

SERIOUS GAME FOR CDIO DISCOVERING

Jean-Yves Dantan,

Arts et Métiers Institute of Technology, Université de Lorraine, LCFC, 57070 Metz, France

Saïda Mraïhi, Nina Lepannetier

Arts et Métiers Institute of Technology, F-75013 Paris, France

ABSTRACT

The CDIO (Conceive, Design, Implement, Operate) framework is an innovative approach to engineering education. It includes several aspects: the goal of the training program, the syllabus, the content of the training program (Design-Implement Experiences, ...), the continuous improvement in engineering education program, the training practices and the quality management of the training program. Learning about the CDIO framework involves gaining a deep understanding of its principles, standards, and the methodology it promotes for engineering education. The CDIO Initiative's website provides access to valuable information, including the CDIO Syllabus, standards, case studies, and reports. Some universities and institutions offer courses or programs related to CDIO. Enrolling in such courses can provide structured learning and hands-on experience. However, motivating colleagues for CDIO discovery can be challenging. Therefore, we developed a serious game in order to introduce key CDIO concepts. The game structure is based on three questions for each standard: Why? (the intent of the standard) Who? (the main actors of the standard) and How? (the facilities and implemented practices of the standard). During the session, participants share knowledge and experiences about CDIO implementation. The game board is based on a taxonomy of CDIO standards which includes 6 groups of standards: (i) goal of the training program, (ii) contents of the training program, (iii) leaning practices, (iv) learning spaces, (v) teacher training, (vi) training program assessment. To analyze the benefits of the game we developed, we conducted a survey to collect the feedback of workshop participants about their experience and their level of assimilation of the CDIO standards at the end of the session. The data collected highlights the relevance of the game as an activity introducing the CDIO. A large proportion of those questioned stated that they had made progress at the end of the game.

KEYWORDS

CDIO, Serious game, CDIO familiarization, Educational development, Standards: 1-12.

INTRODUCTION

The CDIO engineering education framework accentuates the cultivation of professional competencies through project-based and experiential learning. The challenges of the industry of the future require pragmatic engineers, combining technological knowledge, innovation, etc. Generally speaking, the main reasons for implementing the CDIO framework included ambitions to make engineering education more authentic, the need for a systematic methodology for educational design, and desires for increased design and innovation in curricula (Malmqvist et al. 2015).

Since Arts et Metiers foundation, AM engineers are known for their spirit of innovation, their excellent technical skills and their ability to manage and cooperate. These well-recognized skills are enhanced by the AM training program which includes theoretical courses and technical projects. Furthermore, Arts et métiers is committed to a competency-based approach as a lever to (i) articulate its program training with social and economic expectations, (ii) match training content to expected competencies and (iii) rethink teaching and learning assessment methods. By joining the CDIO network in 2020, Arts et Metiers would like to benefit from the richness of the network of CDIO members, in order to share best practices and experiences and participate actively in the reflections of the CDIO network related to the evolution of learning practices.

Successful CDIO implementation requires both top-down and bottom-up approaches. The management team can adopt the CDIO framework using top-down methodology that considers institutional vision compatibility with education development goals. The challenges of implementing CDIO involve a shift in mindset, gaining support from faculty members, managing disagreements, and dealing with the additional workload of national qualification standards and accreditation. To address these challenges, the bottom-up approach is recommended (Oien et al 2023). Involving faculty members, program committees, and department heads in the change process boosts intrinsic motivation, fosters a strong commitment, nurtures ownership, and enhances the value of CDIO.

By combining both bottom-up and top-down approaches, Arts et Metiers is relying on stakeholder involvement and the development of a common strategy for CDIO implementation. In fact, Arts et Metiers is an institution spread over several campuses and institutes, which ensures a territorial presence in line with local industrial expertise and powerful relationships with socio-economic actors. However, this value is also a challenge for the establishment when it comes to sharing a common strategy for implementing the CDIO across all its sites. The design of a serious game based on a common vision of the CDIO and its implementation processes allows the actors of the different sites to appropriate the key CDIO principles and their declination into a set of actions to be deployed.

In this context, we have developed a serious game for faculty members to take ownership of CDIO. The game design involved several actors, including a teacher with in-depth knowledge of CDIO, an instructional designer, and the Vice-President for Academic and Student Affairs. We tested the game with a group of teachers in July 2023 and rolled it out from September 2023.

The “game outcomes” are:

- 1) To distinguish the objectives associated to each of the 12 CDIO standards
- 2) To identify the actors involved in each CDIO standard
- 3) To outline the actions to be made in order to implement each CDIO standard

This paper is organized as follows: Section 2 introduces the adopted serious game design methodology. Section 3 details the CDIO standard taxonomy for designing the game board. The description and the rules of the serious games are summarized in Section 4. The final section includes the player feedbacks and a discussion.

SERIOUS GAME DESIGN METHODOLOGY

Developing serious games about CDIO (Conceive, Design, Implement, Operate) requires a thoughtful approach to integrate content with engaging gameplay. We use the generic **DICE model** (Djaouti, 2011) to design our serious game (Figure 1). The Define step begins with the definition of the learning outcomes: expected skills of the players – The players are faculty members; the goal is to learn about the CDIO standards: 1) the **purpose** of each CDIO standard, 2) the **roles** of each actors in the CDIO implementation, and 3) the **Arts et Metiers practices** which are aligned with CDIO principles.

Following this definition step, start an iterative cycle with 3 different steps:

- The **Imagine step** request to mobilize the CDIO Principles: to ensure a solid understanding of the CDIO framework, we performed an extensive bibliographic analysis of CDIO principles and standards, we developed a **taxonomy of CDIO standards** based on the Arts et Metiers organization.
- The **Create step** focus on the design of the game with the players in mind and made the gameplay challenging but enjoyable. **Interactivity** is crucial for engagement and effective learning in serious games. To increase interactivity and collaboration, we selected a team-based gameplay. We defined a well-structured progression system: The game structure is based on three questions for each standard: **Why?** (the intent of the standard), **Who?** (the main actors of the standard) and **How?** (the facilities and implemented practices of the standard).
- The **Evaluate step** consist in providing a feedback session. Actually, at the end of the game, participants are invited to discuss the key points that they have retained and misunderstood elements to be clarified. They are also requested to complete a survey to gather feedback on their **experience of the game**.

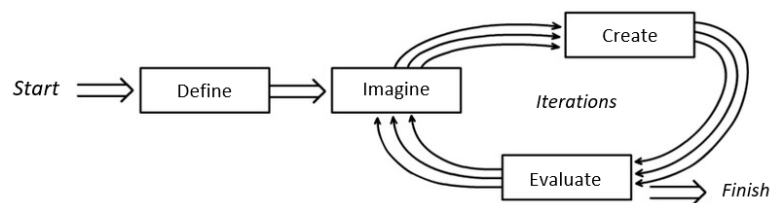


Figure 1. The generic DICE model of the Serious Game Design process (2011, Djaouti, p.105)

GAME BOARD BASED ON CDIO TAXONOMY

It is recommended to provide a visual representation of the standards to facilitate the exploration: A CDIO standard taxonomy. The most known CDIO taxonomy (Figure 2A) is that developed by Brodeur and Crawley (2005); they listed the correspondence between the 12 CDIO Standards and key quality assurance questions:

- **Standard 1 CDIO as Context and Standard 2 CDIO Syllabus Outcomes:** What are objectives and outcomes of a CDIO program? How are they aligned with institutional mission and program goals? What is the context for these objectives and outcomes?
- **Standard 3 Integrated Curriculum:** How does a CDIO curriculum contribute to the attainment of program outcomes? How are CDIO outcomes embodied in the CDIO Syllabus integrated into the curriculum?
- **Standard 4 Introduction to Engineering:** How do first-year courses introduce the CDIO context and motivate students to choose engineering programs?
- **Standard 5 Design-Implement Experiences, Standard 7 Integrated Learning Experiences and Standard 8 Active Learning:** How do active and experiential methods contribute to the attainment of program outcomes in a CDIO context? How are these learning experiences integrate into the engineering program?
- **Standard 6 CDIO Workspaces:** How does the learning environment contribute to the attainment of CDIO program objectives and outcomes
- **Standard 11 CDIO Skills Assessment:** What have students achieved with respect to program outcomes? How are CDIO learning outcomes measured and documented
- **Standard 9 Enhancement of Faculty CDIO Skills and Standard 10 Enhancement of Faculty Teaching Skills:** How are faculty development and motivation encouraged? How do faculty roles change in a CDIO context? How satisfied are faculty with the teaching and learning experiences?
- **Standard 12 CDIO Program Evaluation:** Is there a systematic process in place to evaluate CDIO program outcomes and processes? Are the evaluation results used in continuous process improvement?

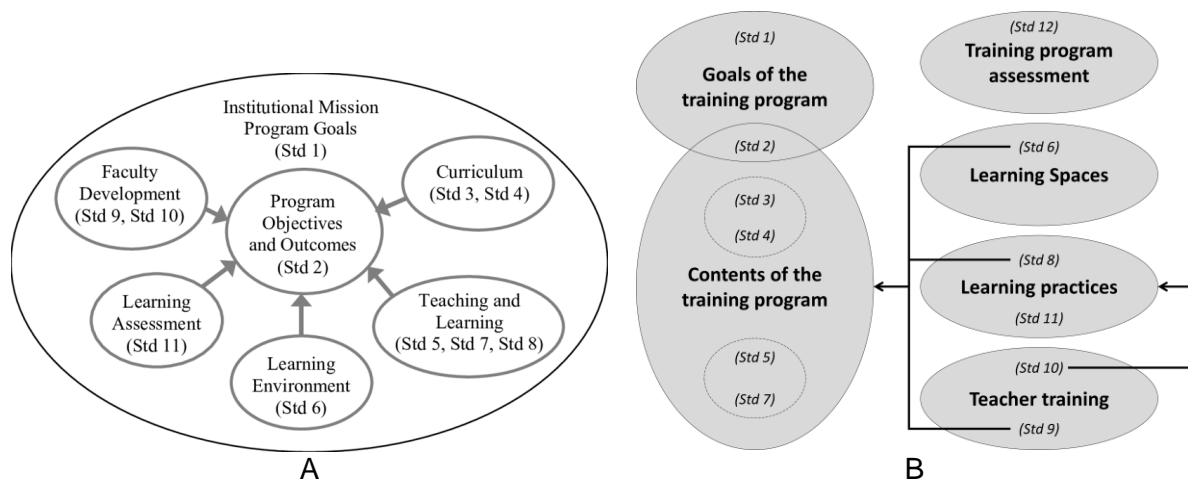


Figure 2. CDIO Standard taxonomy

Based on the CDIO understanding and the Arts et Metiers practices, we propose a taxonomy of CDIO standards which includes 6 groups of standards: (i) goal of the training program, (ii) contents of the training program, (iii) leaning practices, (iv) learning spaces, (v) teacher training, (vi) training program assessment.

The main point of the serious game is to discover and to analyze the scopes, the vision and the aims of all CDIO standards based on (Crawley et al, 2014), (Malmqvist et al, 2020) and (Malmqvist et al, 2022). In order to achieve this, the game board contains a taxonomy of CDIO

standards and one question for each standard that summarizes its goal (Figure 2B). The correspondence between the 12 CDIO Standards and 12 questions is listed below:

- **Standard 1: Why?** In fact, this standard includes the program goals which are the answer to the question: why this training program?
- **Standard 2: What? and Where?** The standard 2 focuses on the syllabus: specific, detailed learning outcomes for personal and interpersonal skills, and product, process, system, and service building skills, as well as disciplinary knowledge. What is the learning outcomes of the training program? Where, in which course?
- **Standard 3: When?** The curriculum includes the sequencing courses and projects, that is designed with mutually supporting disciplinary courses and an explicit plan to integrate personal and interpersonal skills, as well as skills in product, process, system, and service building. When each course is planned?
- **Standards 4, 5 and 7: How?** These standards focus on key contents of the training program: (i) an introductory course that provides the framework for engineering practice, (ii) two or more design-implement experiences, and (iii) integrated learning experiences. How to achieve the learning outcomes and the goals of the training program?

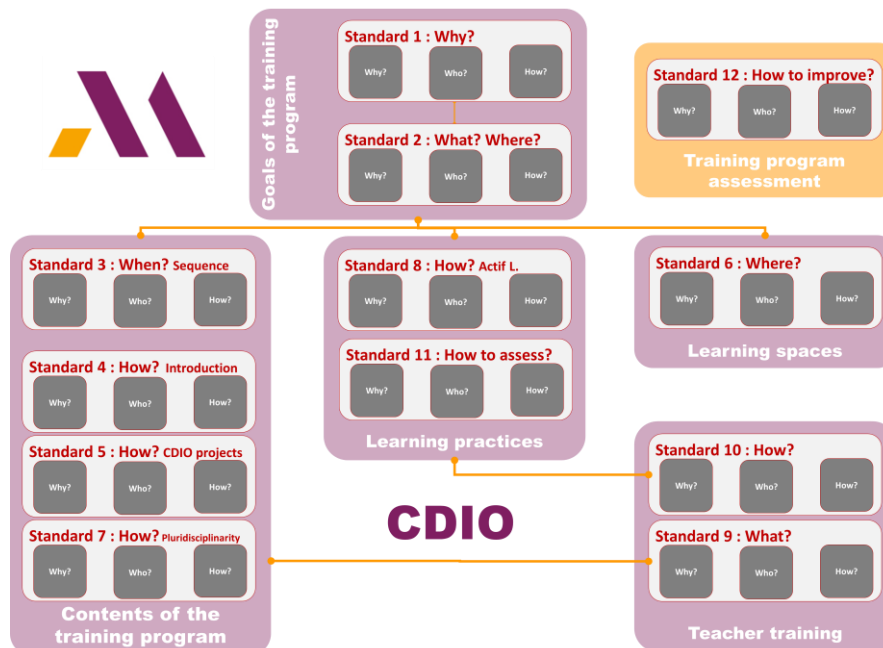


Figure 3. CDIO game board

- **Standard 6: Where?** The standard 6 is dedicated on the engineering learning workspaces - A physical learning environment that includes engineering workspaces and laboratories. Where each course is performed?
- **Standard 8: How?** The standard 8 focuses on the learning practices: active learning - Teaching and learning based on active and experiential learning methods. How to engage students directly in thinking and problem-solving activities?
- **Standard 11: How to assess?** How to measure the extent to which each student achieves the intended specified learning outcomes? In fact, the standard 11 deals with learning assessment.
- **Standards 9 and 10: How and What?** These standards focus on teacher learning: (i) actions that enhance faculty scientific and technical competence, and (ii) actions that

enhance faculty competence in providing integrated learning experiences, in using active and experiential learning methods, and in assessing student learning.

- **Standard 12: How to improve?** How to measure the judgment of the overall value of a program based on evidence of a program's progress toward attaining its goals.

DESCRIPTION AND GAME RULES

The serious game includes a game board (Figure 3), 36 game cards divided into 3 questions categories: Why? the intent of the standard, Who? the main actors of the standard and How? the facilities and implemented practices of the standard. To clarify the aim of each standard, players are asked to place each of the three questions cards in the appropriate standard box.

The participants are invited to place on the board: first the “why?” cards which help them to understand the purpose of each standard, then the “who?” cards to identify the actors involved in the standard and finally the “how?” cards to find out what actions they need to implement.

The game is played by a team and typically lasts between one and a half to two hours. The first team pick a card, addresses the team to its right and reads the statement on the card. If the challenged team identify the standard corresponding to the card, it wins a point and the card is placed on the correct box; on the contrary if the team does not answer correctly, the card is placed back under the stack of cards and it is the next team's turn to play. When all cards have been placed on the board, the team with the highest score wins the game.

PLAYER FEEDBACKS AND DISCUSSIONS

Our analysis of the serious game that we have developed aims to establish if the playful format and game mechanisms contribute to the appropriation of the CDIO framework by the participants. To achieve this goal, we are using the results of a survey based on the first and second levels of the Kirkpatrick model (1994): the first level focuses on experience and satisfaction and the second level on learning. In addition to closed questions, the surveys include open questions to collect feedback about strengths and improvements to be made in the future.

The results we present are based on 31 responses to survey administered following five workshops (game sessions). We organized two workshops in Paris with actors from our different sites, the third in Cluny, the fourth in Bordeaux and the fifth at Aix-en-Provence (Figure 4 Left). 83% of respondents indicated they had a good gaming experience in the CDIO Game (Figure 4 Right). Based on the feedback from the workshops (Figure 5), we note that 81% of the respondents think that this game is a good way to understand what the CDIO is. 90% enjoyed using a game to discover the CDIO and they all agree (100%) that "the exchanges with other participants were rich and useful". 94% of respondents said that the effort and time spent were balanced, and 87% of respondents said that they played the game in good conditions (organisation, order). On the statement "The game provided me valuable examples of action that I can apply", opinions are more divided: 49% of respondents agreed and 51% disagreed. However, 45% related the game doesn't provide them enough examples.

Afterwards, we focus on the second level of the of the Kirkpatrick model, which is a measure of respondents' learning progress at the end of the game (Figure 6). Respondents self-assess their level before and after the game on a scale from 0 (not at all able) to 10 (fully capable).

The data collected illustrates progress in three learning objectives (LOs): 1) distinguish the objectives associated to each of the 12 CDIO standards, 2) identify the actors involved in each CDIO standard and 3) outline the actions to be made in order to implement each CDIO standard.

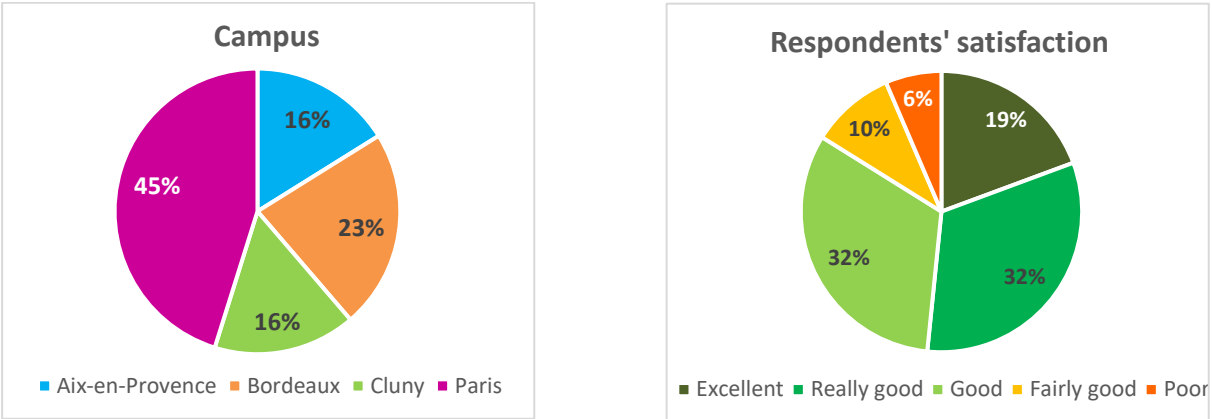


Figure 4. Left: Geographical breakdown of respondents by campus. Right: Respondents' satisfaction

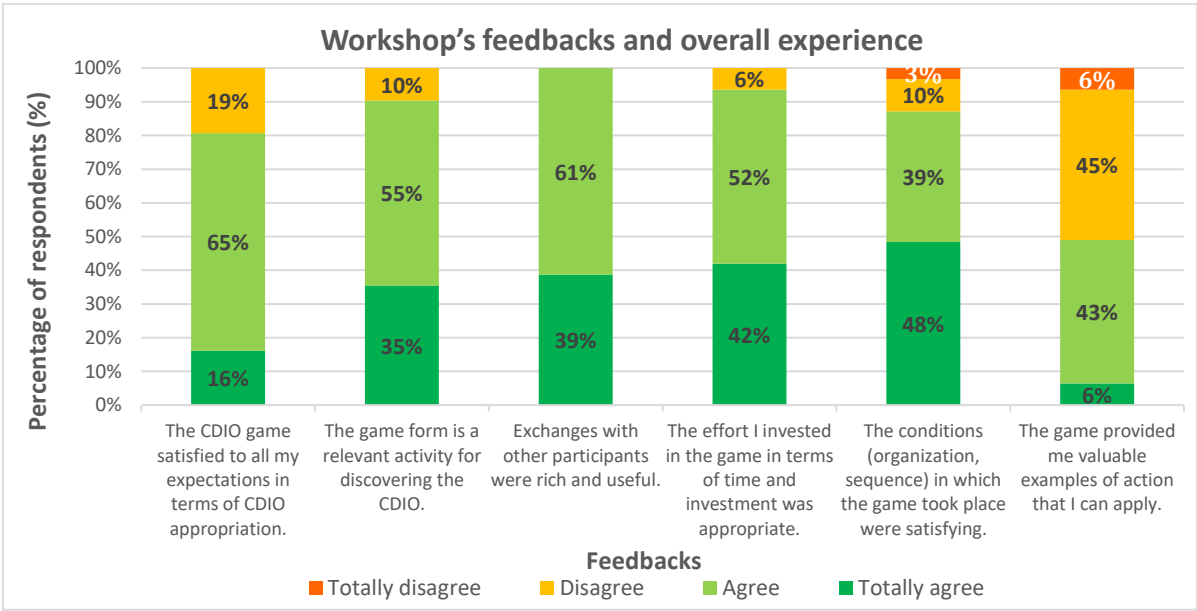


Figure 5. Workshop's feedbacks and overall experience

The total number of respondents for this survey decreased from 31 to 29 as two respondents did not answer this section. Out of the 29 respondents, two did not indicate their progress on one of the assessed items. 86% of the respondents reported making more than 51% progress on the first learning outcome objective, while only 14% felt they had made little progress (below 50%). As for the second learning outcome, 61% of the respondents reported strong progress (over 75%), while 32% felt they had not made as much progress (under 50%). It is worth noting that this objective is the one on which respondents reported the least progress. Finally, 75% of the respondents answered that the CDIO game was a means to initiate discussions about the CDIO implementation and the Arts et Metier practices.

The verbatims collected from open-ended questions allow us to identify several strengths in the game. Respondents appreciate the “playful” side of the workshop; this term was mentioned several times which they thought made the workshop “friendly” and “interactive”. In fact interactivity is a point we develop during the creation phase according to the DICE model (2011, Djaouti). They also emphasize the interest of playing as a team and the duration of the workshop adapted to their busy schedule as the following comments underline:

- “Exchange with the various players in the game”
- “Playing as a team”
- “We can do it quickly, which is important given our busy schedules”

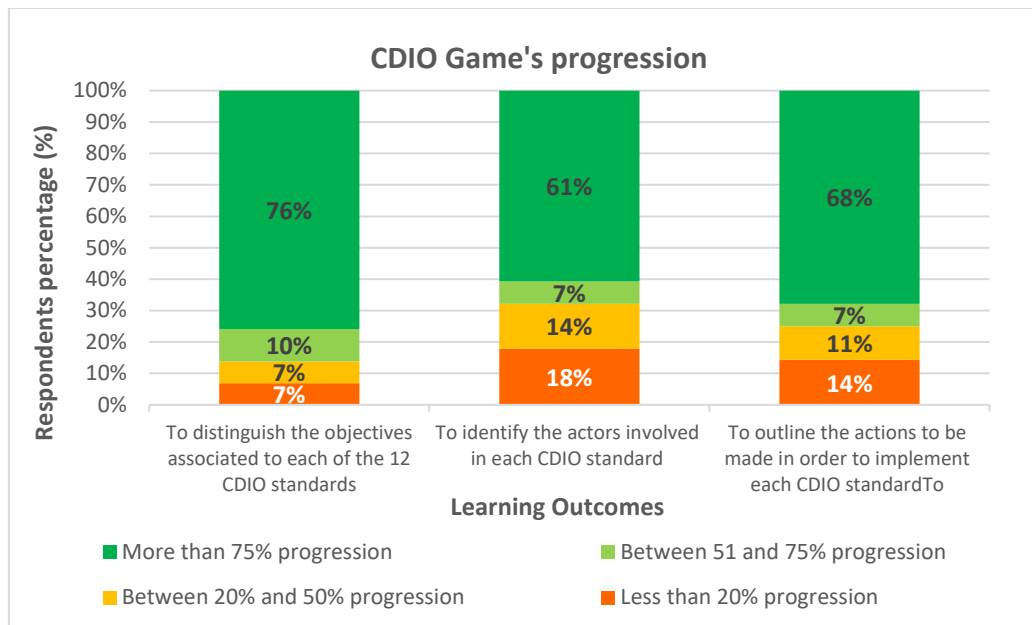


Figure 6. CDIO Game’s progression

Participants even highlight the fact that the game is adapted to participants with different levels of knowledge of the CDIO which promotes exchanges as expressed by one of the respondents “Fun and easy initiation for all levels”. Another highlight of the workshop is its adaptation to the context of the institution Arts et Metiers, which provides concrete elements that help to understand the standards and their mode of deployment.

- “It’s a practical way to get started, and it’s adapted to Arts et Métiers context”.
- “It helps us to understand the purpose of certain issues (teaching assessments, semester committees, best practices for introducing a course, etc.) for which some colleagues are questioning the relevance”.

Regarding improvement points, participants' responses had a limited reference to the form of the workshop as a game and focused mainly on fundamental questions relating to the understanding of CDIO and its deployment. As mentioned on the following comments, the game enables the participants to discover the standards, but it requires further concrete actions to deploy each standard. “Emphasize post-game exchanges to discuss the “who” and “how” that may not be clear to everyone.”, “Not easy to know how to use on a daily basis in my field”. In particular, participants underlined the efforts required to identify and converge to the same actors involved in each standard.

Concerning the game, the respondents emphasize that the questions on certain cards are hard to apprehend and to link to a specific standard “cards and board labels are sometimes very complex to understand”, “the "why" questions are difficult to answer, as the instructions on the board are not detailed enough». They suggested rewording the questions on certain cards and providing more concrete examples.

To improve our game in the light of our serious game methodology proposed by Djaouti and our survey results, we notice we need to be more specific about the learning outcomes of the game, in order to answer to all expectations in terms of understanding the CDIO (Define step). We remind that the aim of the game presented here is to help participants to discover the CDIO and how it works which is necessary before considering a level 2 of the CDIO game more focused on actions to be deployed.

The feedback from participants confirms that a boardgame with cards is a relevant way to discover the CDIO standards. It's requires a few equipment and time to play given the complexity of the subject. Nevertheless, some participants may find the game more challenging than others, the first step with Why? cards, is the longest of the game: it is the time to understand the rules of the game and the content of the cards. However, there's a change when they start to place the other cards (Who? et How?) because they can use the previous cards to help them. The game mechanics defined during the create step mean that the game encourages exchanges between participants according to the survey.

CONCLUSION

The analysis of the data we collected underlines the value of introducing a workshop in playful form as a support in deploying the CDIO in a multi-site establishment. Setting up the same workshop on all campuses means sharing the same framework and common vision for CDIO deployment. The playful aspect of the workshop, takes place for a short time, encourages the participation of all actors, in a convivial format that promotes exchanges between participants.

In terms of CDIO appropriation, the feedback we have collected from participants concludes that the serious game we have designed can be considered as a first step in discovering CDIO principles. In order to continue supporting the community in the deployment of the CDIO, we plan to design a level 2 that will enable them. The aim of level 2 is for players to propose several improvements for each standard deployment.

In terms of the actions taken to measure the impact of the game on participants' knowledge, we based our assessment on respondents' self-reporting of the workshop's learning objectives. To measure the impact of the game more effectively, we plan to set up a knowledge test before and after the game to assess participants' progress.

REFERENCES

- Crawley, E. F., & Brodeur, D. (2005, June), *Program Evaluation Aligned With The Cdio Standards Paper* presented at 2005 Annual Conference, Portland, Oregon. 10.18260/1-2—15474
- Crawley, E. F., Malmqvist, J., Östlund, S., Brodeur, D. R., & Edström, K. (2014). The CDIO Approach. In E. F. Crawley, J. Malmqvist, S. Östlund, D. R. Brodeur, & K. Edström (Éds.), *Rethinking Engineering Education : The CDIO Approach* (p. 11-45). Springer International Publishing.

- Djaouti, D. (2020). DICE: A Generic Model for the Design Process of Serious Games. *International Journal of Game-Based Learning (IJGBL)*, 10(2), 39-53. <http://doi.org/10.4018/IJGBL.2020040103>
- Kirkpatrick, D. L. (1994). *Evaluating training programs : The four levels*. San Francisco, Calif. : Berrett-Koehler Publishers.
- Malmqvist, J., Gunnarsson, S., & Vigild, M. (2008). Faculty Professional Competence Development Programs—Comparing Approaches from Three Universities. *Proceedings of the 4th International CDIO Conference, Gent, Belgium*.
- Malmqvist, J., Hugo, R., & Kjellberg, M. (2015). A Survey of CDIO Implementation Globally—Effects on Educational Quality. *Proceedings of 11th International CDIO Conference, Chengdu, China*.
- Malmqvist, J., Lundqvist, U., Rosén, A., Edström, K., Gupta, R., Leong, H., Cheah, S. M., Bennedsen, J., Hugo, R., Kamp, A., Leifler, O., Gunnarsson, S., Roslöf, J., & Spooner, D. (2022). The CDIO Syllabus 3.0 - An Updated Statement of Goals : 18th International CDIO Conference, CDIO 2022., Reykjavik, Iceland
- Malmqvist, J., Edström, K., & Rosen, A. (2020). CDIO Standards 3.0—Updates to the Core CDIO Standards. *Proceedings of the 16th International CDIO Conference, 1*, 60-76. Gothenburg, Sweden
- Oien, G., Bennedsen, J., (2023). Developing a didactic foundation for Tech Faculty at Aarhus University, *Proceedings of the 19th International CDIO Conference*, Trondheim, Norway

BIOGRAPHICAL INFORMATION

Jean-Yves Dantan is Professor of Mechanical and Industrial Engineering at Arts et Metiers Institute of Technology (France), presently chairing the French German Doctoral College between Arts et Metiers and Karlsruher Institut für Technologie. He obtained his PhD in 2000 at Bordeaux University and his habilitation thesis in 2009 at Ecole Normale Supérieure de Paris Saclay. During the past 25 years, he developed multiple research activities in the field of design under uncertainties and he was the coordinator of “Masters of Science” for the Department of Industrial engineering of Arts et Métiers (8 tracks, 12 Joint programs, 200 students/year). He is CIRP Fellow.

Saïda Mraïhi is lead Instructional Designer. She has 20 years of background in the field of pedagogy and project management. She obtained his PhD in education science in 2023 at Rennes 2 University. She has an experience in advising and supporting teachers in the design of training courses, based on engaging and focused student learning, for both face-to-face, hybrid or distance learning. She also teaches in educational sciences and digital culture.

Nina Lepannetier is instructional designer at Arts et Metiers Institute of Technology (France) since 2020. She holds a master's degree in digital humanities (Paul Valéry University – Montpellier, 2019).

Corresponding author

Jean-Yves Dantan
Arts et Metiers Institute of Technology
France
4, rue A. Fresnel
57070 METZ, FRANCE
jean-yves.dantan@ensam.eu



This work is licensed under a [Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License](https://creativecommons.org/licenses/by-nc-nd/4.0/).