DRONE GAME THAT HIGHLIGHTS ETHICAL AND SUSTAINABILITY IMPLICATIONS OF DESIGN DECISIONS

Siara Isaac, Gianni Lodetti, Jessica Dehler Zufferey, Barbara Bruno

École polytechnique fédérale de Lausanne (EPFL)

ABSTRACT

This paper reports on the development of a brief scenario-based challenge to prompt engineering students' reflection about the broader impacts of their design decisions, and thereby increase their ethical sensitivity and motivation. The game scenario asks players to design a drone for ornithologists to study birds, contextualized as part of a university course. Constrained by their budget, players choose a subset from a variety of actions that can advance their drone design. Each action, for example spending a week prototyping in the lab (200€) or making a one-day field trip with the ornithologists (1000€), allows the players to access specific information and make choices to refine their design. Presenting the task as a mechanical engineering design problem, without reference to ethics or sustainability, gives us a window into how students spontaneously include these aspects in their design decisions. This is important, as previous studies have shown that engineers typically interpret their brief as restricted only to their core engineering disciplinary expertise and do not perceive the ethical implications of their design decisions. The feedback that participants receive after submitting their final prototype highlights potential ethical and environmental issues, with a view to increasing both students' *ethical sensitivity* (recognising that an ethical concern exists) and *ethical motivation* (internal drive towards behaviours coherent with ethical values). This paper reports on the scenario development and first implementation as an online game that constitute the semester project of the second author. We share preliminary participant feedback and our plans for a tangible interface with tabletop robots to observe participants' decision-making processes through haptic functionality and afford opportunities to integrate peer discussions in the activity.

KEYWORDS 4-6 + standards

Engineering design, ethics, transversal skills, tangibles, Standards: 5, 7, 8.

INTRODUCTION

Foreseeing the potential downstream ethical and environmental impacts of engineering design decisions is difficult for professional engineers even when they possess significant experience with the implementation context. This difficulty is addressed in the CDIO curriculum, for example by Standard 5 which requires two or more design-implement experiences. However, the ability to identify ethical implications for the projects they work on was rated by professional engineers, Masters students and Bachelor students as a relative weaker area of their skills sets (Piccard et al., 2022). It is therefore interesting to create additional, brief and low-resource opportunities in an engineering program that enable students to develop experience with the ethical and sustainability implications of design decisions. This paper reports on the creation of a design challenge "game" to develop students' ethical awareness and sensitivity by confronting them with the ethical and sustainability consequences of their design decisions. This paper is coherent with the motivations for the latest update of the CDIO syllabus (2022) to better reflect the "growing awareness and evidence of the impact of human activities on our planetary system and ecosystems"; this activity prompts students to consider aspects related to section 2.5 Ethics, Equity and Other Responsibilities, particularly the subsections 2.5.1 Ethics, Integrity and Social Responsibility and 2.5.4 Staying Current on the World of Engineering (which includes the social, environmental, and economic impact of new technologies).

"The specific nature of the ethical issues arising from digital technology (e.g. privacy, algorithmic bias or transparency issues)" (Hardebolle et al., 2022) requires that engineers integrate ethical considerations in their technical problem solving throughout the design process. Of course, traditional ethical dilemmas still occur as new technologies are deployed in society. While a recent meta-analysis reports major efforts have been made to improve the integration of ethics in engineering curricula (Watts et al., 2017), several studies point to engineers' ethical sensitivity or ethical agency being insufficient to enable them to productively incorporate ethical concerns in their work. To cite a few examples, Ivan Szekely (2011) found that while IT professionals sought to meet ethical standards, their actions were motivated by seeking to comply with criteria set by their employers rather than responding to their own ethical motivation. Isaac et al.'s (2023) observational study found computer engineering students did not spontaneously include sustainability in their software design decisions, and engaged only peripherally with ethical issues related to either privacy or accessibility. Lönngren's (2021) discursive analysis offers a rich exploration of the perceived separation between ethics and technical, disciplinary thinking.

While it is important to acknowledge that workplace environments contribute to the scope afforded to engineers use ethics and sustainability to inform their choices, the strength of their ethical positions also plays an important role (Hwang and Chen, 2022; Karakoç et al. 2022). Further, Griffin et al. found that engineers tended to minimise the ethical dimensions of their work or to describe the ethical dimensions as beyond their sphere of responsibility (2023). In engineering education, requiring students to employ the perspectives and tools of ethical and value-centered design (Donia and Shaw, 2021) is a promising vector to develop students' capacity to make relevant, contextual connections between their disciplinary design approach and ethical concerns. The expectation that ethics be integrated transversally leads to its classification as a transversal skill in terms of expected graduate attributes set by engineering accreditation bodies (CTi; ABET). We accordingly review our model for teaching transversal skills below.

Teaching Transversal Skills

This project is part of the 3T PLAY initiative, which investigates the development of engineering students' transversal skills using tangibles. As can be verified by a cursory review of the program for any recent engineering education conference, transversal skills are omnipresent in engineering education. Improving graduates' transversal skills requires action at several order of magnitude, from macro-level coordination across the curriculum to the micro-level of the teaching of specific skills through the resources, assignments, and feedback provided to students. 3T Play has developed a three-part framework for this micro-level that describes the elements we have identified essential for transversal skill development (Isaac et al., forthcoming). As shown in Figure 1, the first level is *declarative knowledge* which refers to the actual knowledge and concepts that underpin a skill. Taking the example of the transversal skill of ethics, relevant *declarative knowledge* includes sources of bias in machine learning or the role of inequality in climate change. The next level, *procedural skills*, relates to the integration of this knowledge in thinking and behaviour. Continuing the example above on ethics, *procedural skills* involve generating diverse user stories, employing strategies for equitable teamwork, and designing to promote ecological choices. The final level, *metacognitive and meta-emotional reflection*, refers to the self-monitoring of the efficacy and appropriateness of the *procedural skills* being implemented. This skill involves, for example, the ability to assess the effectiveness of the decision-making or design approach being used in the current moment. Is it suitable for current phase or objectives? If it is working better than expected, why is this and why didn't it work well last time? This third level is related both to developing students' capacity to identify when a different approach is needed and to select appropriate strategies in the present moment. This final level is fundamental to students being able to transfer their experiences from the current learning situation to their next project, and hence relevant to their lifelong learning (Bierwolf, 2017).

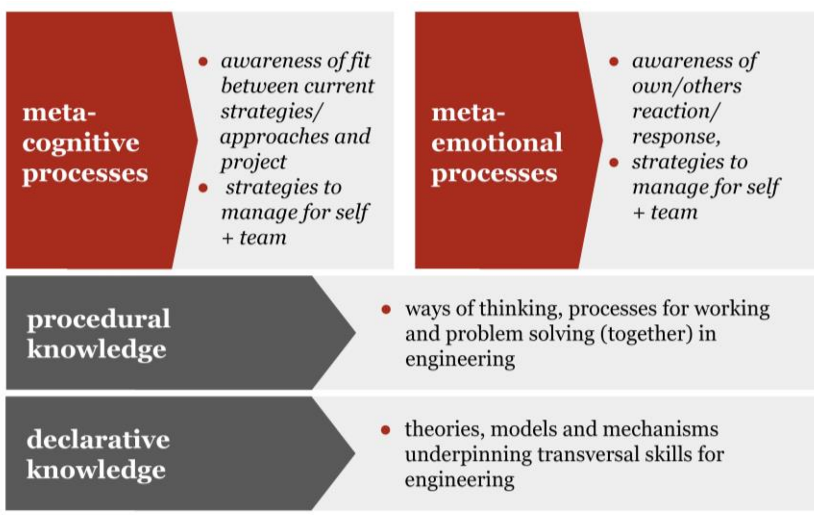

Figure 1. 3T PLAY's 3-level approach to teaching transversal skills

The development of robust transversal skills requires all three of these levels to be addressed over the course of the interventions around the development of a particular skill. Our framework has allowed us to clarify the types of activities and feedback students need to develop a well-rounded skill.

While senior engineering students typically integrate more reflective practices into their design thinking than younger students (Adams et al., 2003), many students requite explicit support to develop their meta-cognitive skills with respect to their design decision (Steele, 2018). It is these meta-cognitive skills that the drone challenge presented in this paper addresses. While it neither teaches about specific ethical or sustainability concepts, nor proposes procedural skills for students to incorporate ethics into their thinking, the scenario seeks to develop students' sensitivity and motivation for identifying ethical and sustainability implications of design choices.

Creating an Ethical Game

Meta analyses have shown that educational games can develop cognitive, affective and motivational skills (Karakoç et al. 2022; Manzano-León et al., 2021). For example, Wang et al. (2021) report that an augmented reality game promoting general environmental actions, such as recycling, resulted in « knowledge absorption » and improved participants' attitudes towards sustainable behaviours. Specific recommendations with regard to ethics education games include "ethical choices and decision-making, which have an effect on the game play" and integrating reflective activities (Schrier, 2015). Mendler de Suarez et al.'s report (2012, p.9) provides a robust argument in favour of games' potential to act as « systems that help us inhabit through gameplay the complexity of decisions about future risks ». In particular, they identify games' (1) power to compress time and therefore allow players to experience how their decisions shape the outcomes or even more long-range future and (2) capacity to "capture relationships between system elements in a way that gives agency » to the player (ibid.). Our understanding of the characteristics that make serious games effective is still being refined, particularly with respect to the meta-cognitive level we seek to access in our game. For example, Tanner and colleagues' (2022) found that their business game did serve to develop university students' moral sensitivity however, in constrast to previous work, versions with pro-social cues or reflection prompts were less effective. As discussed above, we are interested in getting students to integrate ethical thinking in their disciplinary engineering thinking. Accordingly, we are interested in Cécile Hardebolle and colleagues' (2022) development of an interactive scenario for engineering students where players make decisions regarding the design of machine learning algorithms and are confronted with the ethical implications.

With a view to engaging the large number of mechanical engineering students in our institution, informal surveying helped us decide to create a game that challenges players with design decisions related to building a drone. Drones are exciting devices with features and components of varying complexity, allowing for trade-offs during the design process (The Corona Wire, n.d.). Drones are also used for many different purposes (bird monitoring, pipe inspection, delivering supplies to remote areas, etc.) which allows for the development of several scenario within the game, thereby creating opportunities for students to transfer their skills to another context. While the technical verisimilitude is important to us, varying complexity of components also provided scope to make the scenario accessible to people without a specific engineering background. Scope for ethical implications can be found in the potential for drone noise to scare birds; an extreme example occurred when a drone crash caused thousands of elegant terns to abandon their eggs (Washington Post, 2021). Another potential ethical issue is how bias in user testing can exclude categories of potential users, arising from scaling equipment for a healthy, male university-aged person who is likely not representative of the diversity of users in the field.

GAME DEVELOPMENT

As outlined above, the learning outcome for the drone challenge is to get students to reflect on the ethical and sustainability implications of their disciplinary design choices. A drone design challenge was chosen for its attractiveness for bachelors students and scope to integrate ethical issues in parallel to technical ones.

Game Play

The scenario presents as a technical challenge of designing a drone for ornithological field study. Contextualized as a course project, players are provided with a basic drone and given 11 weeks, a small monetary budget, and access to various experts to refine their drone's specifications before submitting their final design. Players choose from a set of actions, such as *speak to the director of the reservoir* or *test in the backyard*; each action is associated with a certain investment of time and / or money. As shown in Figure 2, the actions are presented as tiles on the screen and the player make a choice by dragging a tile to the "enter" box. Once the choice is entered, the player receives specific information in the left hand text box followed by decision proposals (subchoices) to modify certain drone parameters.

For example, players have the option to increase the wingspan of the drone as the result of various actions. The director of the reservoir recommends avoiding medium wingspans to reduce the chance that birds perceive the drone as a predator and testing the backyard identifies stability issues for small wingspans. Players accept or refuse these modifications to their drone parameters (any associated cost is deducted from their budget). Any changes result in the drone specifications displayed in the right hand dashboard being updated.

When the player is satisfied with their design, or have exhausted their monetary or time budget, they submit their final drone design. The scenario concludes with feedback from the several research ornithologists who employed the drone in their work observing birds in Scotland. This feedback is calibrated to the final drone specifications of wingspan, weight, color, etc. and is generated by combining pre-defined sentences based on the features of the drone. The comments are designed to highlight potential ethical and sustainability issues arising from each drone design, and prompt players to reflect on both the intentional and inadvertent effects of the decisions they made in during their design process. In all cases, tensions between design choices, such as between the advantageous increase in autonomy of a larger battery and the accompanying disadvantageous exclusion of smaller researchers unable to carry a heavier drone long distances, are highlighted to increase students awareness of the complexity of real life applications.

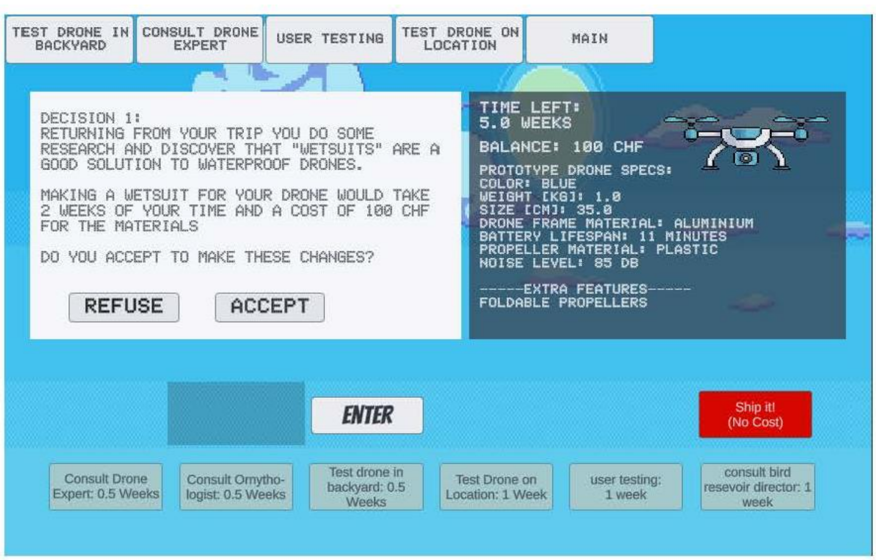

Figure 2. Game play interface

Technical Development of the Activity Interface

Unity is one of the most widely used game engines due to its portability across multiple platforms and support of the game creation process. Additionally, the tabletop educational robot Cellulo, specifically developed to “make tangible what is intangible” (Özgür et al., 2017), provides a package for integration in Unity applications. Keeping in mind our goal of incorporating tangibility in this game at the next stage of development, we thus decided to build our game in Unity. Specifically, the current drone design challenge relies on the Unity game engine and was deployed on WebGL, which allows players to play the game via their browsers, with no local download or installation needed.

The current game prototype presents players with 6 actions that give rise to 13 decision points (1-3 decision points per action) which determine 10 characteristics (i.e. weight, user manual, battery life). One decision can influence several characteristics, for example choosing a larger battery extends flying time but also increases weight. Figure 3 presents a simplified interaction chart with 4 actions and 3 characteristics.

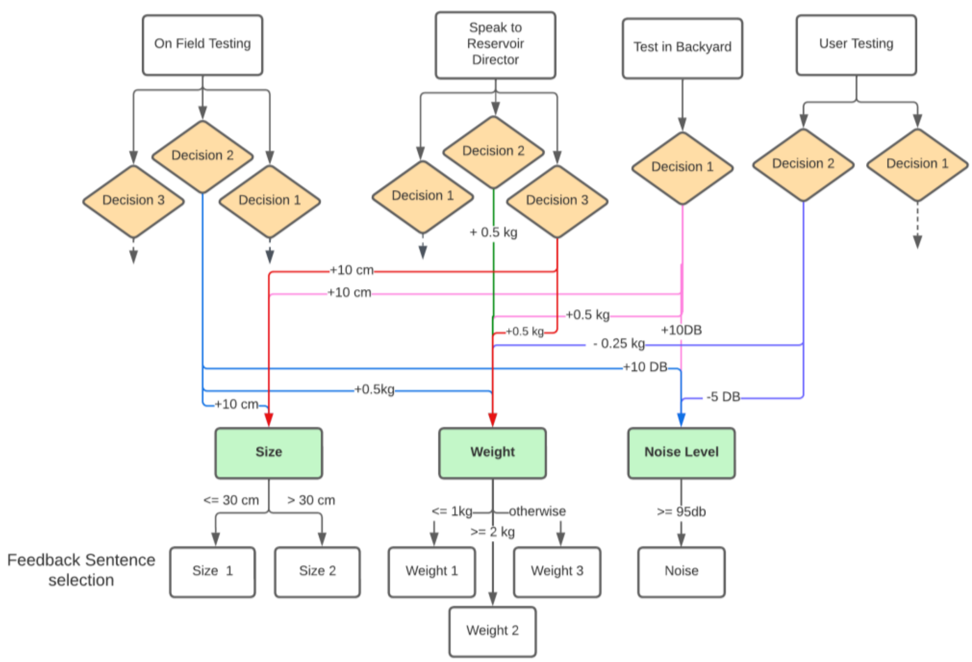

Figure 3. Flow chart showing the relationship between actions, decisions and feedback

Preliminary Testing and User Feedback

In addition to informal feedback on the early iterations of the game, 13 players answered an online questionnaire about their experience in the game. This was a very diverse group of people corresponding to engineering students, educational researchers and mechanical engineers. Players reported spending, on average, 9 minutes playing. As shown in Figure 4, players were engaged by the scenario (item A) and enjoyed the game (item D) despite the topic not being of interest to a significant number of players (item F). That the outcomes of the players choices were not obvious to many players (item G) suggests that the scenario is successful in generating surprise, a useful epistemic emotion for prompting reflection. While we have not assessed this core objective of the activity, it is promising to note that half of players reported that the game will change how they think about design decisions (item I).

Our analysis of the free text responses to the question "What did you learn from playing the game ?" suggests that about half of players experienced surprise or reflected on their design choices but half of players perceived drone knowledge as their major take away. Missing technical drone knowledge was not identified as an issue by anyone in the free text comments, confirming that we were successful in designing a scenario accessible to people without a specific background. While we do want to maintain the engineering context and interplay between ethical and technical considerations, these results suggest that the ethical angle needs to be reinforced.

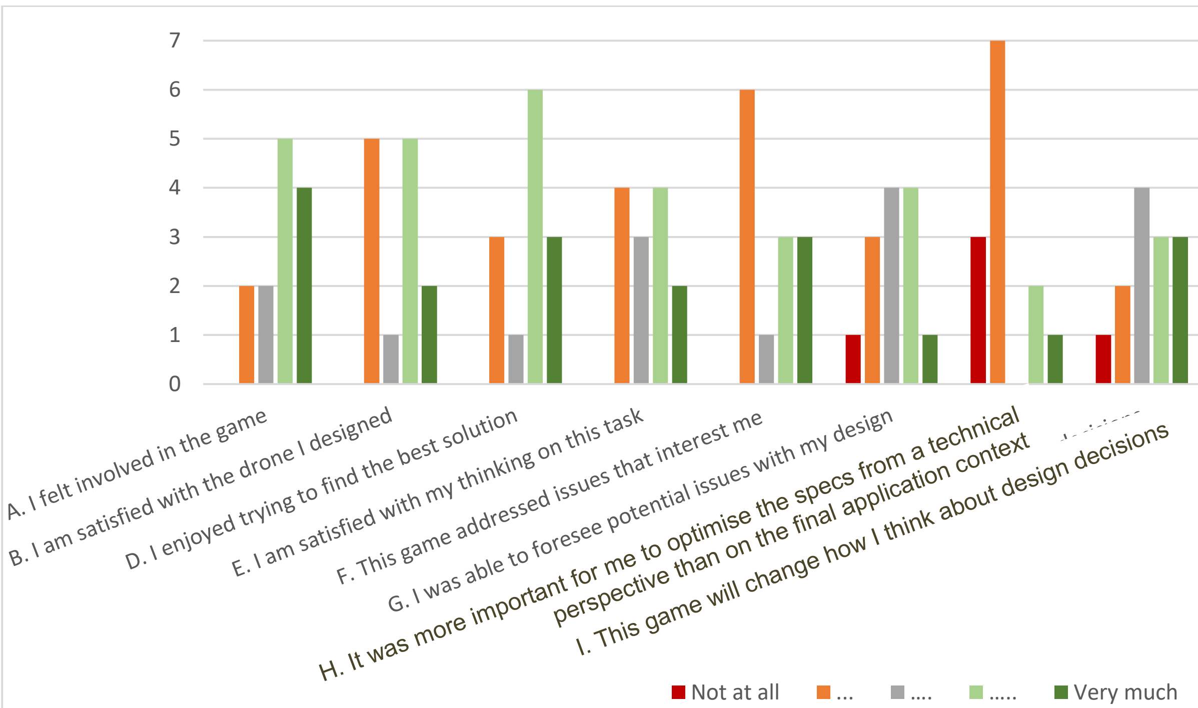

Figure 4. Preliminary feedback from players

Note: Only extremes of the response scale had labels in the expectation that respondents would assign intermediate values to the 3 middle options.

Stimulating Ethical Reflection

While all of the choices presented to players focus on fairly technical aspects, the ethical and sustainability implications of the choices are the central elements in the final feedback. Our goal with creating the scenario in this way was to increase students' ethical sensitivity and motivation, that is their capacity to identify relevant ethical considerations in parallel to their disciplinary or technical reasoning and their commitment to actually doing so. The tensions between favourable and less desirable outcomes for each design choice are highlighted to confront potential epistemically naïve ideas about the existence of a single "correct" design (Isaac, 2021). Thus, the game does not provide a final determination of the success of the drone (i.e. win or lose) but challenges players to experience the ambiguity of having produced a design with both strong and weak points.

The goal here is to prompt some metacognitive and meta-emotional reflection about how students went about their thinking and how they would like to approach design tasks in the future. To continue the example above about wingspan, it appears that a large wingspan is suitable for both birds' perception and drone stability. Figure 3 presents a sample of the interrelations between actions, decision points and the outcomes. However, only field-testing will allow users to potentially identify the implementation issue arising when researchers must carry the drone, camera and other gear on a challenging 3h hike to the remote research site. As shown in Figure 3, when the final drone specifications have a weight ≥ 2 kg then the final feedback from the fictional ornithologists raises the issue of accessibility by stating that only the tall, athletic young man in the team uses the drone because the difficulty of bringing to the field site.

Characteristics of the Activity

We are uncertain what to call this activity; it is not a game in the sense it is not possible to win nor does it contain gamified elements beyond the creation of an immersive scenario. The term game however is useful for getting students to engage and start playing. Maybe our game is actually an interactive narrative. The decision not to set up a winning condition is intentional: we sought to challenge students' epistemic sophistication by requiring them to rely on their own judgement and not to fulfil expectations of dichotomous right or wrong outcomes (Isaac, 2021). Accordingly, the end of game feedback includes both positive and negative aspects for each design. Players are not told if their design was successful but are instead required to judge for themselves. Feedback from our initial testers indicated that this caused some discomfort. We hypothesize that communicating that this is an intentional outcome will improve the impact of this part of the experience. Fun or enjoyment is another fundamental game characteristic. Our testers found the scenario moderately engaging and were positive about both the learning experience and perceived utility the game. Characteristics of games that are useful include the creation of low stakes environment with rapid feedback. While students are certainly aware that there are no consequences for making poor design choices in this scenario, our goal is that the immersive scenario is sufficient to engage students cognitively and emotionally such that they are surprised or challenged by the feedback they receive at the end of the game. While this scenario replicates a semester long course, the feedback about the drone design and the ethical implications of design choices in the game are available to students quickly and with significantly less investment. The creation of this short scenario is intended to provide students with additional opportunities to make design choices and to receive feedback in a short loop. Our goal is that students would then transfer the experience to their next design experiences.

FUTURE WORK

In the context of developing students' transversal skills and particularly their ethical sensitivity and motivation, we are interested in supporting and challenging students to resolve the complex issues around ethics in their disciplinary contexts. In spring 2023, we look forward to conducting empirical studies to assess participants' reaction to the activity and what they may have learned. On the technical side, students working on this project in the coming semester will integrate Cellulo robots to enable us to leverage their haptic functionality to collect data on participants' decision-making processes and afford opportunities to integrate peer discussions in the activity. In this way, we hope to better understand what elements of the scenario are most relevant for triggering relevant meta-cognitive and meta-emotional reflection. Another interest is the development of teaching resources to equip students with strategies to employ during their design process that can assist in mitigating different types of ethics or sustainability issues.

CONCLUSION

This paper reports the development of a drone design challenge that allows students to experience (or perhaps foresee) ethical and sustainability issues arising from design decisions. Teaching about drones was not the core objective of this project but chosen as an attractive context for mechanical engineers to engage with ethics and technological issues. The goal of this game is to surprise the players with unexpected ethical implications of their design decisions by receiving “from the field” feedback on their final drone designs. Although the testing group was small and included non-students, the scenario seems to show some positive results on the game’s impact on how people will think about design decisions. Initial user feedback suggests the balance between technical (drone) and ethical considerations is not optimal to meet our goal for developing students’ ethical sensitivity and motivation around ethical implications of their design choices.

In order to fulfil the goal of training our graduates « not only as first-class scientists, but also as engaged and active members of society and leaders of tomorrow » (EPFL, n.d.), we need to ensure that they consider the environmental, ethical and social implication of their designs. The increasing importance of the ethical and sustainability implications of design decisions is reflected in the CDIO syllabus update; this short design challenge offers an accessible way to increase students’ opportunities to engage with this important aspects. Further, playful approaches are a promising vector for learning due to their capacity to “help us make sense of complex systems by placing us into the system where we can enliven its dynamics and inhabit its complexity as an active participant” (Mendler de Suarez 2012; p. 10). We intend to refine the scenario and then assess the efficacy of the activity in terms of prompting students to reflect on societal and environmental impacts within the context of their disciplinary problem solving.

CDIO standards 5, 7, 8 are relevant to this project. This activity proposes an active, experiential learning experience (standard 8: active learning) that serves as a useful introduction for the skills targeted in design-implement experiences (standard 5: design-implement experiences) by prompting students to reflect on the interplay between disciplinary problem solving and ethical concerns in their design approach (standard 7: integrated learning experiences).

FINANCIAL SUPPORT ACKNOWLEDGEMENTS

Siara Isaac’s work on the 3T PLAY project is funded by a grant from the LEGO Foundation.

REFERENCES

ABET (no date). https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2022-2023/#GC3 Accessed January 25, 2023

Adams, R. S., Turns, J., & Atman, C. J. (2003). Educating effective engineering designers: The role of reflective practice. *Design Studies*, *24*(3), pp. 275–294. https://doi.org/10.1016/S0142-694X(02)00056-X

Bierwolf, R. (2017). Practioners, Reflective Practitioners, Reflective Professionals, *IEEE Engineering Management Review*, 45, pp. 19-24.

Corona Wire, the (no date). https://www.thecoronawire.com/what-are-drones-made-of-detailed-guide-to-drone-anatomy/ Accessed November 25, 2022
Cti (no date). https://www.cti-commission.fr/fonds-documentaire/document/25/chapitre/1217 Accessed January 25, 2023
Donia, J. and Shaw, J. (2021). Ethics and Values in Design: A Structured Review and Theoretical Critique, *Science and Engineering Ethics*, 27(5).
EPFL (no date). PhD Excellence Program https://www.epfl.ch/education/phd/doctoral-studies-structure/customized-curricula/epfl-phd-excellence-programme/ Accessed January 20, 2023.
Fischer, S. and Barabasch, A. (2020), Gamification. A Novel Didactical Approach for 21st Century Learning. Wuttke E, Seifried J, Niegemann H (eds) Vocational Education and Training in the Age of Digitization, 1st ed, Verlag Barbara Budrich, pp. 89–106.
Griffin, T.A., Green, B.P. and Welie, J.V.M. The ethical agency of AI developers. AI Ethics (2023). https://doi.org/10.1007/s43681-022-00256-3
Hardebolle, C. Kovacs, H., Simkova, E., Pinazza, A., Di Vincenzo, M. C., Jermann, P., Tormey, R. and Dehler Zufferey, J. (2022). A Game-Based Approach to Develop Engineering Students' Awareness about Artificial Intelligence Ethical Challenges. SEFI 2022. Barcelona, Spain.
Hwang, G.-J. and Chen, P.-Y. (2022). Interweaving gaming and educational technologies: Clustering and forecasting the trends of game-based learning research by bibliometric and visual analysis, *Entertainment Computing*, 40, p. 100459.
Isaac, S. (2021). *Epistemic Practices: a framework for characterising engineering students' epistemic cognition* [Doctoral dissertation, University of Lancaster]. https://doi.org/10.17635/lancaster/thesis/1400
Isaac, S. Kothiyal, A., Borsò, P. and Ford, B. (2023). Sustainability and Ethicality are Peripheral to Students' Software Design. *International Journal of Engineering Education*, 39(3).
Isaac, S., Petringa, N., Jalali, Y., Tormey, R. and Dehler-Zufferey, J. (forthcoming). *Are engineering teachers ready to leverage the power of play to teach transversal skills?*
Karakoç, B., Eryılmaz, K., Turan Özpolat, E. and Yıldırım, İ. (2022). The Effect of Game-Based Learning on Student Achievement: A Meta-Analysis Study, *Tech Know Learn,* 27(1), pp. 207–222.
Lönngren, J. (2021). Exploring the discursive construction of ethics in an introductory engineering course, Journal of Engineering Education, 110(1), pp. 44–69.
Manzano-León, A., Camacho-Lazarraga, P., Guerrero, M. A., Guerrero-Puerta, L., Aguilar-Parra, J. M., Trigueros, R. and Alias, A. (2021). Between Level Up and Game Over: A Systematic Literature Review of Gamification in Education, *Sustainability* 13(4), p. 2247.
Mendler de Suarez, J., Suarez, P., Bachofen, C., Fortugno, N., Goentzel, J., Gonçalves, P., Grist, N., Macklin, C., Pfeifer, K., Schweizer, S., Van Aalst, M., and Virji, H. (2012). Games for a New Climate: Experiencing the Complexity of Future Risks. *Pardee Center Task Force Report.* Boston: The Frederick S. Pardee Center for the Study of the Longer-Range Future, Boston University. http://tinyurl.com/BUPardee-G4NC
Özgür, A., Lemaignan, S., Johal, W., Beltran, M., Briod, M., Pereyre, L., ... & Dillenbourg, P. (2017, March). Cellulo: Versatile handheld robots for education. In *Proceedings of the 2017 ACM/IEEE International Conference on Human-Robot Interaction* (pp. 119-127)
Picard, C., Hardebolle, C., Tormey, R., & Schiffmann, J. (2022). Which professional skills do students learn in engineering team-based projects? *European Journal of Engineering Education*, *47*(2), 314-332.
Schrier, K. (2015), EPIC: a framework for using video games in ethics education, *Journal of Moral Education,* 44(4) pp. 393–424

Steele, A. L. (2018). Developing Student Meta-Cognition in a Design Course. Proceedings of the Canadian Engineering Education Association (CEEA). https://doi.org/10.24908/pceea.v0i0.13031

Szekely, I. (2011). What do IT professionals think about surveillance? in C. Fuchs, K. Boersma, A. Albrechtslund, and M. Sandoval (eds), *Internet and surveillance: The challenges of Web 2.0 and social media*, vol. 16, Routledge, New York, NY, pp. 198–219.

Tanner, C., Schmocker, D., Katsarov, J. and Christen, M. (2022), Educating moral sensitivity in business: An experimental study to evaluate the effectiveness of a serious moral game, *Computers & Education,* 178, p. 104381.

Wang, K., Tekler, Z. D., Cheah, L., Herremans, D., & Blessing, L. (2021). Evaluating the effectiveness of an augmented reality game promoting environmental action. *Sustainability*, *13*(24), 13912.

Washington Post. (2021). https://www.washingtonpost.com/science/2021/06/07/drone-crash-abandoned-eggs/ Accessed November 25, 2022

Watts, L. L., Medeiros, K. E., Mulhearn, T. J., Steele, L. M., Connelly, S. and Mumford, M. D. (2017), Are Ethics Training Programs Improving? A Meta-Analytic Review of Past and Present Ethics Instruction in the Sciences, *Ethics & Behavior, 27*(5), pp. 351–384.

Worldwide CDIO Initiative. (2022), The CDIO Syllabus, V3.0 http://www.cdio.org/content/cdio-syllabus-30. Accessed April 7, 2023.

BIOGRAPHICAL INFORMATION

Siara Isaac is the project manager and a researcher in the 3T PLAY project at the École polytechnique fédérale de Lausanne (EPFL). Her work focuses on how students develop transversal skills in science and engineering contexts, including her 2022 book with Roland Tormey entitled Facilitating Experiential Learning in Higher Education - Teaching and Supervising in Labs, Fieldwork, Studios, and Projects (Routledge). Siara holds an M.Sc. degree in chemistry and Ph.D. degree in educational research. She has a particular interest in the development of students' epistemic proficiency around managing ambiguity and exercising judgement.

Gianni Lodetti is pursuing M.Sc. in computer science at Ecole polytechnique fédérale de Lausanne (EPFL).

Jessica Dehler Zufferey earned her Ph.D. at University of Tübingen in the field of computer-supported collaborative learning (CSCL) with a focus on knowledge awareness. She held postdoctoral positions at University of Fribourg in university didactics, working on gender-neutral teaching, and at EPFL in the "Computer-Human-Interaction in Learning and Instruction" lab, working on technology-enhanced vocational training. After 4 years in a R&D role in the educational technology industry, she is now executive director of the EPFL Center for Learning Sciences.

Barbara Bruno is a post-doc researcher at the École polytechnique fédérale de Lausanne (EPFL) and deputy head of the CHILI lab, with research interest in Socially Assistive Robotics, Educational Robotics and Human-Robot Interaction. Barbara holds an M.Sc. degree and Ph.D. degree in Robotics. She is currently serving as Associate Editor for the IEEE "Robotics & Automation Letters" journal and the Springer journal on "Intelligent Service Robotics" and has contributed as organiser, invited speaker or panellist to a number of workshops and conferences on assistive robotics, personalised robotics and child-robot interaction.

Corresponding author

Siara Isaac
3T PLAY, Centre for Learning Science
École polytechnique fédérale de Lausanne
1015 Lausanne, SWITZERLAND
siara.isaac@epfl.ch