# EMBEDDING CDIO FRAMEWORK IN EDUCATIONAL STATISTICS COURSES WITH SERIOUS GAMES

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## ABSTRACT

The field of engineering education emphasizes the need for students to have statistical literacy in the process of conducting research, not only in terms of statistical knowledge, but also in terms of the ability to interpret, critique, evaluate, and communicate statistical information. Educational statistics is central to graduate students in engineering education, but many students experience difficulties in learning statistical knowledge and operating software. Traditional lecture-based curriculum of teaching statistics has its limitations. In order to help students to engage more actively in statistical learning, recent research has turned to the use of embedding CDIO (conceive, design, implement and operate) with serious games to creating an innovative classroom style, such as the use of real-life cases and the use of problem-based learning. Integrating the elements of serious games, the study uses the CDIO framework to design educational statistics curriculum modules. The Conceive component refers to using questionnaires, and brainstorming to analyze students' demands, consider relevant technologies strategies, and develop a conceptual plan. The Design component refers to using serious game elements for more detailed course modules. The Implement component refers to using serious game elements revision to advance teaching modules. Final, the Operate component refers to improving the designed curriculum modules. The research used the mixed method to collect and analyze the materials, including survey questionnaires, midterm and final exams, interviews, the teaching diary, classroom observations and videos, and feedback sheets. The study aims to find out whether the use of embedding CDIO framework with the serious game module can enhance students' positive attitudes and learning performance in the educational statistics course. It is hoped that the research findings will provide an in-depth understanding of the learning process of students in the educational statistics course, and then provide specific suggestions for the relevant teachers and future researchers.

## KEYWORDS

CDIO framework, serious games, educational statistics course modules, Standards: 3, 7, 8

## CHALLENGES OF ENGINEERING EDUCATION STATISTICS COURSES AT THE HIGHER EDUCATION LEVEL

An increasing variety of fields are emphasizing the need for students to have the knowledge of statistics in the process of conducting social science research. In addition to the statistical knowledge acquired in the classroom, the ability to interpret, critique, evaluate, and communicate statistical information is essential for students in the field of engineering education. Thus, educational statistics is pivotal to graduate students. However, many students experience difficulties when learning statistical knowledge and software skills, often causing anxiety and lack of self-efficacy in the students due to the perceived complexity of statistics (Tishkovskaya & Lancaster, 2010). Since teachers have a decisive influence in the teaching process, it is a great challenge for them to help students overcome these difficulties (Boyle et al., 2014). Although the traditional narrative method of teaching statistics can impart the relevant knowledge in a progressive manner from basic to advanced levels, it has posed some limitations in recent years. For example, this method is not capable of inspiring students' enthusiasm toward learning, and the students may find application of statistical knowledge a challenge. Therefore, recent research has shifted its focus to serious games that encourage students actively learn statistics. Moreover, there is extensive literature on the comprehensive study of factors such as serious games, online formative assessment, statistics teaching, and statistics learning effectiveness (Boyle et al., 2014; Hsu et al., 2009; Smith, 2017). We hope to create an innovative classroom style with educational significance that is different from the traditional lecture-based courses. Tishkovskaya and Lancaster (2010) pointed out that the study of statistics is a key component of a curriculum and proposed the following possible critical strategies to help students learn statistics more efficiently: shifting the focus of the statistics course to real-world examples, using problem-oriented learning and real-world examples for operation, clarifying myths through supportive critical thinking, and using online resources, among others. In fact, these proposed principles and strategies appear to be aligned with the increasingly popular Conceive- Design- Implement- Operate (CDIO) concept and the connotations and elements of serious games.

CDIO emphasizes the use of an “integrated curriculum” designed to enable students to acquire strong fundamental theories and practical skills and to acquire the required competencies through active, problem-solving-oriented learning methods, as well as teamwork and innovative practice training. Serious games and game-based learning have also been suggested in recent years to help students learn, not because of the fun or novelty they bring (e.g., point collection, leaderboards, and level promotion), but because they can provide students with a wide range of educational learning activities and experiences. This view is consistent with the concept of effective learning, which emphasizes on the educational nature of positive, appropriate, and problem-oriented learning activities (Boyle et al., 2014). This study resonates the above concept and uses the CDIO framework to design educational statistics course modules that include the statistical knowledge level and software operation level by integrating the elements of serious games. This combination of CDIO and serious games is an attempt to develop innovative curriculum and teaching that teachers can use. Through this design, we hope to explore the impact on students' attitudes and effectiveness of statistics learning and to provide a possible solution to the dilemma of teaching statistics courses at the higher education level through a different orientation rather than the traditional lecture-based courses.

## FEASIBILITY OF USING CDIO ARCHITECTURE TO INTEGRATE SERIOUS GAMES INTO STATISTICS COURSES

The CDIO concept, developed by Crawley et al. (2014), has been the culmination of more than 20 years of engineering education reform in Europe and the United States. Its core concepts are "learning by doing" and "theme-based education and learning". The curriculum design of CDIO is based on the cultivation of students' abilities, not limiting to the integrity of theoretical knowledge but also focusing on cultivating students' integrated soft skills such as communication, expression, and cross-domain skills. These soft skills requirements are integrated into teaching objectives and processes. A detailed understanding of CDIO is as follows. C represents “Conceive” – it refers to the use of interviews, questionnaires, brainstorming, and other methods to analyze students' needs; D represents “Design” – it refers to providing more detailed information in the description or in the sketching of the product design; I represents “Implement” – it implies converting a sketched design into a practical product, including the hardware and software manufacturing and testing of the product; O represents “Operate” – it means that after collecting user opinions, the product is redesigned, followed by the subsequent maintenance and upgrade of the product (Al-Atabi, 2014). As a new model of engineering education, the CDIO architecture has a wide range of applications. For example, Song, Tavares, Pinto, and Xu (2017) integrated the CDIO framework with game-based learning with the objective to develop a web design curriculum to enable students to face the future of the 21st century. Aldwairi and Shuhaiber (2019a, b) also integrated the CDIO framework and game-based learning to develop a set of information security courses. Clearly, the CDIO framework can be combined with game elements to design a statistics curriculum suitable for the higher education level.

Serious games have received increasing attention in recent years in various fields, especially in educational application. Unlike traditional entertainment games, serious games are designed to be education-oriented and are an entertainment tool with educational significance. In the learning process, the game itself has elements to promote learning and behavior change. Players (students) can develop their knowledge and practice skills by overcoming many obstacles in the game process, helping them to learn in an environment that emulates real world (Boyle et al., 2016; Connolly et al., 2012; Prensky, 2001). Nadolski et al. (2008) presented the possibility of developing serious games in higher education institutions. They indicated that such a design could enhance students’ experiences and help them achieve the desired learning outcomes with effective tools. The strength of serious games lies in the various effects of the learning experience, which include the following: (1) cognitive: the acquisition of new knowledge or the reorganization of existing knowledge; (2) perceptions: changes in perspectives and values; and (3) relationships: thought patterns that increase understanding of others (Jean et al., 2018). In addition, one of the reasons why serious games can play a role in education may be the effect of serious games on learners' emotions and attitudes. If games are seen as a means of entertainment, they play a large role in the formation of emotions such as pleasure, positive experiences, happiness, anxiety, and anger. Effective serious games attempt to develop positive emotions and attitudes to encourage players to continue playing, which further increases positive attitudes toward the game for better learning outcomes (Smith, 2017).

### *Proposed Research Objectives*

Based on the above aims, the proposed research objectives are as follows: To explore the feasibility of using the CDIO framework to incorporate serious game design course modules in statistics course.

## INTEGRATION OF THE CDIO FRAMEWORK IN SERIOUS GAME DESIGN IN STATISTICAL COURSES

The CDIO framework features a human-centered design that is planned through user need analysis, creative development, and convergence, and encourages learning from failure, especially for students who often encounter difficulties in statistics courses. As a starting point, at the beginning of the course design, interviews are conducted with the students participating in the course and the on-site teachers to determine the reasons for students' learning difficulties in the most difficult course units and to understand the challenges of the teachers in teaching. Next, in the conceive (C) phase, a curriculum plan is envisioned that meets the needs of users, considers the prior knowledge of students, examines the goals of teaching statistics in education, considers the characteristics and needs of stakeholders, and incorporates serious games into the planning and design of the curriculum so that statistics learning is integrated with life situations. In the design (D) phase, the teacher's practical experience is used to design the curriculum and activities for educational serious games, starting from the perspective of stimulating students' interest and creating a life-like learning context. In the implement (I) phase, the first version of the planned curriculum and the designed educational serious game are implemented in on-site trial teaching to evoke meaningful learning styles for students, and at the same time, the opinions of students and teachers are sought through interviews, which will help improve the original game design. Finally, in the operate (O) phase, the revised educational serious game is formally implemented in experiments, reducing the development cost and time and improving the effectiveness of students' statistics learning through an iterative approach.

## DESIGNING AN EDUCATIONAL STATISTICS COURSE THAT COMBINES A CDIO FRAMEWORK WITH SERIOUS GAMES

Conceive, design, implement, and operate is the new model of engineering education. This study attempts to apply this framework to the curriculum design and activity design of statistics studies, considering the real-life statistics problems as the theme to construct the educational statistics curriculum design with CDIO as the main framework and student needs as the primary orientation, integrating educational serious games. This method is implemented to find solutions to the problem of ineffective student learning in statistics through a systematic approach.

### *Instructional Design and Planning Instructions*

The aim, in the conceive (C) phase, is to understand the needs of learners, observe students' learning performance, interview teachers to understand the challenges of statistical teaching, and to identify teaching units that need improvement. At the same time, students are interviewed to understand their challenges in statistics learning and the unit content that they did not comprehend. Concurrently, the content is confirmed after collation and summary to design the subsequent statistical course content and game themes. The exploratory serious game design model proposed by van Staalduinen and de Freitas (2010), which makes extensive use of social interactive learning- and contextual learning-based theoretical teaching methods, is adopted for the model, with the assumption that knowledge can be increased by exploring and interacting with the characters through game-like interactions designed in the environment, thus generating a better sense of immersion and interaction.

The design (D) and implement (I) phase consists of two parts: the teacher curriculum design loop and the student learning process loop. For the teacher's part, the teacher first plans the statistics course schedule, including course arrangement and pre-test (when to implement), the content (what to teach), and the pedagogy (how to teach). After that, the students will be provided with educational and serious game materials to practice, and then classroom evaluation will be conducted to reflect and revise the course content. For the students' part, the students first need to familiarize with the educational serious game, understand how to participate in the game, observe player behavior change, and finally learn how to obtain feedback from the player. These two parts—the teacher's teaching design loop and the student's learning loop—are used to improve the educational seriousness of the game from both the teacher's and student's perspectives. This will be further used as the basis for the formal experimental teaching later on.

During the operate (O) phase, the final version of the game is used for formal statistical instruction, and post-tests on learning effectiveness and statistical scales are conducted to understand the effectiveness of statistical curriculum planning for the CDIO framework of educational serious games.

***Examples of Design Pattern***

In the Educational Statistics course, we hope to consider the section on software operation as a supplement to classroom lectures, and integrate different elements of serious games into the software operation to design the corresponding course modules in a game context. These modules are designed to require students to complete a series of game scenarios ranging from low to high challenges, while guiding them to solve problems step-by-step on different levels in well-defined game scenarios. Table 1 shows the game classification and statistical gamification elements corresponding to the course modules.

Table 1. Classification of Games and Statistical Gamification Elements Corresponding to The Course Modules

| Serious game classification | Educational statistics game elements | Specific operations |
|---|---|---|
| Action language | Players/students use the SPSS interface to answer the questions set for each level of the challenge. | In addition to classroom lectures, SPSS software is used to supplement the lectures. |
| Evaluation | The instructor provides immediate feedback to the player/student in each module, guiding and encouraging students to learn by trial and error. The player/student's ability to progress to the next level depends on the instructor's decision. | Students mark the steps they have completed on the checklist through the immediate feedback "evaluation" provided by the teacher. |
| Conflict/Challenge | Players/students answer a series of challenging questions in a sequential manner in the game scenario that incorporates real-life examples. | The difficulty of selecting suitable students from a large number of applicants is gradually increasing from the initial "overview" selection to |

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|---|---|---|
| | | the advanced "condition-based" screening. |
| Control | Players/students select the variables to be used in the follow-up analysis, and their choices determine the results of the analysis, which in turn leads to the need for further choices regarding follow-up actions. | Students "control" their selection criteria with different filtering channels, e.g., "statistical learning attitude variable" or "statistical achievement variable", and this choice is very relevant because it is re-examined in subsequent course modules. |
| Environment | The physical environment in which the player/student lives. | Computer classroom with software operation. |
| Game scenario | The storyline created by the game. | Students see themselves as university professors and select suitable students for educational studies through various channels. |
| Human interaction | Players/students can share successful strategies or provide tips to help each other overcome difficulties through discussions. | Teachers encourage students to interact with each other to find possible solutions to challenges with their peers in the same group. |
| Immersion | Emotional experiences that arise during the game. | The learning experience that students developed during the game is fun, enjoyable, and entertaining. |
| Rules/Objectives | Players should fully understand the rules and objectives of the mission. | The rules of Module 2 are consistent with those of Module 1, such as complete tasks in sequence, follow instructions, etc. |

## CONCLUSION

In this study, we used the CDIO framework to incorporate serious game design course modules in statistics course. Results showed that (1) CDIO framework with serious game design can be effectively integrated into statistics courses in higher education, and can effectively improve students' concentration, engagement, and performance in an educational statistics course; (2) through the proposed project-oriented design, CDIO framework with serious game design course modules not only helped the students understand basic theories of statistics but also allowed them to apply the knowledge pragmatically, thereby reinforcing their understanding of statistical concepts and how to apply them to solve real-world problems. The example presented in this study proves that the systematic, CDIO-based statistics course with serial game design. It is regrettable that this approach to designing statistics courses is seldom adopted in higher education. Nonetheless, the CDIO framework with serious game design course modules in statistics course can be an effective outline for helping students internalize theoretical knowledge. Therefore, we hope that the proposed project can serve as a template for designing teaching activities. The role of the educator is vital in carrying out

CDIO-based with serial game design course modules. Finally, several suggestions for teaching and research are presented.

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