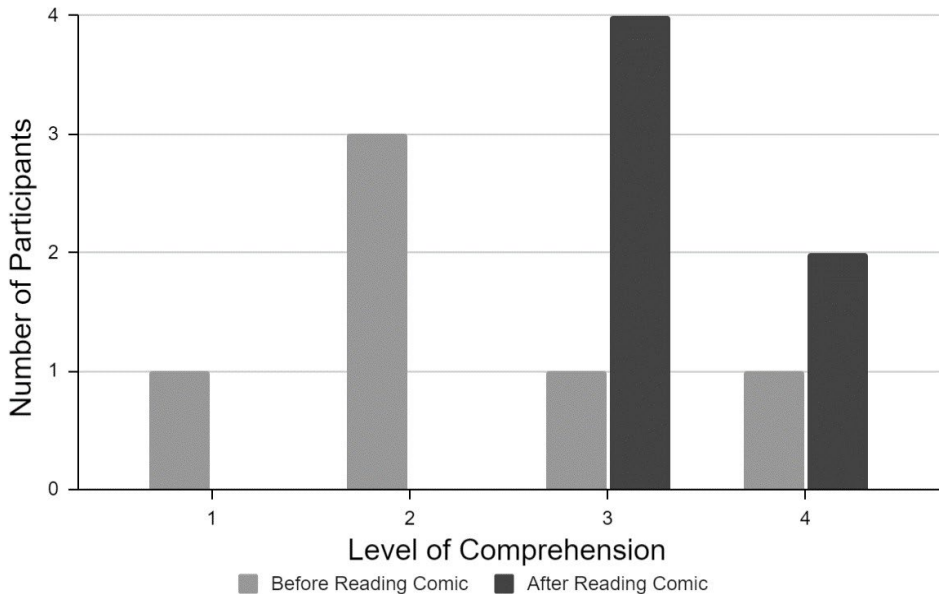

Figure 4: Level of Student Comprehension Pre- and Post-Comic Consumption (N=7)

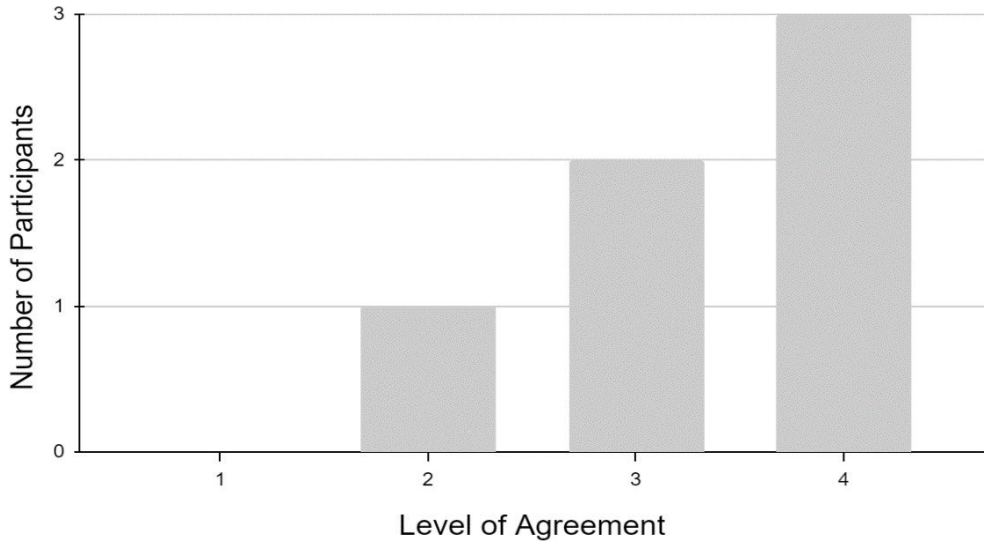

Figure 5: Student Level of Agreement in Recommending Comics as an Effective Learning Tool (N=7)

IV. Conclusion & Future Work

In this study, an educational comic has been developed to introduce the breadth and depth of chemical engineering opportunities that students have access to academically and professionally. Participants of the study found that they preferred visual and sequential learning tools, which were reflected in their feedback of the comic as effective in conveying information. Students became more confident and knowledgeable in the comic's contents after reading it, and suggested comics be used as a resource in other learning environments as well.

Though the study provides a strong foundation for the use of comics to successfully recruit students to chemical engineering, the study is limited in its quantitative evidence of building student motivation to pursue chemical engineering. Several approaches will be taken in the future to support the findings discussed by the current study, primarily involving gathering further feedback from already participating students and hearing from a greater variety of student input.

4.1 Building On Current Student Feedback

The current study examined written feedback from students via short-answer questions or self-placements on various Likert scales. While these indicators of student comprehension and approval of the comic are concise and allow for convenient analysis of its impact, it is restrictive in describing the effectiveness of the comic. Future directions of this study will allow for personal interviews with students that have already completed the Felder-Soloman survey. This will allow for more holistic evaluations of the comic's appeal to students, its ability to transfer knowledge, and areas of further improvement in its development. Students will also be asked for feedback using the MUSIC Model of Motivation. Students will be instructed to answer an on-line questionnaire that evaluates their motivation to pursue a future in their chosen program, as well as how best to structure learning to maintain motivation.

Feedback from this study was also received from students completing their first semester of their first year in an engineering program at Northeastern. This feedback allowed for informed input from students who had a general understanding of the opportunities available to them in chemical engineering, but was limiting in its impact on long-term involvement in the field. To assess the lifespan of the comic's effectiveness for student recruitment to chemical engineering, follow-up surveys will be conducted to determine whether students had either continued to pursue chemical engineering or decided to change their major to chemical engineering. This will guide development of comics as recruitment tools for chemical engineering and other engineering disciplines.

4.2 Gathering Further Student Feedback

Current student feedback is limited to English-speaking students attending a higher education institute in the United States. To understand the integration of this comic as a tool for global chemical engineering recruitment, the comic will be translated to various languages including Portuguese, Korean, and Tamil. This future step of gathering student feedback is honed by input from viewers on LinkedIn requesting access to the comic for use in classrooms outside the United States. Developing the comic in other languages will ensure that the comic's use is not limited by its language or subject and can be easily incorporated in more international curriculums.

This study is also limited by the age groups surveyed for feedback, as only first-year college students are given the opportunity to learn about chemical engineering in a professional and academic context. However, students begin preparing for their professional futures as early as middle school, and the future directions of this study aim to accommodate this timeline. This study will be repeated for students in middle school and high school to determine how best to contribute to curriculums for these age groups to pursue chemical engineering. This will also allow for engagement with chemical engineering from students earlier in their academic career and potentially stronger retention in the field.

The study will also include assessments of diversity in background and identity as factors that motivate students to join chemical engineering programs. Currently, student feedback was

gathered without the consideration of diversity and inclusion as a driving factor for involvement in chemical engineering from minority groups. Future feedback will be gathered from students pertaining to the diversity highlighted in the comic and whether that increased the comic's appeal to a greater range of students.

Ultimately, this study aims to motivate students early on in their academic and professional journeys to pursue chemical engineering, and results have shown the potential for comics to assist in reaching this goal. To better understand how comics can be used as a tool to encourage students to pursue various career paths, future directions of this study will explore various types of student feedback and will include further discussions with current participants. This will allow the comic to be employed in wider contexts for a greater range of student involvement in chemical engineering.

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