Applying the chemistry of polymers to daily products by creating infographics for engineering students

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Abstract

Infographics visually display information to the target audience by combining graphics, photographs, illustrations, and text elements. Research suggests that using infographics in learning can help develop students’ higher-order thinking skills, including critical, logical, reflective, metacognitive, and creative thinking. To develop such skills among engineering students, we planned an assignment that included the use of infographics. Students in the “Polymers and Plastic Materials” course were asked to examine the polymer structure of various products and create an infographic that would coherently integrate the content learned in the course. Most students chose products from their everyday life, such as surfboards, drinking bottles, and sports clothes.

The infographics were evaluated using indicators that examined the quality and clarity of the graphic and textual content, their adherence to the course content, and presentation accuracy. Analysis of the students’ work demonstrated that the process of creating the infographic developed their higher-order thinking skills, including their ability to conduct in-depth research and process data. We suggest that an infographic assignment can be a suitable alternative to a final exam for course evaluation. The students’ feedback indicated that they enjoyed creating the infographic and that the process increased their interest and expanded their knowledge about polymers in general and about the specific products they presented in the infographic. The assignment can also be adapted to suit other subjects in different courses.

Keywords

Chemistry of polymers, infographics, HOTS, reverse engineering

introduction

Industrial companies today need employees who are able to think at a high level and have the capacity to apply, synthesize, analyze, evaluate, and judge information critically. It is essential, therefore, to develop these abilities in students as part of their training and disciplinary studies.1 The assignment described in this article aimed to support the development of these higher-order thinking skills in students.

Higher-order thinking skills include critical, logical, reflective, metacognitive, and creative thinking. These skills are activated when people encounter unfamiliar problems, uncertainties, questions, or dilemmas.2 Higher-order thinking skills are important in learning, especially in advanced studies in higher education institutes, and it is important to inculcate them in every student.

Studies show that students who have developed higher-order thinking skills are able to improve their academic performance and overcome weaknesses.3 For example, an initiative aiming to develop higher-order thinking skills in engineering students was introduced to an engineering drawing course. The staff delivering the course proposed that these skills would enable students to realize their potential and solve problems they would encounter later in the professional environment.4

In chemistry, it is also important to develop students’ higher-order thinking skills because it enhances their understanding of complex chemical concepts at the particle or sub-microscopic level which otherwise might be perceived superficially and non-scientifically. Graphs and pictures, for example, were used by Habiddin & Page to teach complex chemical concepts in a kinetic chemistry course.5

Active and innovative learning, such as problem-based and hybrid learning, promotes the development of higher-order thinking skills.6 Working with infographics is another way to contribute to the development of these skills and has been used frequently and extensively for teaching and learning purposes in recent years. Infographics use visualization to present information to the target audience by combining shapes, symbols, graphics, photographs, illustrations, and text.7

Several studies have shown that producing infographics helps develop higher-order thinking skills among students. Kothari et al.8 reported that students who used infographics found the learning fascinating and noted that the infographics helped them understand the concepts taught in the course and apply them in their daily lives. The study also found that learning through infographics improved the students’ ability to simplify complex concepts and make them accessible to a general audience. Damyanov & Tsankov9 found that various infographic templates promote learning and contribute to the development of cognitive skills. Inspired by these studies, we developed an infographic assignment for our engineering students. The aim was for students to apply study material on polymer chemistry using reverse engineering.

The inclusion of infographics as a requirement in chemistry courses in higher education institutions is a growing trend, as demonstrated by the following examples. Kothari et al.8 asked their students to create a visually appealing, quick and easy-to-read infographic containing information about one or more organic molecules included in a consumer product. The infographic assignment was used as a tool for connecting the course material to the real world. Blackburn et al.10 described an interesting assignment given to chemistry undergraduates who were asked to create an infographic based on research by faculty members in the Department of Chemistry. The aim of the assignment was to introduce the faculty’s research to the students. In an infographics assignment designed by Grieger & Leontyev11, students were free to explore any topic as long as it was relevant to both organic and green chemistry. Students were required to work systematically: summarize and evaluate existing infographics, study the organic and green chemistry literature, propose a topic for their own infographic, review infographics produced by their peers, revise their infographic according to feedback, and upload the finished product to Twitter.

The assignment we created, which aimed to develop higher-order thinking skills among our students and contribute to their future professional success included the design of an infographic on the topic of polymer-based plastic materials and their use. We gave the assignment to engineering students in the “Polymers and Plastic Materials” course who were nearing the end of their studies. These students had already completed most of their degree courses and had a broad perspective and experience in analyzing articles and preparing and delivering presentations. We designed the assignment on the premise that the knowledge and skills already acquired by our students could enhance their learning and provide them with additional skills which would prepare them well for their future work in the industry. The assignment we describe here can easily be adapted to other academic courses, secondary educational settings, and other learning contexts, such as online or hybrid courses.

SETTINGS AND PARTICIPANTS

Mechanical engineering students majoring in materials at the Afeka College of Engineering in Tel Aviv were assigned an infographics project as part of the “Introduction to Polymers and Plastic Materials” course. This course was delivered in the second semester of 2021 (63 students) and in the first semester of 2022 (59 students). Most students were nearing the end of their degree studies, with 70 and 20% of students in years four and five, respectively. The infographics project comprised approximately 70% of the final grade for the course.

ACTIVITY DESIGN

The fundamentals of infographics and its effectiveness in presenting information were explained in the opening lecture of the semester. This was followed by examples of infographics used in resumes, infographics depicting chronological timelines, and comparative infographics. Finally, the connection between the assignment and the goals of the course was explained: to connect the course content with the students’ personal interests and to develop their ability to apply the course material and the higher-order thinking skills required for their professional future.

Groups of two or three students were required to create a visually appealing infographic that was easy to read and understand and contained information about a polymer-based plastic product of their choice. The students were encouraged to use the graphic tools available in several free software packages (e.g., PowerPoint, Canva). The infographics had to present the following information: end-user requirements, the polymer used to make the product, the monomer, the polymerization process, the properties of the polymer aggregate, and the relationship between the polymer aggregate and the product properties. Students were also required to present at least one of the following extension topics: additives, manufacturing process, recycling, history, and interesting facts. Most of the students chose products from their everyday life.

Four lessons were dedicated to the infographic project during the semester. These included a lesson on the fundamental principles of infographics, consultation and guidance for each group of students by the course lecturer, and project presentation. Students mainly prepared the infographics in their free time. While working on the infographics, both in and out of class, students had unrestricted access to email consultations with the course lecturer. The infographics were assessed according to four categories: visuality and creativity (25%), product presentation (20%), other content, including the analysis of polymer structure and properties (40%), and the selected extension topic (15%) (see S1 for full marking indicator).

RESULTS AND DISCUSSION

The 29 infographic projects that were submitted presented information on various products: implant coatings used in heart surgery, wind turbine blades, PVC pipes, skateboard wheels, bicycle tires, drinking bottles, airplane windows and wheels, sports clothing, surfboards, resistance bands, motor vehicle tires, climbing ropes, firefighter’s helmets, protective vests, shoe soles, epoxy glue, Lego, and chewing gum.

All assignments met the requirements. Infographics were presented on a single slide, mostly prepared in PowerPoint, and included illustrations and photos sourced from online databases. Several groups also demonstrated the actual product to the class.

Sixteen infographics presented information in the form of facts about a product. For example, an infographic about a football shirt described the three polymers that made up different parts of the shirt and outlined their properties. Another infographic about shoe soles presented the information on a timeline from ancient shoes to customized, 3D-printed soles. Thirteen infographics presented product analysis and, of these, four compared two different polymers used to manufacture the same product. For example, the chemical structure, mechanical properties, environmental impact, allergenic properties, and resistance to UV radiation and ozone were compared in resistance bands made from either natural or synthetic rubber (Figure 1A). Four other projects used a reverse engineering approach in their infographics. One of these was a project about a firefighter’s helmet. The infographics first described the helmet and the conditions it is required to withstand, followed by an analysis of the two polymers that constitute the helmet, their chemical structures, bond angles, and the intermolecular bonds that determine the structure of the polymer aggregate and its properties (Fig 1B). The analysis justified the choice of these polymers for the production of firefighter’s helmets. Five other projects presented the product at the end of the infographic. For example, a project about plastic drink bottles described the monomer and the polymerization process first, followed by the aggregate structure according to the material percentage of crystallinity, and then the production process, including extrusion and injection into the mold to manufacture the final product.

**Figure 1** Infographics created by engineering students **(A)** An infographic comparing two types of resistance bands **(B)** An infographic presenting a firefighter’s helmet using a reverse engineering approach. Pictures are reproduced with students’ permission. Images are blurred for copyright reasons.

The course lecturer reported that the use of visual aids had several advantages. One was the ability to convey complex content in a simple manner. Hence, a complex production process can be made far more understandable when presented visually, step by step, from the raw materials to the finished product. An example of this can be seen in infographic 1B, where the chemical models of Kevlar® and Nomex® are presented. The infographic illustrates how the difference in bond angles affects the spatial structure of the aggregates and their properties. The second advantage of using visual aids is that complex relationships between variables can be presented in graphs and tables. For example, in an infographic about skateboard wheels made of different polymers, a graph provided a simple visual representation of wheel durability in terms of friction and wear over time under identical conditions. The third advantage was stimulating curiosity and motivation for learning through the design of colorful and creative infographics.

The ratios of visual content to text in the infographics (visual-to-text ratio) were examined to determine whether students had understood the principle of using visuality in infographics. Visual-to-text ratios were categorized as high when the visual content was ≥66% of the infographics, medium when it was 33-66%, and low when it was <33%. High, medium, and low visual-to-text content was seen in 41, 24, and 35% of the infographics, respectively. Interestingly, however, there were no significant differences between the average grades in the three visual content categories. A potential explanation is that not all infographics with high visual-to-text content were of good quality.

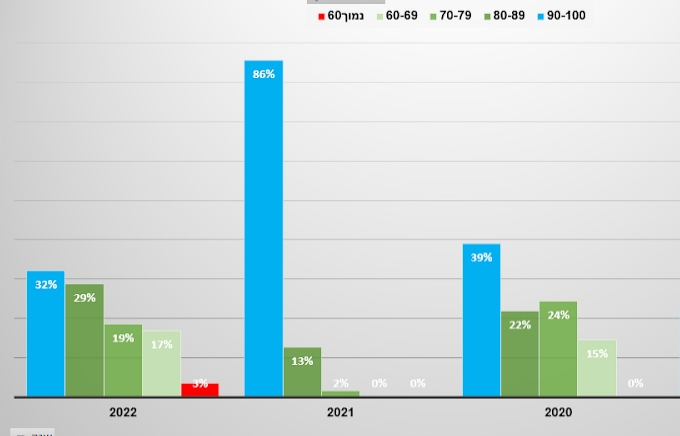
We evaluated the infographic assignment by considering student feedback on the course and their grades. Students reported that they found the infographic assignment interesting, original, and enjoyable. They indicated that the assignment provided them with an experiential learning opportunity different from their previous experience in academic studies and that learning through infographic design had no negative impact on the course’s academic level. Students expressed interest in additional learning experiences of this kind and wished to continue practicing active learning. They enjoyed the team environment, which stimulated their interest, and learning to use the software that was required for the project. The fact that they could choose to explore a topic they were interested in increased their enthusiasm for the project.

The feedback also suggests that the assignment helped students engage with the course and the concepts that were taught. Students enhanced their knowledge about polymers, the polymerization processes, production methods, the effect of polymer properties on the product, and the extensive use of polymers in commonly used products and in industry. They reported that they learned how to investigate the polymer structure of products and that the depth of their investigation went beyond what was necessary to prepare the infographic. Taken together, it is evident that, in the process of preparing the infographic, students developed higher-order thinking skills, such as problem-solving, summarizing, processing and integrating information, organizing data clearly, and conducting thorough research at an individual level.

The students’ marks indicate a medium-to-high level of visuality and creativity in their infographics, as observed in the graphic design, planning, and matching content to visual presentation. Presentation of product properties and use were also marked at a medium-to-high level for 93% of the students. In contrast, only 62% of students achieved a medium-to-high grade for their analysis of the polymer chemical structure and its correlation with the thermal and mechanical properties of the product. The performance of the remaining students (38%) in this category was assessed as low.

Students were also required to include an extension topic of their choice in the infographic. Thirty-eight percent of students expanded on the production process, 24% described the product development process over time, 24% investigated environmental aspects, and 17% discussed other uses for the main polymer. Several groups included more than one extension topic. Most groups demonstrated a high level of performance in this part of the project, which comprised 15% of the overall infographic grade.

A comparison of grade distribution during the years 2020–2022 was used to determine the impact of the infographic assignment on final course grades (Figure 2). During these years, the course was taught by the same lecturer, who followed an unchanged syllabus. In 2020, the main component of the grade was an examination, whereas the main component in 2021 and 2022 was the infographic assignment. Approximately 70% of the final grade was based on the examination or infographic and the remaining 30% was based on additional assignments given throughout the course. The narrow grade distribution in 2021 is an outlier and reflects concessions given to students with the transition to distance learning, which led to a significant increase in grades. The graph shows similar averages and distribution of grades in 2020 and 2022 (with a small standard deviation of approximately 4%), meaning that, in these years, the percentages of students who received medium, medium-high, and high grades were similar. Additional factors that may have impacted the final grades include the transition from face-to-face teaching in 2020 to a hybrid teaching model in 2022 because of Coronavirus-related restrictions.



**Figure 2** Grade distribution for engineering students in the course “Polymers and Plastic Materials” in 2020, 2021, and 2022

ADVICE FOR INSTRUCTORS

Based on the analysis of the infographics, the course marking, and student feedback, we propose the following changes for future applications of infographic assignments:

1. Refining guidelines and requirements: improve marking indicators, provide more examples, divide the assignment into sub-tasks to help students understand the requirements and achieve better results, emphasize the correct balance between text and visual elements, and provide more tools for converting textual information into visual elements.
2. Incorporating student peer evaluation. This would assess the students’ ability to understand the information presented in an infographic, test the quality of the infographic, and allow for correction of mistakes and refinement of messages.
3. Establishing an infographics exhibition event attended by students and college staff to increase students’ motivation to learn.
4. Conducting the project in the industrial field. Creating infographics according to real needs expressed by industry representatives. These representatives could also evaluate the infographics.

IMPLICATIONS

Infographic assignments have many benefits for students: they are enjoyable to create, establish interest in the course, improve understanding of course content, and develop higher-order thinking skills, which are critical for students’ professional futures. Allowing students to experiment with infographics maximizes the benefits of this tool and improves the skills necessary to create excellent infographics, such as creativity, understanding course content, analytical ability, the ability to simplify information, and the ability to make them accessible to a wider audience.

Associated content

Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.XXXXXXX. [ACS will fill this in.] Example brief descriptions with file formats indicated are shown below; customize for your material.

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REFERENCES

1. Griffin, P.; Care, E. *Assessment and Teaching of 21st Century Skills, Methods and Approach*; Springer Science and Business Media, 2015.
2. King, F. J.; Goodson, L.; Rohani, F. *Higher Order Thinking Skills: Definition, Teaching Strategies, and Assessment*; A Publication of the Educational Services Program, now known as the Center for Advancement of Learning and Assessment, Florida. 2018.
3. Ahmad, S.; Prahmana, R. C. I.; Kenedi, A. K.; Helsa, Y.; Arianil, Y.; Zainil, M. The instruments of higher order thinking skills. *J Phys Conf Ser* **2017**, *943*.
4. Sharma, G.; Raja Murugadoss, J.; Rambabu, V. Fostering Higher Order Thinking Skills in Engineering Drawing. *J Eng Educ Transform* **2020**, *34* (1), 28-40.
5. Habiddin, H.; Page, E. M. Probing students’ higher order thinking skills using pictorial style questions. *Maced J Chem Chem* **2020**, *39* (2), 251-263.
6. Prahani, B.; Jatmiko, B.; Hariadi, B.; Sunarto, D.; Sagirani, T.; Amelia, T.; Lemantara, J. Blended Web Mobile Learning (BWML) Model to Improve Students’ Higher Order Thinking Skills. *Int J Emerg Technol* **2020**, *15* (11), 42-55.
7. Ozdamli, F.; Ozdal, H. Developing an Instructional Design for the Design of Infographics and the Evaluation of Infographic Usage in Teaching Based on Teacher and Student Opinions. *Eurasia J Math Sci Technol* **2018**, *14* (4), 1197-1219.
8. Kothari, D.; Hall, A. O.; Castañeda, C. A.; McNeil, A. J. Connecting Organic Chemistry Concepts with Real-World Contexts by Creating Infographics. *J Chem Educ* **2019**, *96* (11), 2524-2527.
9. Damyanov, I.; Tsankov, N. The Role of Infographics for the Development of Skills for Cognitive Modeling in Education. *Int J Emerg Technol* **2018**, *13* (01), 82-92.
10. Blackburn, R. A. R. Using Infographic Creation as Tool for Science-Communication Assessment and a Means of Connecting Students to Their Departmental Research. *J Chem Educ* **2019**, *96* (7), 1510-1514.
11. Grieger, K.; Leontyev, A. Student-Generated Infographics for Learning Green Chemistry and Developing Professional Skills. *J Chem Educ* **2021**, *98* (9), 2881-2891.