



STEAM and theatrical education: when engineering students play a role

STEAM e educação teatral: quando estudantes de engenharia assumem um papel

 **Jefferson Rodrigues-Silva**

Doctor in Education

Federal Institute of Minas Gerais Campus Arcos – IFMG

Arcos, Minas Gerais – Brazil

 **Ángel Alsina**

Full professor in Mathematics Education

University of Girona – UdG

Girona, Catalonia – Spain

Abstract: Eleven mechanical engineering students participated in a STEAM (interdisciplinarity between Science, technology, engineering, Arts/Humanities, and Mathematics) drama activity of conceiving and performing a play which addressed their course. Following, we pursued a Thick Description of this project, including the meanings and intentions of the play. Accordingly, we interviewed the students so that this description could reflect their voices. As a result, we observed that the drama activity permitted learning about engineering and theatre. Moreover, it was a space to contrast the ideal and the real engineering toward society and to call students to play the role of subjects responsible for their personal, professional and political lives.

Keywords: Augusto Boal; engineering; subject-ness; STEAM education; theatre of oppressed.

Resumo: Onze estudantes de engenharia mecânica participaram de um projeto STEAM (interdisciplinaridade entre Ciência, Tecnologia, Engenharia, Artes/Humanidades e Matemática) a partir de uma atividade teatral de concepção e encenação de uma peça sobre seu próprio curso. Ao respeito, realizou-se uma Descrição Densa desse projeto, incluindo os significados e intenções da peça. Nesse sentido, entrevistaram-se os alunos para que essa descrição pudesse refletir suas vozes. Como resultado, observou-se que o a atividade permitiu aprender sobre engenharia e teatro. Além disso, foi um espaço para contrastar a engenharia ideal e real perante a sociedade e chamar os alunos para o papel de sujeitos responsáveis por suas vidas pessoais, profissionais e políticas.

Palavras chave: Augusto Boal; engenharia; subjetificação; Educação STEAM; teatro do oprimido.

Cite como

(ABNT NBR 6023:2018)

RODRIGUES-SILVA, Jefferson; ALSINA, Ángel. STEAM and theatrical education: when engineering students play a role. *Dialogia*, São Paulo, n. 49, p. 1-21, e24694, maio/ago. 2024. Disponível em: <https://doi.org/10.5585/48.2024.24694>

American Psychological Association (APA)

Rodrigues-Silva, J., & Alsina, Á. (2024, maio/ago.). STEAM and theatrical education: when engineering students play a role. *Dialogia*, São Paulo, 49, p. 1-21, e24694. <https://doi.org/10.5585/48.2024.24694>

1 Introduction: How did theatre enter a mechanical engineering course?

This article reports a theatrical experience in higher education in the Brazilian city of Arcos. A city that recently celebrated opening a Federal Institute of Minas Gerais (IFMG) campus, offering a single course—mechanical engineering bachelor.

Arcos is a small city with less than two square miles of an urbanised area that stands out from its several limestone mining companies. Whereas limestone companies develop surrounding this community, arts and culture, seem to be relatively forgotten.

In this context, a mechanical engineering teacher (the article's first author) felt a call of responsibility to promote artistic activities according to his possibilities. Subsequently, he created the Engineering & Arts project, where different creative activities took place: a dance company performance addressing women in engineering, a mosaic workshop with primary school students, and an art exposition with mosaics about mechanical engineering (Rodrigues-Silva *et al.*, 2018).

Those activities were initially understood as modest gestures, but they somehow seemed to have impacted this community. Donizetti Bernardes—an experimental actor and theatre director—heard about those initiatives and came up with an idea. Thus, on 2nd August 2019, he proposed a partnership with this professor for a drama activity.

That day, the Engineering & Theatre project was born: a four-month project where students would engage in group discussions about engineering and theatre, participate in theatrical laboratories, and then conceive and perform a play which addressed mechanical engineering. All this planning followed was theoretically scaffolded in STEAM education, an educational approach which refers to the interdisciplinary teaching between science, technology, engineering, arts/humanities, and mathematics (Perignat; Katz-Buonincontro, 2019; Rodrigues-Silva; Alsina, 2023a). The acronym STEAM was created in 2007 at a roundtable in the United States as an opposite movement of STEM education, whose efforts and investments privileged the technical areas of science, technology, engineering, and mathematics (Catterall, 2017).

Besides this inclusion of arts and humanities, STEAM is commonly criticised for a utilitarian approach by attributing a subservient role to arts and humanities regarding the technical ones (Chesky; Wolfmeyer, 2015; Mejias *et al.*, 2021). In this direction, STEAM is frequently reported as a neoliberal pedagogy concerned only with *qualification*: where education is reduced to nurturing knowledge and skills the twenty-first-century society seems to require (Biesta, 2020; Kettle *et al.*, 2023). However, literature also shows that STEAM is suitable for addressing sustainable issues (Guyotte, 2020; Rodrigues-Silva; Alsina, 2023c), such

as the pursuit of gender equity (Silva-Hormazábal; Rodrigues-Silva; Alsina, 2022), food literacy (Silva-Hormazábal *et al.*, 2022), and the introduction of engineering at precollege level (Rodrigues-Silva; Silva-Hormazábal; Alsina, 2023b).

Moreover, STEAM may enhance students' attitudes towards science (Carrasquilla; San roque; Pascual, 2023), and performance is a powerful language to address and develop science (Parry, 2020). For instance, it shows drama reported on experiences involving AIDS (Almeida *et al.*, 2021), science museum performances about robots (Peleg; Baram- Tsabari, 2017) and prevention of scientific denial theories such as flat earth (França *et al.*, 2021).

Accordingly, we were confident about the feasibility of creating a dense and overwhelming STEAM experience through the connexion between engineering and arts. For that, we should always remain vigilant that both knowledge areas have a value *de per si and* must evenly benefit from each other (Mejias *et al.*, 2021). Moreover, we directed our efforts to reach educational purposes other than *qualification* (acquiring knowledge and skills). The drama activity intends for students' *socialisation*, which means introducing them, in this case, to cultures of artistic and engineering communities.

Studies evidenced that children from a very early age tend to conceive engineering as a manual activity, developed individually, in fieldwork and destined for men (Rodrigues-Silva; Silva-Hormazábal; Alsina, 2023a; Rodrigues-Silva; Alsina 2023d; Vo; Hammack, 2022). In this regard, reflecting and presenting engineering to the community is vital in overcoming stereotyped conceptions of this profession. Simultaneously, this activity should provide students with a personal space where they could, using Boal's Theatre of Oppressed terms, express themselves, study their realities and change it (Kina; Fernandes, 2017). Furthermore, the project aimed to call students *subject-ness* (which is different from subjectivity); in other words, *subjectification* refers to their autonomy as subjects who decide to embrace (or not) ethical dilemmas and responsibilities of their actions that they will encounter in their personal, professional, and political lives (Biesta, 2020; Martins; Rodrigues-Silva, 2022).

Considering all that, we pursued a Thick Description of the Engineering & theatre project, including the meanings and intentions of the play.

2 The Engineering & theatre project

First, we consulted the institutional project archives and found no registers of theatrical activities, which means those students had not had similar experiences on this campus before. At this moment, 131 students were regularly enrolled in the mechanical engineering course, 110 males

and 21 females, according to the Office of Academic Records. We invited all students from this course, and eleven (8.4%) showed interest in participating in the project.

All interested students were accepted into the project as volunteers. Those students firmed consent authorisation to use their images and productions for research purposes. Regarding their gender proportion, we should remark that it was inverted in the project compared to the course's general distribution, so women became the majority, six females and five males. We will further address this aspect later.

We pursued the qualitative methodology of a Thick Description, defended as a good form of understanding people and peoples' self-understanding within a specific context (Tholen, 2018). Hence, at the end of the project, seven students participated in a semi-structured interview. Those interviews were recorded, transcribed, and then analysed through multiple comparisons. We addressed the issues that emerged from the data so that this description reflected students' voices. We identified the students with fictitious names to ensure their anonymity according to their opinions.

We start describing the preparation sessions, which were dedicated theatrical laboratories and three cycles of reflections: Connections between engineering and theatre, Engineering from what you eat to what you shit, the history of theatre, and the aesthetic method of the Theatre of the Oppressed (TO). Following, we describe the creational process of writing the play. Then, we focus the description of the play on its three acts. Lastly, we address educational outcomes, and we make some final considerations.

3 Connections between engineering and theatre: Let's think about it

The STEAM project had one apparent demand: conceiving and performing a play which addresses mechanical engineering. Ana, one of the students, commented that this proposal awakened a state of reflexivity. According to her, "from the first group meetings, everyone had an interrogation: what will the text be? What do we want to talk about in the play?"

Accordingly, the initial sessions were dedicated to discussion circles. In the first discussion cycle, students reflect on their prior conceptions, expectations and feelings regarding the interdisciplinary approach to engineering and theatre. This discussion was vital because the drama was new to them and, as Daniel emphasised, the junction with engineering caused oddity at first sight:

People find the relationship between theatre and engineering weird because they have prejudice. For them, those who do theatre are not responsible people. In the beginning, we also saw the theatre as something disconnected: why engineering and theatre? But when you zoom in, you start to see that the two have a lot in common.

For Bernardo, the prejudice about theatre comes from a lack of knowledge, “there is still prejudice and shame in participating in theatre because it is unknown in our environment [the mechanical engineering course]. You have to participate to see what theatre is like.” Gender differences are addressed when another student hypothesises criticism, and mockery may have discouraged some boys from participating in the project. “Men take longer to develop maturity, and many are ashamed. They fear being mocked by their colleagues. So our group had more women than men: we did not care much about others’ opinions” Bianca.

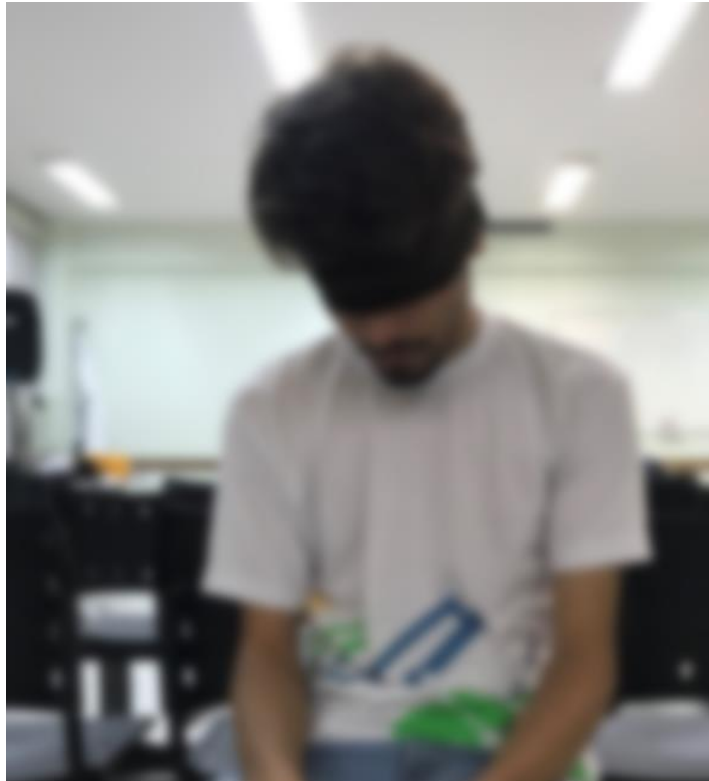
Fortunately, the project helped those students (and perhaps the audience) deconstruct some of those misconceptions and gender stereotypes. Daniel says, “While participating in the project, I realised how theatre is fascinating and can offer countless opportunities.” Ana initially expects male students not to participate in theatre activities. “I was even surprised about the number of men participating in the play because I expected it to be less”. Nevertheless, she comments that the contact of engineering students as spectators of the theatre may have had some effect in this aspect on prejudices about theatre that may have prevented men from participating, “everyone was amazed by the theatre, and I think it ended up breaking that barrier for some. I think that if the project continues, more men will enrol.”

In a second session, the students investigated the history of theatre and the aesthetic method of the Theatre of the Oppressed (TO), created by Brazilian playwright Augusto Boal (Kina; Fernandes, 2017). Then they shared information about theatre and drama. Moreover, Donizetti (experimental actor and play director) deepened the discussion about theatre in this session and throughout the project. We clarified to the students that arts and engineering should be evenly addressed in the project. We also highlighted that one knowledge area should not be reduced into an instrument to convey the other (Mejias *et al.*, 2021; Rodrigues-Silva; Alsina, 2023a).

In the third section, we focused on the reflection on engineering. We provided the students with two videos about the fabrication process of spoons and ceramic toilets. Afterwards, they used that information to ignite the discussion “Engineering from what you eat to what you shit”. During this conversation, the students highlighted the presence of this discipline in every aspect of contemporary human life. Interestingly, despite being engineering students, some remarked they usually do not think about their course from broader perspectives, such as its presence and imbricated relation to society.

In subsequent sessions, we developed theatrical laboratories with the students: improvisation, perception, hearing, and vision, or in Daniel's voice, "we did a series of dynamics to develop group trust." Through this comment, we may infer that this student's memory was captivated by an activity devoted to developing group trust. As shown in Figure 1, students were blindfolded and relied on their fellowship in an exploration journey around the campus.

Figure 1 – Blindfolded students during an activity of group trust



Source: Project archives. Photography of Cláudia Borges Coelho.

Addressing their prior conceptions and deepening their knowledge about engineering and theatre was crucial to construct a shared vision of engineering, theatre, and the engineering-theatre junction. Additionally, this preparation intended to make the project proposal meaningful to them. Altogether, those discussion cycles and laboratories prepared them for the subsequent activities within the project: playwriting, scenario conception, rehearsals, and the play performance.

4 Writing a script: We are about to have a play!

We supported students with writing the play, but they had significant autonomy in this process since addressing mechanical engineering remains a somewhat open arena. Accordingly, students were aware of this autonomy and embraced this responsibility and ownership during text conception. In this sense, Roberto says, "it was anything imposed. We always discussed when we

thought something should be changed. We could do it because the text was ours”.

They also have the freedom to develop their strategies for writing the script. Ana explains that they initially deepened into more research “we started researching texts that portrayed engineering in everyday life. We looked for information about the evolutionary history of technology development to determine the sequence of the text according to the chronology of the inventions”. Another student comments on how they focused their work on the mechanical engineering course: “We always tried to cover as much as possible within the area of mechanical engineering, which is the course we take, and then develop the play.” Daniel.

After they gathered information, they started writing the play. Daniel reports positive feelings regarding this phase. As another strategy, he explains that they created an initial text as a base, “the beginning of the text production was exciting. We created scenes, and keywords appeared in the middle of those scenes, giving a structure to the text, a base.” The student completed the explanation with a second writing stage in which they enriched and refined the text, “after we created this base, we added more content related to engineering throughout some keywords to give more fluidity to the text.”

We may refer to a safe and trustworthy space to share opinions and work collaboratively (Uria-Iriarte, 2021). Daniel emphasises the enthusiasm and collaborative work of writing the play. For example, when they independently scheduled additional meetings: “we got together to see how the text was evolving. We even had some extra meetings to talk about the play”. In addition, students’ interviews evidenced that they adopted a democratic posture. For instance, Ana commented they had discussions until they had a consensus and approval of the text. “Among all students, we gathered ideas and opinions until we reached a final text. We approved it when we all accepted that it was sound and transmitting the message we wanted. Moreover, Bianca highlights the respect for different opinions in those meetings “the atmosphere of work allowed us to have different opinions from each other.”

After all that collaborative writing, they finally have a play script! So now we describe the play, whereas we expand considerations such as scenario conception and the rehearsals. Starting from the play’s name, the participants called it “*Integrados*” –translated as “integrated” from Portuguese – because of a triad of meanings of this word in its original idiom. The students explained that the name broadly expresses the integration of engineering and theatre; second, the idea of integrating engineers into society emerges. In addition, “*Integrados*” also alludes to the mathematical operation of integrals, which is highly representative of engineering calculations.

From an intimate perspective, “*Integrados*” also referred to interpersonal relationships since they felt a strong connection with each other; For instance, they decided to create a T-shirt to

celebrate and create an identity as a group. Related to the collaborative working, Ana remarks surprise, “I did not expect such a nice interaction in the group. Everyone in the project was trying their best.” Likewise, Santos says, “I developed a quite strong relationship with my colleagues and instructors. We constructed friendships that go beyond the theatre.”

Once they had chosen the play’s name, they settled on its performance date: 7th November 2020; the big day was coming! In order to disclose it, we sent an open invitation to the internal community of the campus (students, professors and university staff) and the external community (students’ families, friends and any people interested). Now on, we describe the play and its three acts: 1) We are not robots, are we?; 2) Guilty Conscience; and 3) Graduation ceremony.

4.1 First act: *We are not robots, are we?*

Staging awaited the public with a robotic ambience. As Ana explains, “the play starts with some students wrapped in aluminum foil in a static position.” In Figure 2, we can observe how students cover each other with aluminum foil during a rehearsal.

Figure 2 – Mechanical engineering students wrapped in aluminum foil to address the misconception of engineers as robots



Source: Project archives. Photography of Cláudia Borges Coelho.

Ana continues describing that “while the audience enters, it sounded a robotic music ambience.” The robotic music that this student mentions is the song *Die Roboterm* (The Robots in English) from the German band *Kraftwerk*. It is a single that provides robotic imagery through repetitive refrains, pitched voices and electronic notes. In addition to the robotic atmosphere, students choose it because the song discusses the subservient roles between robots and humans.

Moreover, they conceived a scenario to immerse the actors and the audience in a world built on machines. As Bernardo explains, “the scenario focused on the engineering course. It had several bicycle rims, tools, and other machine mechanisms.” Carla remarks, “The scenario we created was impressive. I observed the audience astonished from the stage entrance.” In Figure 3, we can observe an element from the scenario made up of cords and bicycle rims.

Figure 3 – Element from the scenario constructed with bicycle components



Source: Project archives. Photography of Cláudia Borges Coelho.

After the audience arrived and settled down, a student started dramatising a text that addresses the Greek myth of Prometheus and Epimetheus concerning the origin of humankind. The legend says the Gods charged the brothers to distribute skills and goods among the animals, such as force, speed, and wings. At the end of the distribution, Epimetheus perceived he had forgotten the man, who was fragile and could not defend himself from the beasts. Therefore,

Prometheus stole the fire of technique from Olympus and gave it to men. This fire represents men's intelligence to adapt and transform the environment to survive. In the play, students remarked that this fire represents engineering and its technological development, or in Ana's words, "we presented the Prometheus myth bringing the engineering until today."

In the sequence, the play reports that humans created machines, but at some point, men became so dependent and overshadowed by their glow that humanity was now at risk of technological servitude. Bernardo explains, "we criticised that machines are replacing man, leaving him behind, now machines do everything. Through this criticism, we try to alert that this should not happen. The man is the one who needs to be on command." Figure 4 shows how the students created a worship scene for the machines. In this scene, some were kneeling while praying to the robotic figures.

Figure 4 – Rehearsal of the scene of worship for the machines



Source: Project archives. Photography of Cláudia Borges Coelho.

During this worship, the group on their knees said things men used to do, whereas the robots answered that now the machine does such things. As is illustrated in the following fragment:

Men ploughed. Machines do!
Men harvested. Machines do!
Men fought. Machines do!
Men killed. Machines do! Men
healed. Machines do!
Everything men did? Machines do!
Zero hours. Machine, pray for us!

Roberto made an exciting lecture that goes beyond the message of humanity and technological servitude and addresses psychological healthy. He criticises the current social pressure of being productive all the time. For him, the theatre was a temporal space that permitted him to see engineering differently and, by extension, escape from the bubble of this course to see an outside world. In his own words:

When people become machines, they focus on studying or being productive 100% of the time. They end up forgetting about their principles. Then comes psychological diseases: depression, anxiety, and panic syndrome. The theatre project helps significantly in this matter. It represents a moment of distress to see engineering in another way. The play showed us a world outside the bubble of our course.

A character of another student interrupts the worship by warning about the role of engineering for man's welfare instead of servitude to machines. They suddenly break free from the technological illusion. This awareness is physically expressed with them stripping from the robotic covering and assuming their humanity. As Roberto explains, "we started as machines. Then you have a shock of reality. We are not machines, and we have human values! As engineers, we should superimpose ourselves above the machine." This first act is strong evidence that the drama activity called students to recognise themselves as subjects. Biesta (2020) defends that *subjectification* is an essential and frequently forgotten purpose of education. Since they are not robots (objects) but subjects, they are called to take responsibility in the world. However, as subjects, they decide to take or not on those responsibilities—this *subject-ness* leads to ethical dilemmas and consciousness as a self. That is furthered in the play's second act.

4.2 Second act: The "Consciência Pesada" (Guilty Conscience)

Ethical concerns brutally cross those students from the eruption of *subject-ness*. The character "Consciência Pesada" (Guilty Conscience) enters the stage, pointing out a series of inappropriate behaviors of these students, such as dishonesty and arrogance.

You cheated on the test! You mocked your colleagues who failed thermodynamics. You transformed your parents' money into beers instead of buying those supposed books.

Regarding this episode, Santos clarifies that they intended to portray their agonies within the course. In this sense, the Guilty Conscience represented those regretful feelings mixed with the pressure and willingness to succeed: “The text also shows our struggles within mechanical engineering, which is a difficult course. The text shows our feelings when we fail in a discipline, and we think: why haven’t we studied more? Why not seek more information resources to succeed in the discipline?”

“*Consciência Pesada*” means literally heavy Conscience in Portuguese. Accordingly, the students had idealised a costume for this character as a heavy/big person, alluding to the weight. However, the girl who would play this character felt uncomfortable doing it that way. In this specific case, the student had her subjectivity respected by changing the representation of this character. Roberto explains:

Regarding the appearance of Guilty Conscience, Carla changed its clothing. In the end, she incarnated the character and played a perfect role. The play’s main character, or at least the one that caught the most attention, in my opinion.

The physical reference to weight was replaced by an obscure and mysterious outlook. The student who acted this character proposed wearing formal shoes, a long dress and a mask. Then she contrasted the dark clothing of Guilty Conscience with a bright object which clearly referred to a brain, as shown in Figure 5.

Figure 5 – Guilty Conscience character holding a brain

Source: Project archives. Photography of Cláudia Borges Coelho.

Continuing the play description, after making accusations of students' antithetical behavior, Guilty Conscience decided to sit in a chair, which in this case, represented all engineering products. Roberto remembers, "the Guilty Conscience was going to sit in a chair; then we said the chair could not support it because she was too heavy." At this moment, several mathematical and engineering concepts emerged, as evidenced following fragment:

Guilty Conscience: I will sit down and get some rest. The Conscience of this class is too heavy!

All: No!

Ana (pulls back chair): Don't get me wrong, but this chair might not support you. Let me say your center of gravity is a little off.

Guilty Conscience (takes back the chair): my center of gravity is very well located, thanks.

Roberto: Not wanting to be intrusive, but given the dimensions, maybe just X, Y, and Z axes are not enough to locate it.

Regarding this fragment, Bianca comments that "there was a part of the theatre where we talked about the center of mass and made a joke about coordinates: that only the x, y and z axes were not enough to find the center of mass of Guilty Conscience because it was cumbersome. She explains, "this axis that Roberto did has to do with the fact that Guilty Conscience was heavy. I think the people watching understood the message we wanted to communicate."

After Guilty Conscience argued with the students, she finally sat on the chair. After a while, students showed her the engineering goods, such as shoes, textile manufacturing, and airplanes, as shown in Figure 6. Concerning this scene, Ana remarks, "the main message we wanted to convey

in the play was that engineering is present in everything in our lives.” This part of the play was probably influenced by the discussion cycle “Engineering from what you eat to what you shit”.

Figure 6 – A student hands a blanket to Guilty Conscience



Source: Project archives. Photography of Cláudia Borges Coelho.

Nevertheless, Guilty Conscience counter-argued those benefits of engineering with another side that accompanies engineering, and that may harm society. This part of the play frames Boal’s encouragement in Theatre of Oppressed to create images of the *real* and *ideal* (Kina; Fernandes, 2017). As demonstrated in the fragment below, there is a contrast between ideal and real engineering:

Student: Engineering makes shoes to protect our feet!
 Guilty Conscience: Engineering makes bombs and has nowhere to run.
 Student: Textile manufacturing provides clothing to protect us from the cold.
 Guilty Conscience: Clothing does not protect you from bombs.
 Student: Engineering made airplanes.
 Guilty Conscience: Well, you are right. I like airplanes, such a formidable invention! I call them “bomb launchers”.

At this point, it is noteworthy to say that the example of the airplane is quite emblematic for Brazilians. This country attributes the Brazilian Santos Dumont the title of inventor of the airplane. Dumont fell into a deep depression and committed suicide to the agony of seeing his invention being used to kill people in wars (Oliveira, 2022).

As stated before, this second act signs students' *subjectification* process as an educational outcome of the drama activity (Biesta, 2020). The character of Guilty conscience remarks on the existence of a subject that takes (or refuses to make) decisions in the middle of contrasting ideas of engineering.

4.3 Third act: Graduation ceremony

Once students have emerged from their humanity, faced the Guilty Conscience, and reflected on ideal and real engineering contrast with its benefits and harm to society. In this third act, students cover Guilty Conscience with black cloth. Then, the students wear graduation gowns and take the engineering oath – a symbolic element which remarks their integration into society under the identity of a sound engineer, as shown in Figure 7.

Figure 7 – Students take the engineering oath with a coved, but always present, Guilty Conscience



Source: Project archives. Photography of Cláudia Borges Coelho.

While they promise to be good professionals, one student recites the oath with a hand over Guilty Conscience's head. After all, she may be coved, but she is still present.

The oath is transcribed below.

I promise that, in fulfilling my duty as an engineer, I will not let myself be blinded by the excessive brightness of technology, never forgetting that I work for the good of man and not of the machine. I will respect nature and avoid designing or building equipment that pollutes or destroys the ecological balance. I will put all my scientific knowledge at the service of the comfort and development of humanity. So I will be at peace with myself and with God.

This part of the play was particularly emotional to the students participating in the project, and we risk saying it might also substantially impact those students from the audience. Ana states:

The dream of everyone in an undergraduate course is to conclude it. The graduation ceremony is the culmination of that. What impressed us the most was imagining ourselves wearing that gown and taking an oath that we did not even know existed. I discovered it in the play.

Moreover, we should pinpoint that the oath is intrinsically related to the purpose domain of education of *socialisation*, which means being introduced to society or a culture of community, a professional community in this case (BIESTA, 2020). Since students reported that one intention of the play was to present engineering to society, in this sense, the play responds again to the educational purpose of *socialisation* if we consider the audience.

Once the students have taken the oath, the play finishes with everyone choring “Some people see how things are in the world and ask –why? Engineers dream with things that do not exist and wonder –why not?”

5 Educational outcomes

Throughout the description of the play, we have remarked on educational outcomes related to *subjectification* and *socialisation*. Following, we focus on another domain of educational purposes: *qualification*, so we address the outcomes of the drama activity regarding content knowledge and skills development (Biesta, 2020).

5.1 Content knowledge

We identified that some were motivated to participate in the project to learn from new areas, indicating they were open to learning about theatre in this particular case. Bianca says, “I decided to participate in the project to bring knowledge from new areas, subjects that would probably not be available in the classroom”. In this sense, we can affirm that the project reached such expectations because they were taught about things they would not have the opportunity otherwise, for instance, historical and methodological aspects of theatre. Specifically, Santos reports overcoming difficulties and acquiring skills in the theatre which might help him in future engineering studies, “for me, memorising the text for the theatre was a hard job. An ability which will be important for studying following engineering disciplines.”

At the same time that the drama activity brought knowledge from new areas, it also instigated the deepening of engineering concepts. In this sense, Roberto explains, “I had many

speeches about engineering. So I should know those concepts in-depth to present them appropriately in the play. For example, the meaning of the centre of mass is” Roberto said. Bianca corroborates this idea, “we spoke about several topics related to materials stiffness, such as tensions and deflection. Many other technical terms”.

For several moments, students showed concern in approaching engineering concepts so that an audience of non-engineers could understand them. “The play involved the technical concepts in a way that everyone could understand”, Bernardo said. Furthermore, they demonstrated awareness of the complexity of the concepts addressed. “Our theatre had terms that perhaps only an engineer could know. However, as we aimed at our public, we did more explanation to bring these concepts to lay people as well,” Daniel. They even explained some strategies to make engineering concepts accessible to the public, “since the rehearsals, I noticed that Roberto was gesturing so that the spectators from the theatre would understand the centre of mass. Maybe they did not have much engineering knowledge, so these movements presenting the axes with his hands and arms helped people understand what we were talking about.” Ana.

Bernardo further relates this attention to a public understanding as a communication skill required in engineering: “A good engineer has to know how to listen and speak. Explain solutions to problems in a way that others will understand.” In sum, the educational outcomes reinforce that STEAM education can be approached by playful pedagogies in higher education (Rodrigues- Silva; Alsina, 2023b).

5.2 Disinhibiting and oratory

Roberto reported that fear and shyness in public speaking might have prevented many students from enrolling in the project. He says, “I was so excited to participate in the project that I invited some friends to participate as well. They did not accept it because of their shyness, fear of interacting and presenting to an unknown public.”

However, other students faced this fear. Among those students who participated, disinhibiting and oratory was the primary motivation. Roberto comments, “I was afraid to present myself in public presentations. I decided to participate in the theatre to develop this skill.” Bernardo says, “The motivation to participate [in the theatre] was mainly about helping to speak in public because I am timid sometimes.”

Ultimately, they indicated satisfaction concerning disinhibiting and speaking in public development. Santos, for example, was specific by identifying an initial difficulty in stuttering during speeches “the theatre was perfect for my diction. It helped me a lot in my speech. At the beginning of the course, I stuttered in presentations”. Bernardo reports improving his self-

expression and confidence in defending his opinions. “I used to be reticent. I saw the wrong things and omitted myself. I could not express and defend my opinion about things.” Bernardo said.

Roberto emphasised that he started the project focusing on oratory but was surprised by his personal development in other domains. “I started to develop my oratory skills and diction, and I fell in love with that. I liked it a lot more after I was there because it activated my humour side, which I like.” Roberto.

5.3 Satisfaction

Students demonstrate high satisfaction throughout the project, e.g., Daniel says, “since the first meeting, I realised the project would be much better than I expected. Others emphasised a great feeling of fulfilment after the performance. “The most satisfying moment for me was after the play performance, the compliments we received.” Ana. In this regard, we recall the idea that knowledge of affective nature plays a vital role in the transformation of the subject (Magalhães, 2012).

Approximately 50 people watched the play. Regarding the audience’s satisfaction, Ana remarks that they liked the play. “I think that the result was overwhelming. Those who watched gave us positive feedback. People loved it and then congratulated us.” Bianca.

In tune with the student’s satisfaction, they felt motivated to continue the project. For example, Santos says, “I would like to continue the project, so we could explore other fields, provide and expand it.” Bernardo further suggests the proposal should be extended to all mechanical engineering students, “I believe that theatre should be for all students in the course.” Roberto highlights that the audience supports them to continue “we were highly praised in the end, many teachers were watching our play, and some of them motivated us to continue.”

The play was performed only one time. For two reasons, other performances were not possible because of the Covid-19 pandemic, which prevented doing those activities for a significant period. Second, the whole experience of the Engineering & theatre project had an unexpected effect, or we could say an aesthetical, on the mechanical engineering professor’s professional development itinerary (Pillotto; Camargo; Gomes, 2022). He felt incentivised by this interdisciplinary enterprise and started doing a doctorate in education centred on STEAM Education. He has returned from the qualification license to his teaching activities on campus and is willing to reactivate the project.

Acknowledgements

We acknowledge Donizetti Bernardes for his initiative and partnership with this project.

References

- ALMEIDA, C.; BENTO, L.; JARDIM, G.; RAMALHO, M.; AMORIM, L.; FOLINO, C. H. Theater as a strategy for youth engagement in the fight against aids. *Interface: Communication, Health, Education*, v. 25, 16 abr. 2021. <https://doi.org/10.1590/INTERFACE.200402>
- BIESTA, G. Risking Ourselves in Education: Qualification, Socialization, and Subjectification Revisited. *Educational Theory*, v. 70, n. 1, p. 89–104, 16 fev. 2020. <https://doi.org/10.1111/edth.12411>
- CARRASQUILLA, O. M.; SAN ROQUE, I. M.; PASCUAL, E. S. Actitudes hacia la ciencia en la educación STEM: desarrollo de una escala para la detección y fomento de vocaciones tempranas. *REOP - Revista Española de Orientación y Psicopedagogía*, v. 34, n. 1, p. 122–140, 29 abr. 2023. <https://doi.org/10.5944/reop.vol.34.num.1.2023.37421>
- CATTERALL, L. A Brief History of STEM and STEAM from an Inadvertent Insider. *STEAM*, v. 3, n. 1, p. 1–13, dez. 2017. <https://doi.org/10.5642/STEAM.20170301.05>
- CHESKY, N. Z.; WOLFMEYER, M. R. Introduction to STEM Education. *Philosophy of STEM Education*, p. 1–16, 2015. https://doi.org/10.1057/9781137535467_1
- FRANÇA, G. S.; RIBEIRO, R. C.; SOARES, L. R.; CALMONI, J.; DE FRANÇA, G. B.; BRITO, P. E. The Flat Earth satire: using science theater to debunk absurd theories. *Geoscience Communication*, v. 4, n. 2, p. 297–301, 2021. <https://doi.org/10.5194/gc-4-297-2021>
- GUYOTTE, K. W. Toward a Philosophy of STEAM in the Anthropocene. *Educational Philosophy and Theory*, v. 52, n. 7, p. 769–779, 6 jun. 2020. <https://doi.org/10.1080/00131857.2019.1690989>
- KETTLER, M.; HEIMANS, S.; BIESTA, G.; TAKAYAMA, K. In recognition of teachers and teaching. *Asia-Pacific Journal of Teacher Education*, v. 51, n. 1, p. 1–4, 1 jan. 2023. <https://doi.org/10.1080/1359866X.2023.2168334>
- KINA, V. J.; FERNANDES, K. C. Augusto Boal's Theatre of the oppressed: democratising art for social transformation. *Critical and Radical Social Work*, v. 5, n. 2, p. 241–252, ago. 2017. <https://doi.org/10.1332/204986017X14951776937239>
- MAGALHÃES, S. M. O. Atitude transdisciplinar no ensino de psicologia. *Dialogia*, n. 13, p. 101–122, 8 mar. 2012. <https://doi.org/10.5585/dialogia.N13.2776>
- MARTINS, L. de S.; RODRIGUES-SILVA, J. Das crises às possibilidades da Educação Superior no Brasil: uma leitura a partir de Hannah Arendt. *Educação e Filosofia*, v. 35, n. 75, 19 abr. 2022. <https://doi.org/10.14393/REVEDFIL.v35n75a2021-64064>

MEJIAS, S.; THOMPSON, N.; SEDAS, R. M.; ROSIN, M.; SOEP, E.; PEPPLER, K.; ROCHE, J.; WONG, J.; HURLEY, M.; BELL, P.; BEVAN, B. The trouble with STEAM and why we use it anyway. *Science Education*, v. 105, n. 2, p. 209–231, 3 mar. 2021. <https://doi.org/10.1002/sce.21605>

OLIVEIRA, P. L. S. Transforming a Brazilian Aeronaut into a French Hero: Celebrity, Spectacle, and Technological Cosmopolitanism in the Turn-of-the-Century Atlantic. *Past & Present*, v. 254, n. 1, p. 235–275, 27 jan. 2022. <https://doi.org/10.1093/pastj/gtab011>
PARRY, S. *Science in performance*. Manchester: Manchester University Press, 2020. <https://doi.org/10.7765/9781526150905>

PELEG, R.; BARAM-TSABARI, A. Learning Robotics in a Science Museum Theatre Play: Investigation of Learning Outcomes, Contexts and Experiences. *Journal of Science Education and Technology*, v. 26, n. 6, p. 561–581, 1 dez. 2017. <https://doi.org/10.1007/s10956-017-9698-9>

PERIGNAT, E.; KATZ-BUONINCONTRO, J. STEAM in practice and research: An integrative literature review. *Thinking Skills and Creativity*, v. 31, n. October 2018, p. 31–43, 2019. <https://doi.org/10.1016/j.tsc.2018.10.002>

PILLOTTO, S. S. D.; CAMARGO, J. A.; GOMES, A. H. Percursos formativos na educação: experiências estéticas, memórias e narrativas. *Dialogia*, n. 41, p. e21215, 10 maio 2022. <https://doi.org/10.5585/41.2022.21215>

RODRIGUES-SILVA, J.; ALSINA, Á. Conceptualising and framing STEAM education: What is (and what is not) this educational approach? *Texto Livre*, v. 16, p. e44946, 2023a. DOI <https://doi.org/10.1590/1983-3652.2023.44946>.

RODRIGUES-SILVA, J.; ALSINA, Á. La educación STEAM y el aprendizaje lúdico en todos los niveles educativos. *Revista Práxis*, v. 1, p. 188–212, 24 jan. 2023b. <https://doi.org/10.25112/rpr.v1.3170>

RODRIGUES-SILVA, J.; ALSINA, Á. STEM/STEAM in Early Childhood Education for Sustainability (ECEfS): A Systematic Review. *Sustainability*, v. 15, n. 4, p. 3721, 17 fev. 2023c. <https://doi.org/10.3390/su15043721>

RODRIGUES-SILVA, J.; ALSINA, Á. Systematic Review About Students' Conceptions of Engineering Accessed Through Drawings: Implications to STEAM Education. *International Journal of Cognitive Research in Science, Engineering and Education (IJCRSEE)*, v. 11, n. 2, p. 199–211, 31 ago. 2023d. <https://doi.org/10.23947/2334-8496-2023-11-2-199-211>.

RODRIGUES-SILVA, J.; BRITO, A. L.; FARIA, G. T.; GABRIEL, L. de C.; OLIVEIRA, W. J.; VIANA, L. A. F. Engenharia & arte: Representação da engenharia mecânica através de mosaicos. *Revista Extensão & Sociedade*, n. Edição Especial do 8o Congresso Brasileiro de Extensão Universitária, p. 19–27, 2018. Available at: <https://periodicos.ufrn.br/extensaoesociedade/issue/view/Edi%C3%A7%C3%A3o%20especial%20%7C%208%C2%BA%20CBEU/Artigo%2002> accessed on 15 Jun. 2023.

RODRIGUES-SILVA, J.; SILVA-HORMAZÁBAL, M.; ALSINA, Á. Colocando a engenharia sobre a mesa: uma atividade de engenharia reversa e matemática. *Pesquisa e Debate em educação*, 2023a [In press]. .

RODRIGUES-SILVA, J.; SILVA-HORMAZÁBAL, M.; ALSINA, Á. Students' conceptions about Engineering and its connections with mathematics and science. *Enseñanza de las Ciencias*, 2023b [In press].

SILVA-HORMAZÁBAL, M.; ALSINA, Á. Exploring the Impact of Integrated STEAM Education in Early Childhood and Primary Education Teachers. *Education Sciences*, v. 13, n. 8, p. 842, 18 ago. 2023. <https://doi.org/https://doi.org/10.3390/educsci13080842>.

SILVA-HORMAZÁBAL, M.; RODRIGUES-SILVA, J.; ALSINA, Á.; SALGADO, M. Integrando matemáticas y ciencias: una actividad STEAM en Educación Primaria. *Unión - Revista Iberoamericana de Educación Matemática*, v. 18, n. 66, 30 dez. 2022. <https://union.fespm.es/index.php/UNION/article/view/1412>

SILVA-HORMAZÁBAL, M.; RODRIGUES-SILVA, J.; ALSINA, Á. Conectando matemáticas e ingeniería a través de la estadística : una actividad STEAM en educación primaria. *Revista Electrónica de Conocimientos, Saberes y Prácticas*, v. 5, n. 1, p. 9–31, 2022. <https://doi.org/https://doi.org/10.5377/recsp.v5i1.15118>

THOLEN, B. Bridging the gap between research traditions: on what we can really learn from Clifford Geertz. *Critical Policy Studies*, v. 12, n. 3, p. 335–349, 3 jul. 2018. <https://doi.org/10.1080/19460171.2017.1352528>

URIA-IRIARTE, E. Pedagogy of paradox: Discovering the role of drama-facilitator in the secondary school classroom. *Youth Theatre Journal*, v. 35, n. 1–2, p. 25–36, 3 jul. 2021. <https://doi.org/10.1080/08929092.2020.1867682>

VO, T.; HAMMACK, R. Developing and Empirically Grounding the Draw-An-Engineering-Teacher Test (DAETT). *Journal of Science Teacher Education*, v. 33, n. 3, p. 262–281, 3 abr. 2022. <https://doi.org/10.1080/1046560X.2021.1912272>