# Introducing Students To Chemical Engineering Through Educational Comics

**Nethra Iyer, Northeastern University**
**Dr. Luke Landherr, Northeastern University**

Dr. Luke Landherr is a teaching professor in the Department of Chemical Engineering at Northeastern University, conducting research in comics and engineering education.

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## Abstract

There is a stigma surrounding chemical engineering that the field and major are difficult and complex. While this can be true as evidenced by nuanced topics such as fugacity and kinetics, one technique to make the theoretical challenges more approachable is to present the concepts more visually, given the general preference of students in STEM for visual learning. As such, this research study focuses on the creation, compilation, and analysis of chemical engineering comics geared towards K-12 students. Comics have become increasingly more prevalent as visual learning tools, with a long history of their educational potential dating back to the 1940's, so they could be used to help guide more students into chemical engineering without the stigma of the field being too complex.

A series of comics was created displaying how chemical engineering is found in everyday common applications, including chocolate and shampoo. These comics were shared with early engineering students via anonymous survey to analyze the latter half of an educational bridge from K-12 to undergraduate education. All survey participants were evaluated in terms of learning preferences using the "Index of Learning Styles Questionnaire" to determine their general stated preferences towards learning approaches, including visual versus verbal and sequential versus global, as a means of considering how open to visual learning tools that they would be. Students were then asked how comfortable they were with basic ideas of chemical engineering, establishing a baseline for their understanding. After reading the comics, students were further assessed to evaluate students' interest and confidence in the engineering content. Analysis from the surveys focused on gauging the potential and validity of chemical engineering comics as a gateway from K-12 curricula. With the characters in the comics being depicted of various backgrounds, additional questions were asked to assess students' perception of representation in the curricula.

This paper will share the results from this investigation. Further studies will seek to determine how K-12 students feel when they have no knowledge of college-level engineering courses, how students from public and private schools understand these topics, and the effects of diversity, equity, and inclusion within the characters and storylines.


## Background and Previous Work

Chemical engineering is challenging with complex and highly theoretical concepts. These concepts, such as fugacity, can lend themselves to be difficult for not just students but also instructors to conceptualize and explain[1]. This is due to the fact that many STEM (science, technology, engineering, and mathematics) concepts are not overtly or obviously visual or easy to model via experimentation, demonstrations, or traditional hands-on tools. Therefore, visual instruction is key for all learners, not just those who have a proclivity for more visual modes of instruction. Studies have shown that a combination of images and text[2,3] has improved students' retention of the information. Thus, an educational tool that incorporates visual elements is a technique that can be used by instructors, especially those in K-12. One educational technique with visual integration that can address this need are comics.

Although established that comics had a lot of potential in educational uses since the 1940s[5], backlash in the 1950s prevented research from furthering into this field until the last decade or so.

Graphic novels like "Science Comics" have been implemented inside classrooms as novels and explore various topics such as the brain, volcanoes, and whales. As a result, it is possible for comics to delve into chemical engineering concepts and be implemented in K-12 classrooms to help students understand the application of the field.

However, the social perception of comics and the negative stigma surrounding them being "childish" continues even with the graphic novel genre growing with pieces like "Maus"[19] or "Science Comics."[18] Regardless, there are many benefits to implementing comics in the classroom. Comics are first less expensive than textbooks and other multimedia resources. Furthermore, comics allow for the readers to interact with the pages through moving dialogues, creative visuals, and various characters. These aspects of comics allow for higher engagement and better retention as opposed to walls of text presented by textbooks.

Comics may also allow for the promotion of greater representation in curricula through its form as more diverse and inclusive learning tools. With diversity in a field comes higher levels of innovation[4], so having learning tools act as voices for K-12 students interested in chemical engineering and potentially STEM can benefit academia as a whole.

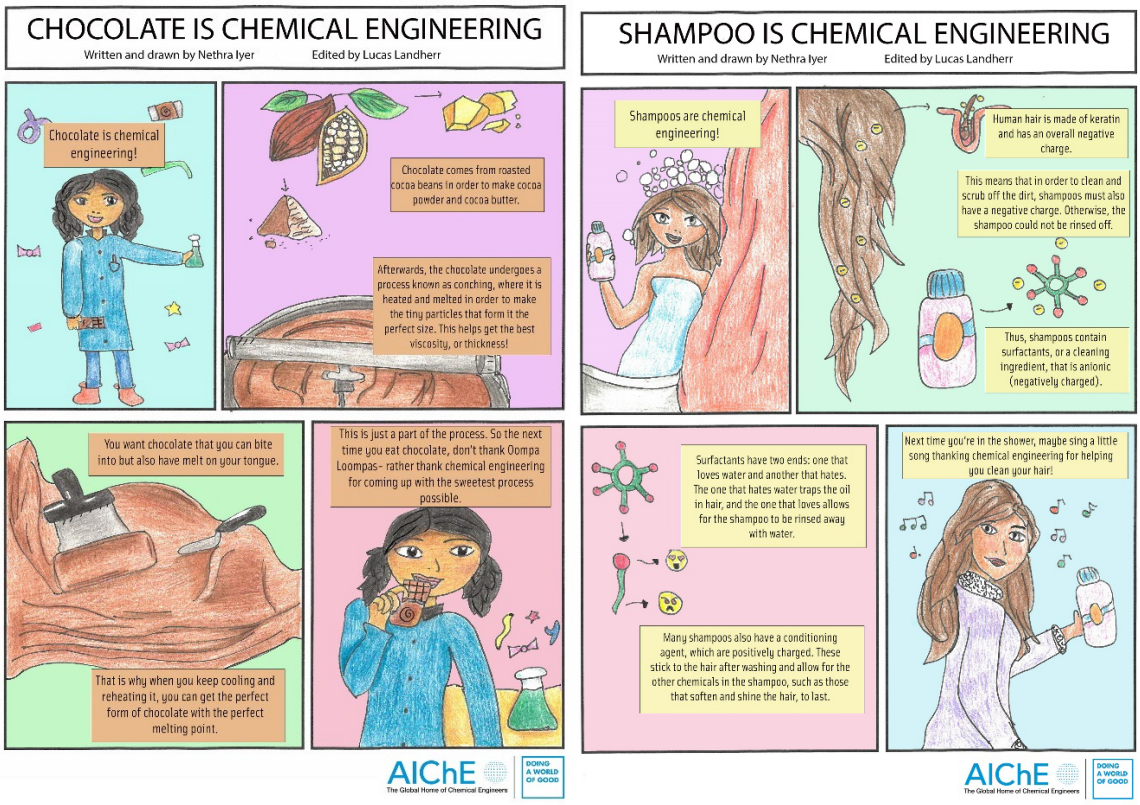
Studies regarding the use of comics as educational tools are being done at a handful of universities today. For example, many chemical engineering comics have been created by this research team at Northeastern University regarding topics such as heat transfer[6], fugacity[7], PID controls[8], and recycle/purge streams[9]. There have already been studies[10] showing that comics disseminated at higher level education systems allow for better understanding and confidence of subject matter. This paper will focus on the implementation of chemical engineering on a K-12 basis, introducing students to the world of chemical engineering as opposed to teaching them concepts for class.

**Methods**

Six comics were produced by several student and professional artists through the support of grants from the AIChE Foundation and the Northeastern Provost. These comics were created and developed with specific themes such as how chemical engineering can be found in common everyday applications such as ice cream, shampoo, and hockey. Each comic presented different characters from different races and discussed concepts of chemical engineering at a general level for students without much context or experience in the field. All the comics were developed by students or faculty with experience in chemical engineering subject matter and finalized only after refining the visual and textual aspects.

In this context, the comics were single-paged visuals with text arranged sequentially to share a story. Whilst comics can be longer, the reasoning behind single-paged comics was to get K-12 students thinking about the various uses of chemical engineering and introducing them into the field as opposed to teaching direct concepts. Furthermore, single-paged comics also allow for easier distribution and sharing for outreach purposes by all AIChE associated groups. Multiple single-paged comics were sent to a mass and energy balances course at Northeastern University, the introductory course for chemical engineering students. The comics were distributed and presented to students as part of an anonymous survey to collect data regarding their learning

preferences and effectiveness of said comics on various factors. The class size was 33 with 14 students responding to the survey.



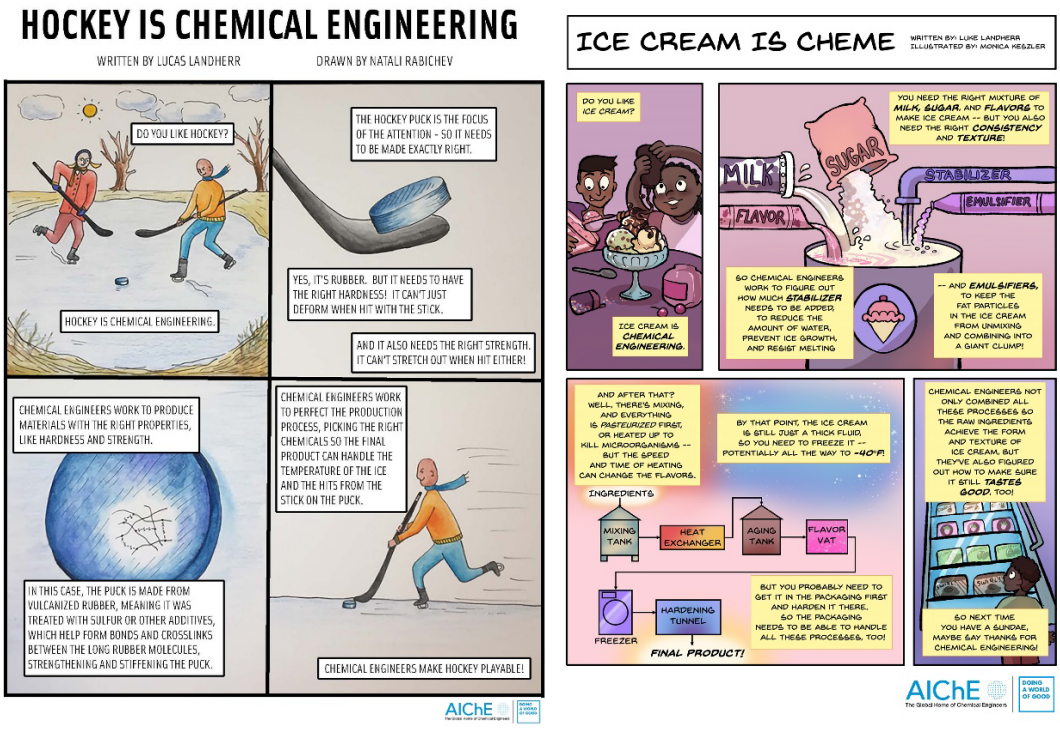



**Figure 1:** These comics[12,13, 16, 17] were written and drawn by various student artists and edited by a chemical engineering professor. They were also disseminated at the 2022 and 2023 AIChE STEM Showcase and utilized for the Doing a World of Good Campaign.

**Assessment**

The survey was sent in two different parts– the first regarding the students' learning preferences based on the North Carolina State Felder-Solomon[11] "Index of Learning Styles Learning Styles Questionnaire." These questions gauged what preferences students had on a numerical style from 1-9, with the categories being visual versus verbal, sequential versus global, active versus reflective, and intuitive versus sensing. The numerical values dictate whether one's preference for a specific learning type is mild (1), medium, or strong (9). Each student received four different values for their learning styles.

Visual learners[15] retain information when they see graphs, pictures, diagrams, and flow charts whilst verbal learners prefer written or spoken explanations. Comics in this sense are highly visual through their graphics, but they also include written aspects such as blurbs. Thus, comics employ aspects appealing to both visual and verbal learners albeit mainly towards the former. Sequential learners understand information in a linear manner, with one step logically following another. Global learners, however, focus on the big picture as opposed to connections between steps, essentially learning in "leaps." Comics in relation are inherently tailored to sequential learners as each panel within a comic follows a very specific order for the reader to follow along. Whilst it is possible to grasp the big picture of a comic, much of the understanding and storytelling aspects are done through the connections between panels.

Sensing learners prefer learning facts and concepts as opposed to intuitive learners who prefer abstract relationships and concepts. Finally, active learners prefer application of concepts learned whereas reflective learners ponder questions surrounding issues at hand. Essentially, active learners like very hands-on work whilst reflective learners prefer thinking alone about the problem first. Comics in this instance do not necessarily lean one way or another for either sensing, intuitive, active, or reflective learners.

Each student takes in information differently, and it is imperative that instructors find an instructional method that strikes a balance between the styles. That way, students can feel more comfortable learning as they have a method that is at least partly tailored to them.

While there are concerns regarding the usage Felder-Solomon Index of Learning Styles, it is important to first understand that learning styles are wholly a spectrum as opposed to categories to place students in. Learners have different preferences of varying strengths that can change over time as they are "fluid traits"[20], and given that learners are rarely evaluated as preferring the extreme ends of the learning style spectrums, instructors can provide a variety of tools while potentially providing resources that help serve the students determined preferences. Concerns with the Learning Styles Index stem from a concept known as the meshing hypothesis[21], where the instructional method matches or meshes with the learner's preference as opposed to providing multiple means of content delivery. These concerns have validity if such an instructional approach was taken. However, learning styles are not rigid structures, and the purpose of determining a learner's style is to identify the types of tools that can be used to increase material engagement.

These tools can also have multiple aspects (visual and verbal, hands-on and theoretical) to keep students engaged with the material.[22] Identifying student preferences can help instructors develop and use tools that reach many student preferences to allow for increased engagement and learning; benefits may extend beyond students' reported preferences.

The Index of Learning Styles has also been studied and tested for any modifications. This model has been used for decades with consistent and reliable results[20] when used as a blueprint and guideline for developing teaching methods. It is important to note that studies have shown that most engineering students prefer visual tools.[22] The chemical engineering comics used in this study can be used to determine student engagement with the high visual material with some verbal aspects. The impact of comics on student success in the classroom can be debated, but the purpose of this study was to focus on engagement and the potential for comics to be used. Implementing tools like the MUSIC Model of Motivation to further quantify students' engagement and understanding based on the comics can be plans for future study.

Figure 2 provides the breakdowns of the Felder-Solomon results from the sample set of 14 students. The comics were distributed to a class of 33 students, of which only 14 participants agreed to participate in the study; student survey fatigue contributed to this limitation in the overall study, which will need to be addressed in future expansions of the research.

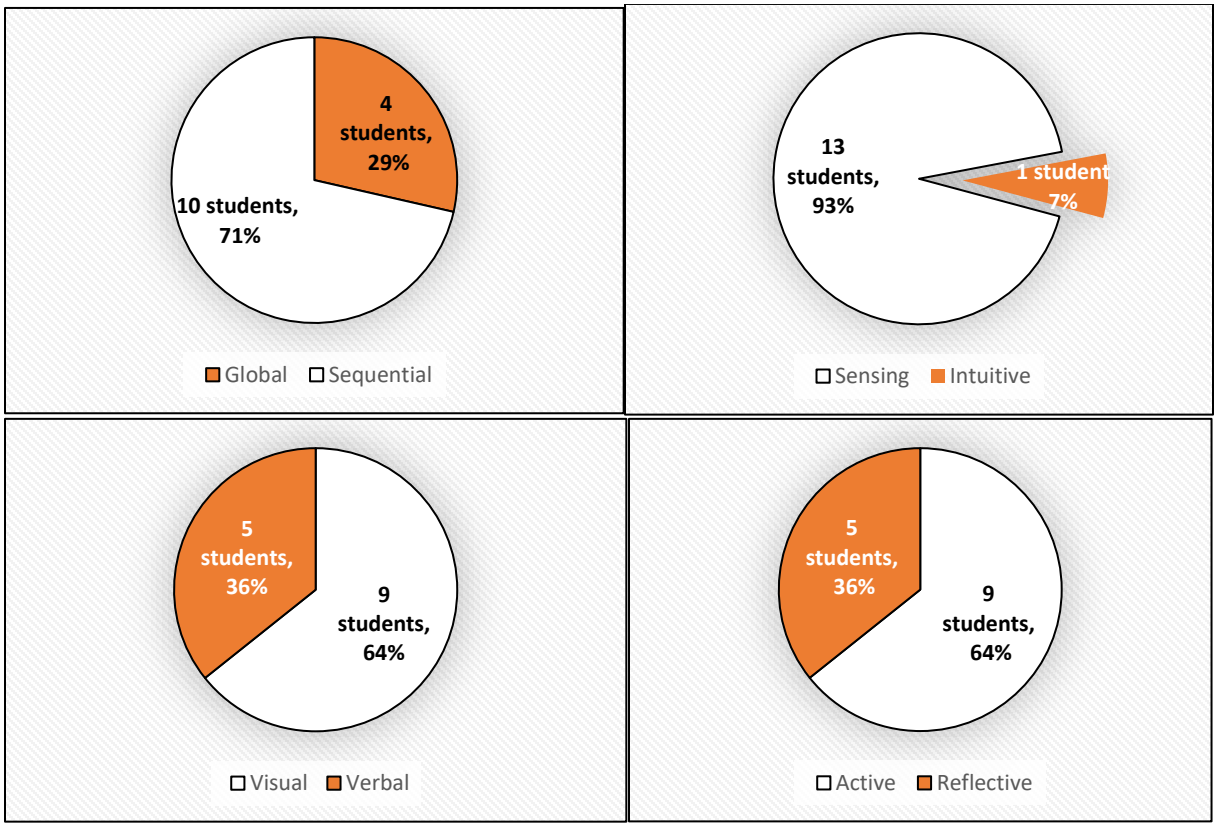



**Figure 2:** A breakdown of the various learning style indices from the class.

As shown in Figure 2, 71 percent of the respondents reported being global learners, 93 percent as sensing learners, 64 percent as visual learners, and 64 percent as active learners.

Afterwards, a second survey was sent with six comics, including those shown in Figure 1, followed by questions first and foremost regarding the students' confidence and improvement in understanding. These would be answered on the students' self-perception of these changes before and after reading the comics. Questions following included if they would like comics integrated into engineering/ science classes and if they would recommend comics as educational learning tools to their friends. The primary use of the comics on the students was to gauge student interest and engagement, even if the material did not necessarily align with course outcomes. Future iterations of this study could have a course assignment that utilizes information provided in the comics. These questions were based on a 1-5 Likert scale, with 1 being strongly disagree and 5 being strongly agree. Furthermore, students were asked to provide comments regarding their perception of the comics presented and what they disliked and liked.

Some of the comments are also included below.

- "Sometimes it feels a bit too crowded, and the words get lost with the images, so it is hard to read."
- "There's lots of writing for small amounts of visuals, however I do not think this completely hinders the comic just something that I noticed."
- "I feel like if I saw them when I was trying to decide what to major in, I would have had an easier time deciding my major."
- "I am very much a visual learner so things like this resonate since they are very easy for me to learn from."

Negative comments were typically centered on the number of words per slide or per page as compared to the visuals. This feedback was important to note as a balance should be achieved before the comics are implemented as teaching tools. The positive comments varied from the overall structure, the visuals, or the purpose of the comics being to help younger students find their major or field of interest.

In terms of numerical results, out of the total respondents, 71 percent reported an increase in confidence and 14 percent decreased in confidence after reading the comics. This can be seen especially through sequential vs. global and visual vs. verbal learners, as shown below. One note is that some data points overlap when plotted in a scatterplot.

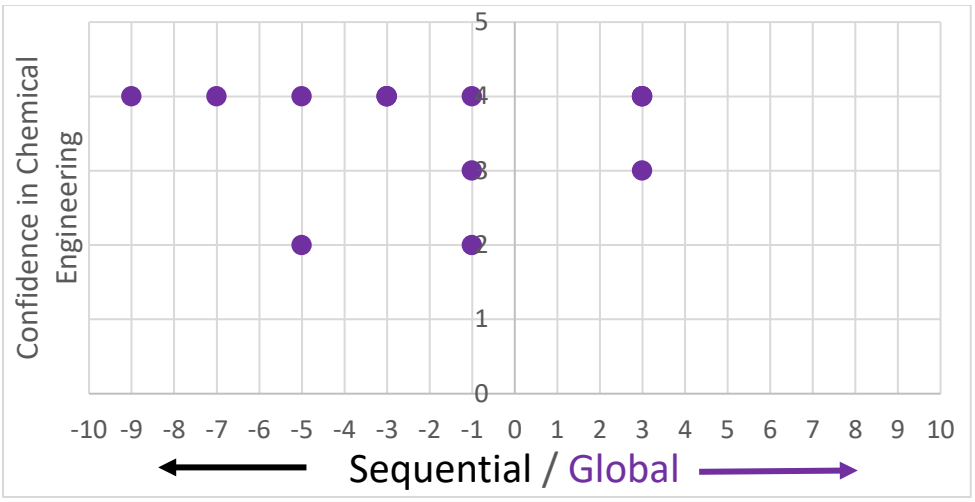



**Figure 3:** Students' confidence in chemical engineering after reading the topics, plotted according to whether and how much of a sequential or global learner they are.

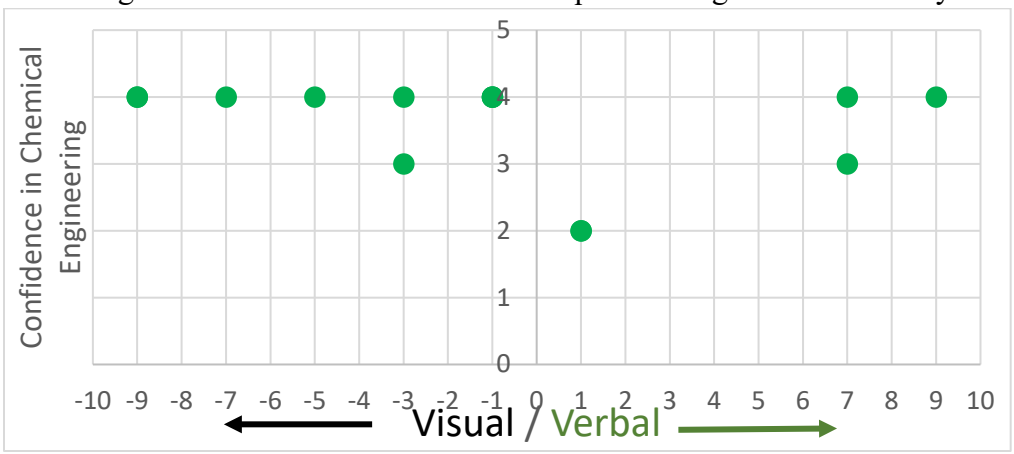



**Figure 4:** Students' confidence in chemical engineering after reading the topics, plotted according to whether and how much of a visual or verbal learner they are.

As presented in Figures 3 and 4, a general positive impact was observed for sequential and visual learners, respectively. This impact is expected as comics are inherently visual tools delivered through a sequential series of text and panels across the page. However, positive impact was also observed for verbal and global learners, especially the latter.

From the surveys responses, 64 percent of the respondents had an improvement in their understanding of chemical engineering topics, with 14 percent having a negative impact on their understanding. Furthermore, 78 percent of the students postively recommended comics as engaging learning tools whilst 14 percent had a netural response. From the results, verbal learners reflected any negative impact from the comics learning tools suggesting that comics are tailored for more visual learners. This meant that there was a very positive response from visual learners. However, as shown in Figures 5 and 6, some verbal learners expressed improvement in understanding and would recommend comics as learning tools. These comics may not work for every single person, but the positive trend indicates that comics have potential for verbal learners, as well to be implemented in a classroom or educational setting.

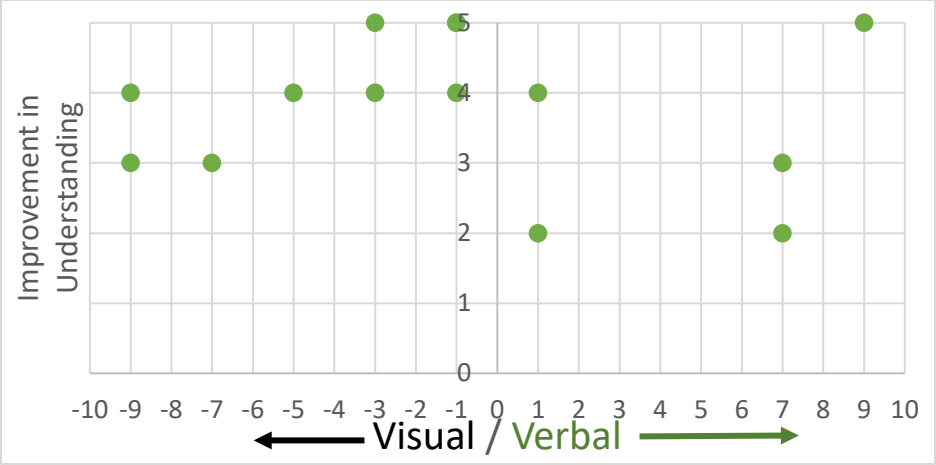



**Figure 5:** Students' improvement in understanding of chemical engineering after reading the topics, plotted according to whether and how much of a visual or verbal learner they are.

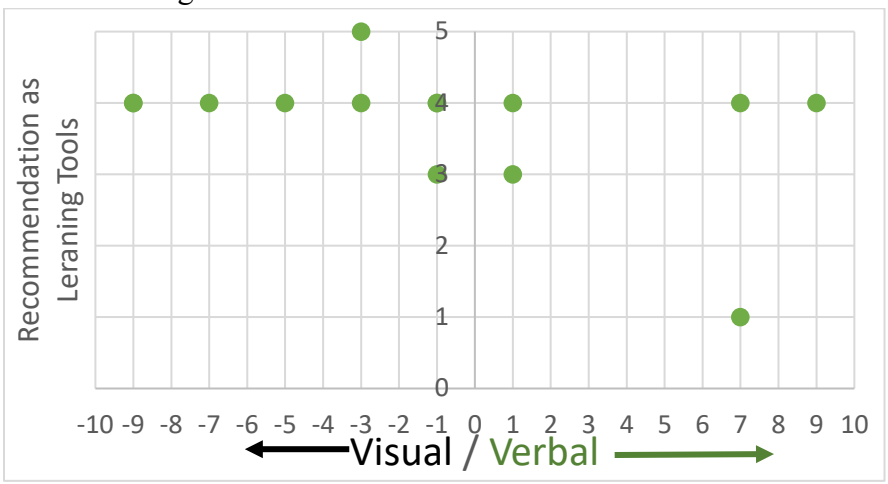



**Figure 6:** Students' recommendation of comics as learning tools after reading the topics, plotted according to whether and how much of a visual or verbal learner they are.

The results also showed no significant statistical difference in confidence, improvement in understanding, recommendation of comics as learning tools, or want of integration of said comics in terms of active versus reflective and intuitive versus sensing learners. This was to be expected as comics do not inherently focus on solely facts or theoretical concepts for sensing and intutive learners.They also do not lend themselves to be hands-on work for active learners or notes for reflective learning. However, this suggests that comics work equally well for both learning styles, with a potential to be tailored in the future for one of these learning types.

Analysis regarding the impact of these comics on gender and racial diversity was also conducted. There was an equal split amongst male and female respondents, but there were no statistical difference amongst the genders. This once more demonstrates that the comics worked equally well amongst the genders. In terms of race, the demographics were limited, so no meaningful statistical results could be determined.

**Conclusions**

The creation of comics as learning tools has significant potential for first-year and K-12 students' improvement in understanding and confidence in complex chemical engineering topics as there was a positive impact on most students in these areas. There was also a strong recommendation to be used as learning tools, especially from visual and sequential learners. There was also some positive recommendations from verbal learners, proving that comics can be tailored to achieve a balance between visual and verbal learners. Whilst there was no observable impact or on the other four indices, that only indicates that comics worked equally well amongst active, reflective, sensing, and intuitive learners. Comics are equally helpful for these learning styles.

As this is the beginning stage of comics' research, future work includes the implementation of the MUSIC Model of Motivation[14], a model that guages factors such as interest, success, and empowerment to determine students' overall motivation to engage with chemical engineering comics. These surveys would also be sent separately across a semester as students had survey fatigue from the current one.

Furthermore, whilst these comics were disseminated at the AIChE 2022 and 2023 STEM Showcase to K-12 students, the purpose of the comics was to focus on the interative components of these tools as opposed to drawing data. This study specifically focused on first and second year students taking a preliminary chemical engineering course. Furture steps would include having a wider range of particpants such as K-12 students themselves, course instructors, and guardians of K-12 students to guage the direct effects of these comics on the targeted audience. This study also reached 33 students, of which only 14 consented to participate in the analysis. As this is the first step in implementing chemical engineering comics in curricula, any future work will expand on the total number of particpants. This can be done through looking at expanding the study to other institutions that offer a similar course. The comics themselves have been made freely available, so plans to conduct a similar study is of interest. However, the more driven focus of this study is on K-12 students and implementation of these comics in elementary, middle, and high schools as opposed to college.

Future questions and areas of interest for research include the method of implementation of comics in classrooms. Whether or not they will be handed directly to instructors, given to students to read at their own pace, or used in classrooms directly will need to studied. Further assessment of the impact of diverse characters on students, especially those from underrepresented backgrounds or minorities, will also help determine the appropriate method of implementation. As this is a K-12 study, the use of comics in K-12 and the method of instruction will also need to be examined.

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* - Dante Shepherd is the pseudonym for Lucas Landherr in much of their creative work.
Note: References in comics for writers are (w) and for artists are (p), when the writer and artist are different individuals.