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STUDENT ENGAGEMENT IN SUSTAINABILITY ISSUES THROUGH VIDEO PRODUCTION: A CRITICAL CONSCIOUSNESS-BASED APPROACH TO ENGINEERING EDUCATION

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ABSTRACT

The formation of engineering students should prioritize both technical skills in engineering and a critical awareness of the designed world. This qualitative methods study aimed to analyze the extent to which a teaching approach, based on the in the integration of Freire's critical pedagogy and Multimodal literacy frameworks, promotes first-year engineering students' development of critical consciousness. Drawing from Paulo Freire's work on critical pedagogy, the critical consciousness framework emphasizes that individuals and their practice in community awaken

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critical awareness of their surroundings, including the interconnectedness that exists between economic, social, political, cultural, historical, and environmental factors. To this end, we designed an activity for students to research and create videos that illustrate the interconnectedness that exists between these factors. The activity provided an opportunity to build, express, and shape their thoughts regarding the connections between the designed world and its implications on society (i.e., who wins, who loses, who is involved, etc.). Preliminary analysis identified that multimodal video production allowed students to investigate and express their own interpretations of socio-political and sustainability issues related to the use of precious minerals, specifically cobalt. Furthermore, students included descriptions of their proposals for reducing child labor abuse in cobalt mining and identified the environmental impacts of excessive use of cobalt in technological devices. Overall, this research suggests that integrating critical consciousness and multimodal literacies can be an effective strategy for promoting engineering students' formation in terms of engineering design, literacy, sustainability, and social awareness.

1 INTRODUCTION

In order for engineering students to see the complexity of their roles as engineers in the world, it is important to participate in critical pedagogies that provide them with the tools to critically analyze the world around them (Freire 1997). Freire and Macedo (2005) argued that in order to critically analyze the world around us, it is important to engage in practices that contribute to meaning- and sense-making through different modes that allow for codification and decodification. Thus, the use of multimodal literacies becomes essential in the education of engineering students as multimodality involves the extraction, construction, integration and critique of information through various modalities such as conceptual frameworks, drawings, symbols, text, images, sounds, and gestures, among others (Frankel et al. 2016).

This study contributes to the expanding research on engineering literacy and the ethical professional development of engineering students deepen to become critical and informed participants in the world's decisions. This paper, which is part of a larger research project, was guided by the research question: *to what extent does a multimodal activity based on the extraction and use of cobalt promote the development of critical reflexivity among engineering students?* The activity sought to engage students in the development of short informational videos about the extraction and use of cobalt. This research demonstrates the impact of multimodal artifacts and the significant role these play in the engineering curriculum and the development of students' critical consciousness.

2 CONCEPTUAL FRAMEWORK

2.1 Critical consciousness

In 1970, Paulo Freire discussed the significance of critical pedagogy, which encourages individuals to examine how they are situated within systems of oppression that are shaped by their historical and cultural contexts (Freire 2003; Giroux 2010; Shor and Freire 1987). By reflecting on themselves and the systems they are part of, individuals can "read the world" and gain an understanding of their power and options for action (Freire and Macedo 2005; Freire 1985). Freire called this process the development of critical consciousness, which is not a linear process but rather a framework for self-actualization that enables individuals to envision new futures for themselves and achieve self-liberation through action and reflexivity (Freire 2003). Freire (1997) outlined it as a five-stage, where the first stage was the "semi-transitive state." In this stage, individuals are preoccupied with survival and have limited critical perception of their surroundings and lived realities. The second stage involves the "transitivity of consciousness," where individuals can reflect on themselves, their lived realities, their roles and responsibilities, and work with others to replace their disengagement with commitment to change (Freire 1997). The third stage is called "naive transitivity," where individuals are characterized by "an over-simplification of problems; by a nostalgia for the past; by underestimation of the common man; by a strong tendency to gregariousness; by a lack of interest in investigation, accompanied by an accentuated taste for fanciful explanations; by

fragility of argument; by a strongly emotional style; by the practice of polemics rather than dialogue; by magical explanations" (Freire 1997, 18). This stage is critical because the individual may rely on argumentation, oversimplification, or simple reasoning that prevents critically thinking about what lied beneath the surface (Shudak and Avoseh 2015). This is also a critical stage to overcome because the individual's critical thinking may still be fragile and easily fall back to a state of semi-transitivity. Therefore, engaging in a more in-depth analysis of the world is necessary to continue toward the fourth stage, "critical transitivity," which is characterized by a deep analysis of problems and an increase in agency (Freire 1997). Finally, the fifth stage is "critical consciousness," which represents an awakening of critical awareness from a critical educational effort. In this paper, we draw from Freire's framework of critical consciousness to describe how students used multimodal literacies to engage in a critical analysis of content knowledge, writing and communicating the impacts of modern technologies on society, and to highlight the ways in which multimodalities provide students with the ability to question social, cultural, historical, and political factors in engineering.

2.2 Multimodal Literacies

Engineering literacy practices build not only on scientific literacy practices but also draw from a complex combination of communication standards, symbolic representations and computational simulations and calculations (Wilson-Lopez et al. 2022). For example, disciplinary literacy in engineering may involve the use of specific vocabulary, tools, and knowledge, as well as the ability to communicate effectively within specific fields of expertise (Wilson-Lopez et al. 2022; Shanahan and Shanahan 2012). These practices also include visualizing models, interpreting data, identifying information sources from various disciplines, using specialized language to convey ideas, and utilizing other expertise specific to the discipline (Cejka, Rogers, and Portsmore 2006; Robinson and Kenny 2003; Wilson, Smith, and Householder 2014). It is noteworthy that engineers apply their own individual beliefs, values, and ways of knowing, doing, and being when developing their literacy practices (Mejia and Revelo 2022). Thus, engineering is not only a cognitive process, but also an embedded set of social practices and tools within the field of engineering (Pawley 2009; Mejia, Revelo, and Pawley 2020).

Given that engineers produce and interpret different oral, written and symbolic representations through literacy practices, it is important to think about the role that multimodal literacies play in the development of critically conscious engineers. Multimodal literacies involve the use of different modes of meaning (i.e., written, oral, visual, etc.) that are used for meaning making (Mills and Unsworth 2017). Multimodal literacies in engineering are important because engineers require multimodal representations (i.e., symbols, equations, visual aids, schematics, writing, simulations) for sense- and meaning-making. Moreover, multimodal literacies allow engineering students – those that are on their path toward becoming engineers – to develop a critical understanding of the world around them.

Multimodal literacies allow individuals to read the word – and the world – through "critical perception, interpretation, and rewriting of what is read" (Freire and Macedo 2005, 24). Thus, we argue that multimodal literacies in engineering are necessary for helping engineering students develop their own critical consciousness about the world that surrounds them through the use of multimodal semiotics (i.e., signs, symbols, and any other elements of language) (Mills and Unsworth 2017). Multimodality has been widely explored in the sciences and science education (Unsworth et al. 2022; Tang and Moje 2010; Jones et al. 2020; Klein and Kirkpatrick 2010), but more work on the benefits of multimodality and literacy are needed in engineering education research.

3 METHODOLOGY

This study involved 40 first-semester engineering students (8 teams of 5 students each) who were enrolled in a course that analyzed the impact of modern technologies on society. An activity based on Multimodal Literacy was developed for this research, which required students to create a video using Animaker to raise awareness among society, engineers, and government about the critical issues arising from the extraction and use of cobalt. Animaker (https://www.animaker.com/) is a free access software that allows users to create videos, incorporating different multimodal representations such as images that can modify gestures and facial expressions in addition to audio, voice, music, and text.

The research design employed a qualitative methods approach. The data was collected from students' final videos (i.e., artifacts), classroom discussions in the form of field notes, and audio transcripts. The analysis began with open coding using NVivo 12 to divide, examine, and compare the information in search of similarities and differences (Strauss and Corbin 1990). Through repeated analyses, the categories were defined through a second coding process, which involved a coding protocol (Saldaña 2015) developed from the codes obtained during the first round of coding. Both researchers reviewed the analysis separately and discussed discrepancies until they reached agreement. To answer the research question, special attention was given to three relevant aspects: (1) the types of representations used by the students through multimodalities, (2) the critical issues that the students included in their videos regarding the extraction and use of cobalt, and (3) the students' suggestions to reduce critical problems related to the extraction and use of cobalt.

4 RESULTS

In this section, we present the results of the analysis of the construction process of the teams' videos. The first section describes the type of multimodal representations the teams considered important to include in the construction of their videos to express their thoughts on the critical issue of cobalt extraction and use. Regarding the second and third sections, it should be mentioned that based on Freire's (1997) concept of critical pedagogy, the students had the freedom to include the critical

elements they considered relevant. Here we present the most noteworthy aspects of the videos using representative examples obtained from the data. Future work will further expand on all of these characteristics.

4.1 Multimodal representations used by the teams

The teams utilized at least two out of the four possible modes (video, audio, written text, images) offered by the software to construct their videos (Figure 1). Specifically, three teams employed four modes of representation, three teams used three modes, and two teams used two modes. This indicates that the teams recognized the importance of incorporating multiple ways to convey their interpretations. Moreover, the results also indicate that combinations of multimodalities were the preferred method for students to convey messages related to the social impacts of cobalt use and extraction.

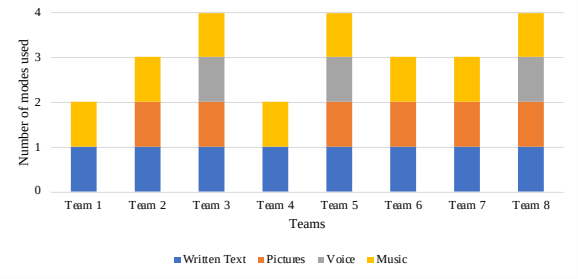

Fig. 1. Types of multimodal representations used by the teams

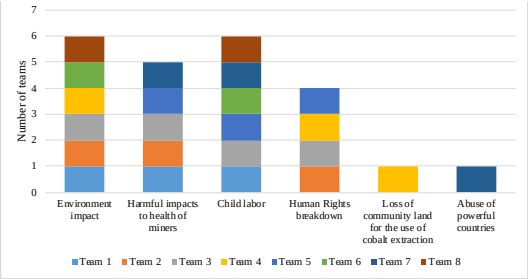

Fig. 2. Critical impacts included in the team's videos

4.2 Critical impacts of cobalt use and extraction included in the team's videos

Through the analysis, we were able to identify six critical aspects that were recognized by the students (Figure 2). Six teams identified the impact to the environment and child labor, while five teams highlighted harmful health impacts on miners. Additionally, four teams addressed the aspect of the violation of human rights. One team, in particular, addressed the loss of land and the displacement of the community, which was seized by the government or companies for cobalt extraction. Another team explicitly pointed out the abuse of power by more powerful nations over those with less power, making the comparison between the Global North and the Global South.

4.2.1 Environmental impact. Six out of the eight teams included descriptions associated with the environmental impact of the extraction and use of cobalt. For instance, Team 6 created a video that included a section with the image of a person throwing a big rock at trees depicting the destruction of the surrounding environment. This image is accompanied by descriptions associated with both direct and indirect environmental damage due to cobalt extraction (Figure 3). Team 4, for example, included a written description in their video that highlights how cobalt extraction systemically affects different elements of nature, including people's health. The text read:

[Cobalt extraction] Pollutes water, air, and soil leading to decreased crop yields, contaminated food and water, and respiratory and reproductive health issues.

Fig. 3. Video section of Team 6

The excerpt from this video demonstrates the analysis done by the students and the social, environmental, and health implications of cobalt extraction. Nonetheless, it is important to note that the students did not specifically indicate who is at fault, and who is the most affected. Instead, the text generalizes the impacts of cobalt extraction. Other teams included images of a cloudy sky and written text of the effects of climate change due to emissions created by jet engines that use cobalt as part of their systems. Thus, in some instances, the students problematized the use of cobalt in everyday technologies and not only on the extraction of the mineral.

4.2.2 Harmful impacts on miners' health. Five teams included in their videos descriptions associated with cobalt miners' health. For example, teams 3 and 4 included images and phrases that highlighted the high levels of radioactivity generated at the extraction zones affecting the health of the miners. Below is an excerpt from the text included by Team 3:

> *In mining regions, scientists have made note of high radioactivity levels. 70% of cobalt resources are located in high-risk contexts. Exposure to cobalt may cause weight loss, dermatitis, and respiratory hypersensitivity.*

The text shows how students tried to identify the health repercussions for those that worked in the mines, particularly miners. The students also mentioned the health impacts of cobalt mining on people living near mine sites such as asthma-related problems, thyroid problems, nausea, and vomiting.

4.2.3 Child labor. Six out of the eight teams included descriptions expressing their concern about the presence of, and sometimes forced labor of, children in cobalt mining activities. For example, Team 5 included a message written on top of an image of two people talking that mentioned the following: *6-year-old children are working in these [cobalt] mines.* Images were also used to convey the message, which created a huge impact on students. For instance, Team 7 included images showing mothers and children extracting cobalt from mines, accompanied by a "thumbs down" symbol, demonstrating their disapproval. In a later section, they included the following text: *Reduce and eliminate child labor across the world.*

4.3 Proposals to reduce adverse effects

All Teams proposed solutions to reduce adverse impacts of cobalt (Figure 4). The proposals related to governmental actions included, seven teams suggested better regulations to protect miners and minors, while five teams proposed rescuing children from forced labor. Regarding device users (i.e., society in general), three teams advocated for reducing and recycling usage, and four teams suggested raising awareness. five teams proposed device modifications to reduce cobalt use, while another five teams emphasized action by companies selling such devices. Finally, two teams identified the necessity for collaborative efforts.

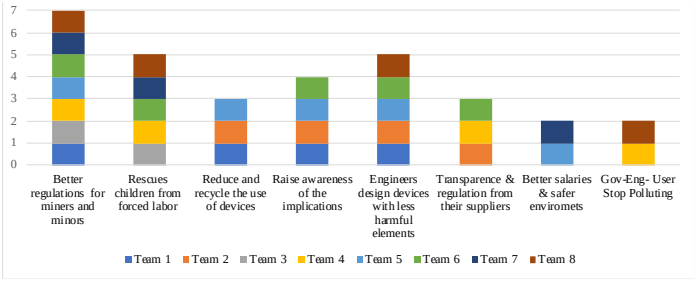

Fig. 4. Team's proposals to reduce adverse effects

4.3.1 Governmental involvement. Seven teams proposed actions, such as better regulations for miners and minors, and rescuing children from forced labor, that governments should address to reduce abuses created by cobalt extraction. For example, Team 1 recognized the need to improve regulations for both adult miners and children, while Team 3 included animated images of two women, a written message, and a voice message about their proposal for joint efforts between governments and international agencies to rescue children. The message read:

> *Regularly inspect workplaces, rescue children and adults from forced labor slavery, and reliably prosecute mine managers, owners, and buyers who violate the law and abuse child and adult workers. Major corporations, UN agencies, NGOs, and foreign government donors should collaborate with the Democratic Republic of Congo to make a reality.*

This excerpt shows that students focused on the complexity of solving the problem of irregular mining and the players that must be involved to provide solutions. They also indicated particular subjects in their descriptions (i.e., children, mine managers, owners, NGOs, etc.) to provide more specificity to the context of the problem. In addition, the students situated the problem in one particular geographical location – the Democratic Republic of Congo – to signify a specific locality of the issue.

4.3.2 Engineers' actions. Five teams included descriptions of how engineers can contribute to the reduction of problems created by the extraction of cobalt. Team 6 included superimposed text on an image of a machine to convey their message regarding their proposal for engineers to build machines that improve mining conditions for workers. Teams 1, 2, and 8 proposed that engineers improve the efficiency of devices or minerals to reduce adverse effects. And Team 5 included text and voice to describe their proposal for engineers to develop renewable action projects. The audio mentioned the following:

> *In order to solve this human rights crisis, engineers can work towards creating renewable cobalt programs, while governments can work to place regulations on the mining industry and increase pay of miners.*

It is important to note from this excerpt that the students named the issue at hand as a "human rights crisis," and clearly identify engineers as subjects in the problem itself. Thus, the students communicated the critical role that engineers play in ameliorating the impacts of cobalt use and extraction.

4.3.3 Users' actions. Four teams mentioned actions that users should take to reduce the problems triggered by cobalt use. Teams 1, 2, and 5 proposed reducing the use of devices that use cobalt and recycling them after use. These same teams and Team 6 proposed increasing awareness of the excessive use of cobalt devices. For example, Team 2 included images of a phone that was turned off, accompanied by the caption "*Moving away from cobalt dependence.*" Team 5 included a video of a person recycling and included audio mentioning awareness of cellphone usage:

> *Users can be aware of the implications of buying common products like phones and work towards recycling these products.*

In this case, students also identified users as actors in the cycle and proposed recycling and reducing the dependence on cobalt.

5 DISCUSSION

The results obtained from the data indicate that multimodalities were used not just to convey messages of the impacts of cobalt use and extraction, but also the ways in which students used modalities to help other engineering students make sense of the words (i.e., the research surrounding the use and extraction of cobalt) and the world around them (i.e., the detrimental impacts and social, environmental, and health ramifications) (Freire and Macedo 2005). The combinations of audio, text, video, and images provided the students with semiotic resources to organize their understanding of the problem, creating meaning for others, and helping the students themselves make meaning of it (Danielsson and Selander 2021). It is important to note that the multimodal artifacts created by the students also included their own personal touch to what they believed would better convey the message to the audience, and, in the process, they also utilized multimodal literacies to first get a better understanding of the concepts themselves. Thus, multimodal literacies have a great value for engineering education since they provide the tools for sense- and meaning-making.

Moreover, multimodal literacies also serve as an analytical tool to determine the ways in which engineering students are able to develop their own critical consciousness. Based on the data collected, it was observed that most of the students were able to overcome the stage of naïve transitivity (Freire 1997) because they reflected on their roles as users, as engineers, and as members of society when discussing the issues related to cobalt use and extraction. Of great importance is the fact that students try to engage in an "in-depth interpretation of the problems" (Freire

1997, 19) through an “interrogative, restless, and dialogical form” (Freire 1997, 19). The videos created by the students demonstrated a critical transitivity state (Freire 1997) that was concerned with in-depth analysis of the role of engineering.

It is important to mention that multimodal literacy also provides a way for engineering educators to engage students in a process that will help them develop their critical consciousness. Since the progression to critical consciousness is not automatic, the use of multimodal literacies are important to the “active, dialogical educational program concerned with social and political responsibility” (Freire 1997, 19) that is necessary to prepare socially responsible, critical, empathetic engineers. As the world of engineering continues to become more complex and solutions require not just mathematical and scientific prowess, it necessary to consider the role that multimodal literacies play in ensuring that engineering students problematize social, cultural, historical, environmental, political, and economic factors embedded in engineering work.

6 CONCLUSIONS

Multimodal literacy extends Freire’s emancipatory understanding of literacy to other disciplines, like engineering, and frames critical consciousness and literacy as steps toward collective action and social justice, rather than simply serving the interests of employers or capitalism. The analysis presented in this paper shows that the integration of multimodal literacies provides an effective strategy for engineering students to develop their own critical consciousness and awareness. The multimodal constructions created by the students integrated various interrelated modes of expression, which closely resemble engineering practices that rely on diverse semiotic representations to convey complex ideas (Wilson-Lopez et al, 2022). This paper suggests that multimodalities can facilitate understanding and communication of engineering concepts while preparing students for the natural complexity of engineering. This study also shows that critical pedagogical approaches (Freire 2003) allow students to investigate, identify, and express their own views on topics of interest, particularly pressing modern issues to reduce injustices through critical thinking. The themes on the videos also reflect a holistic view of the world where injustices and abuses are committed against children, miners, and embedded in globalized contexts. The findings of this study are specific to the chosen population and implementation. Future work can address these methods with other populations of students, allowing for a broader understanding of engineering students’ reflections.

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