Action Reflected and Project Based Combined Methodology for the Appropriate Comprehension of Mechanisms in Industrial Design Education

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Abstract

In industrial design (ID) education, mechanics-based courses are mainly based on a traditional lecture approach and they are highly abstract for ID students to comprehend. The existing studies highlight the requirement of a new approach for mechanics-based courses in ID departments. This study presents a combined teaching model for mechanisms mainly based on an applied teaching style and action learning to improve ID students' learning experience and competencies through promoting the transference of theoretical knowledge into practical experience and learning. The combined teaching model, consisting of three phases, was integrated into a design studio project named mechanical game design. A total of forty-one sophomores taking the 'Product Design II' course offered in Gazi University Department of Industrial Design during the second semester of the 2016/2017 academic year, participated in the mechanical game design project. Project observations and a post-questionnaire were employed to objectively analyse the appropriateness of the teaching model. The results indicated that the combined teaching model improved ID students' learning outcomes and competencies in terms of transferring the gained theoretical and practical knowledge into action learning.

Key words

Design education; mechanisms; design studio; combined teaching method; action learning; project based learning.

Introduction

Industrial design is not making things beautiful; it is about far more than how a product looks. As a transdisciplinary profession, it covers many areas, including engineering, science, marketing, aesthetics, and anthropology as well as social, cultural and ecological issues (WDO, 2016; NASAD, 2016; MSU Denver, 2016; ND, 2016; NJIT, 2016). Generally, the students having good skills and competency in these areas are considered to be well equipped for employment. Nevertheless, industry's expectations from ID graduates change with the rapid industrial developments (Liu, Lee, Lin, and Tseng, 2013). Therefore, ID schools should continuously update their curricula and modify their teaching methods according to industrial needs.

The WDO (2016) categorizes three main competencies that design students should be trained in. These are; 1) general qualifications-problem solving, communication skills, etc., 2) specific industrial design abilities and understanding - design thinking, design process, visualization skills, manufacturing, materials, design management etc. and 3) knowledge aggregation.

Many ID departments in Turkey orientate their educational systems and curricula in order to comply with the above-mentioned competencies of their students and they provide multiple courses covering engineering, ergonomics, management, arts, and computer-related areas. Liu et al. (2013) interviewed participants having more than ten years' experience implementing industrial design and teaching and reported that industrial designers must develop professional competencies in eight dimensions; aesthetic literacy, design expression, creativity, planning and integration capability, engineering capability, computer application skills, ergonomics knowledge, and foreign language skills. For the sub-categories (knowledge of manufacturing processes, capability of material usage, knowledge of mechanical designing and principles) of the engineering capability dimension, knowledge of mechanical designing and principles was reported as the most important item. ID students need a considerable understanding of mechanisms in addition to manufacturing processes and material to create innovative ideas. Since the mechanism forms affect both the function and the appearance of the product, it is vital for students to have sufficient knowledge of mechanisms to start a design for a relatively complicated product. To be able to actualise proposed functions for a new design idea, students have to be able to predict which mechanisms could be effectively used. Throughout professional life as an industrial designer, they will be also responsible for the mechanical details of their product designs. However, mechanical design courses generally tend to be taught through traditional methods, mainly depending on verbal lectures. Video-based three-dimensional animations are also not sufficient for design students due to their lack of knowledge of mechanical mechanisms (Liu, Sun, & Wu, 2013). Verbal, visual and video-based lectures are highly abstract for comprehending the practical aspects of the mechanisms particularly when used for the transfer and activation of motion.

Traditional lecture-based education methods, reinforced with proper laboratory activities is generally common and accepted among engineering students. However, design students are hesitant about convergent learning styles and strongly prefer applied learning methods that provide active experimentation, even though they are aware of the benefits of engineering-based education (Bingham, Southee & Page, 2015). The majority of design students are not satisfied with the teaching methods applied to Mechanical Design courses (Bingham et al., 2015; Liu et al., 2013). In addition, Bingham et al. (2015) have reported that according to the outcomes of Final Year Design Practice Projects at Loughborough University, mechanical design and functionality were used inappropriately. Liu et al. (2013) examined 1500 student projects submitted to the Chinese Hardware Products Industrial Design Competition and reported that less than 10% of the students utilised advanced mechanical concepts. The rest of the works were based on styling, which indicates the limited mechanical design ability of industrial design students. Chou and Hsu (2007), indicated that different from engineers, industrial designers rely more on creative problem solving than procedural knowledge, and therefore they need a fundamental training of scientific thinking, in which they may learn how to expand their knowledge domain efficiently. They concluded that, in the long run, well-designed and certificated PBL (problem-based learning) problems for design sciences and technologies can be organized to form a data base, forming a teaching resource for all courses in their department of industrial design.

There is limited research on the engineering-based learning of ID students. However, the existing studies highlighted that design students need a new approach for engineering-based courses and complementary courses and studios that would need holistic perspectives. The aim of this study was to present a combined teaching and learning model for mechanism included products mainly based on an applied learning style together with the functional theory and active experimentation, to improve ID students' practical learning experience. To achieve this, a teaching model, consisting of 3 phases, was integrated into the design studio project (4th Semester) to promote the transfer of the theoretical knowledge obtained in the prior lecture of "Mechanisms" into practical and concrete learning by doing experience. The integration was important to analyse the contribution of the model to the design process and to reveal the students' knowledge of mechanisms through final product designs. The study initially examines existing mechanics-based courses in main ID departments of Turkish Universities, followed by the research methodology to improve ID students' learning experience on mechanisms. Finally, results, conclusions and limitations of the study are presented with some implications.

Learning Styles in Design Education

Different studies on learning styles exists in the literature. Nevertheless, Kolb's Learning Style Inventory (K-LSI) is the most widely utilised model due to its generalised and reliable structure (Carmel-Gilfilen, 2012; Demirbas and Demirkan, 2003; Demirkan and Demirbas, 2008; Demirkan, 2016; Kayes, 2002; Kvan and Yunyan, 2005). Similarly, K-LSI model is employed widely in the different design disciplines (Carmel-Gilfilen, 2012; Demirbas and Demirkan, 2003, 2007; Demirkan and Demirbas, 2008; Kvan and Yunyan, 2005; Nussbaumer and Guerin, 2000; Tucker, 2007, 2009). According to Kolb's model, a learning cycle is composed of four stages; concrete experience (CE), reflective observation (RO), abstract conceptualisation (AC) and active experimentation (AE).

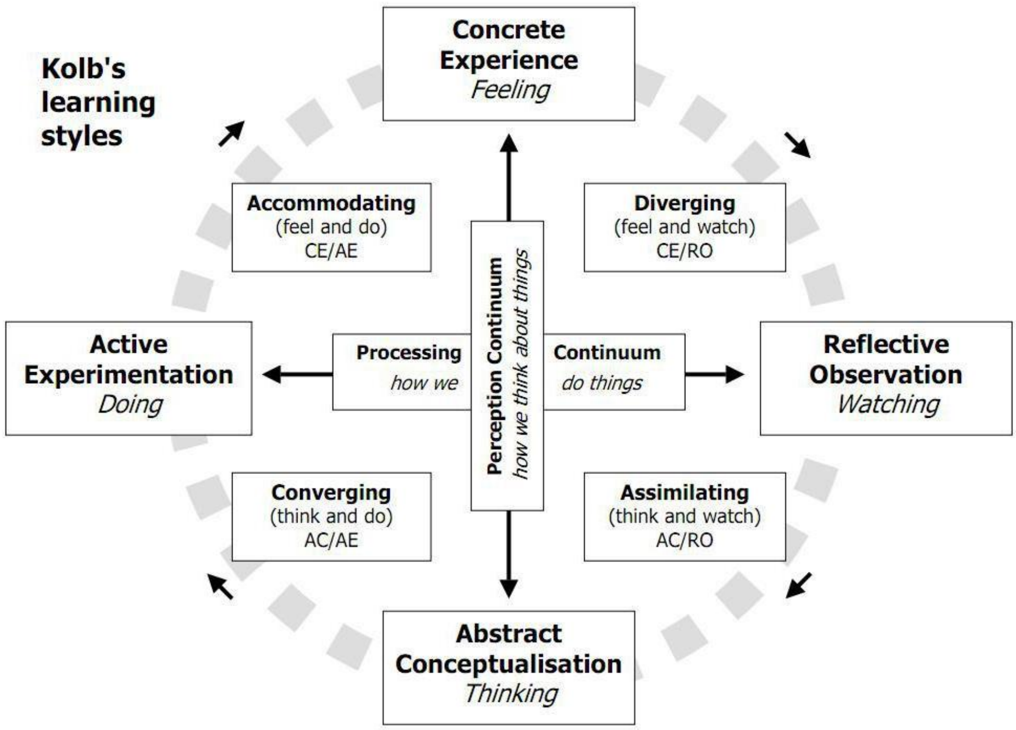


Figure 1. The four-staged learning cycle and the four learning styles (http://www.n-co.org/wp-content/uploads/2016/01/david-kolb-method1.jpg)

Based on these four stages (Figure 1), Kolb classified learners into one of four learning styles, namely converger (AC and AE), diverger (CE and RO), assimilator (AC and RO), and accommodator (CE and AE) (Kolb, 1984).

Studies on learning styles of design students indicated different results. Studies by Demirbas and Demirkan (2003, 2007), and Tucker (2007) determined that the most of design students were converger and assimilator. In contrast, studies by Kolb and Wolfe (1981), Nussbaumer and Guerin (2000), Bender (2004), and Carmel-Gilfilen (2012) determined that design students were mostly diverging and accommodating learners. Carmel-Gilfilen (2012) supports that although all learning styles are found in studies due to the multidisciplinary nature of design, diverging and accommodating learning styles are more appropriate for design majors. These learning styles match up with a studio-based learning style in design disciplines. Based on Kolb's learning styles (1984), divergers are good at brainstorming and idea generation, inclined to be imaginative and emotional. Accommodators show preference for doing and feeling. They like working in teams and experimental studies. The common point of these two learning styles is concrete experience (CE) or learning by experience. Carmel-Gilfilen' study supports that designers prefer experiencing the concrete and substantial qualities of the world to discover meaning.

Studies on learning styles of design students reveal that despite differences in ratio, all of the four learning styles exist in design education. Therefore, it is supported that instead of applying one of the four learning style, a diverse instruction covering all learning styles should be adapted to design education (Carmel-Gilfilen, 2012; Demirbas and Demirkan, 2003, 2007; Demirkan and Demirbas, 2008; Demirkan, 2016; Kvan and Yunyan, 2005). In addition, it is found that teaching including all learning styles in balance develops learning outcomes (Nussbaumer, 2001).

Demirkan (2016) investigated the learning-style (Sensing/Intuitive and Visual/Verbal) and knowledge-building (Active/Reflective and Sequential/Global) preferences of design students utilising Felder-Soloman's Index of Learning Styles. The study found that design students prefer a sensing learning style such as facts and concrete material rather than theories. The study also revealed that designers prefer visual information rather than verbal ones. It is unsurprising that designers learn better with pictures, schemas and videos. Moreover, it is found that design students are active learners; they prefer teamwork and hands-on activities, like sketching or constructing a 3D model. They learn better by doing and applying.

Design education needs a holistic approach that emphasises learning by doing and experiencing but allows students to learn by reflecting and thinking as well. It can be achieved by providing different type of assignments like two- and three-dimensional work, visual and verbal assignments, and individual or teamwork (Carmel-Gilfilen, 2012).

Teaching of Mechanisms in Industrial Design Education

Engineering-based courses in the main ID departments in Turkey are generally taught either by instructors from Mechanical Engineering Departments or by industrial design instructors with a professional background in engineering. Engineering-based courses in main ID departments of Turkish Universities are indicated in Table 1. As seen in Table 1, mechanics-based courses only exist in some universities' curricula. In Gazi University, the Mechanism and Details course was added to the curriculum in 2014-2015 academic year.

Engineering-based courses	Gazi Uni.	Middle East Technical Uni.	Istanbul Technical Uni.	Izmir University of Economics	Anadolu Uni.	Bahçeşehir Uni.	Marmara Uni.
Mechanics-based	Mechanisms and Details		Introduction to Mechanical Design			The Way Things Work	Design Construction
Manufacturing-based	Manufacture Methods	Principles of Production Engineering	Manufacture Methods	Production Technology	Manufacture Methods		Production Techniques
Material-based	Materials	Manufacturing Materials	Statics & Strength of Materials	Materials for Industrial Design	Material Science	Manufacture Materials	Material Technology

Table 1. Engineering-based courses in ID departments

Through the learning outcomes indicated in Table 2, it is seen that the courses in Gazi University and Istanbul Technical University cover mechanisms and mechanical design issues in detail, whereas the other two courses (The Way Things Work and Design Construction) are included partially.

The courses summarised above are generally lecture-based with a high degree of abstraction. As seen in Table 2, the outcomes of these courses are generally evaluated through quizzes, midterm and final examinations and homework assignments. Therefore, students do not have the opportunity to transfer theoretical knowledge into practical achievements throughout the course period.

In contemporary design education, the courses are divided into four categories: 1) fundamental courses 2) technology-based courses 3) artistic courses 4) design studio courses (Demirbas and Demirkan, 2007; Demirbas, 2001; Uluoğlu, 1990). The second category, technology-based courses, consists of the courses that are theoretical based but directly related to practice named as construction, structure, material etc. (Uluoğlu, 1990). Accordingly, engineering-based courses belong to the second category. This implies that students' acquired knowledge in mechanics-based courses should be not only theoretical but also practice-based. It is widely accepted that a theoretical teaching style alone is insufficient to equip design students with the skills required during professional life (Hook, Hjermitslev, Iversen & Olivier, 2013). Design educators look for teaching models that form the combination of theories, techniques, and skills to reflect the students' individual approaches (Demirbas and Demirkan, 2007; Schön, 1987). Therefore, it is essential to combine theoretical knowledge with real-world practical experience for design students.

	Gazi Uni.	Istanbul Technical Uni.	Bahçeşehir Uni.	Marmara Uni.
Course Names	*Mechanism and Details*	*Introduction to Mechanical Design*	*The Way Things Work*	*Design Construction*
Learning outcomes	*1. Understand the basic mechanisms components* *2. Understand and interpret the mechanisms and connection types* *3. Have full knowledge of exploded view and detail display through mechanisms* *4. Understand the place and contribution the solution of electronic circuits in mechanisms* *5. Develop mechanism based problem solving*	*1. Understand the fundamentals of mechanical systems* *2. Understand the physical principles of mechanical systems* *3. Understand the basic elements used in mechanical systems* *4. Develop the basic skills for analysing existing mechanisms* *5. Develop the skills to find mechanical solutions during designing*	*1. To identify assembling and disassembling procedures of objects in order* *2. To explain the circular movement, linear movement and ex-centric movement* *3. To differentiate the elements of simple mechanics* *4. To apply the principles of simple mechanics to the new design of objects* *5. To compare various power sources* *6. To support the mechanics and working principles of objects with the renewable energy sources*	*1. To evaluate design from a different perspective* *2. To examine about design development process and development of its applications* *3. To identify both design and engineering contexts about statics, dynamics and mechanics* *4. To analyse the basic principles of physics in the context of industrial design* *5. To explain the relationship between design and construction*
Assessment Criteria	*Midterm exam Final exam*	*Homework Assignments* *Quizzes* *Midterm project* *Final project*	*Homework Assignments* *Quizzes* *Midterm exam* *Final exam*	*Homework Assignments* *Midterm exam* *Final exam*

Table 2. Summary of the courses

In design education, design studio courses are the most crucial part and they are the synthesis of all other courses (Demirbas and Demirkan, 2007). The aim of courses other than design studio courses is to provide students with theoretical and practical knowledge that they can utilise in design studio projects. However, it is seen that there is no concrete bridge between the design studio courses and mechanics-based courses. Although students gain sufficient theoretical and practical knowledge of mechanisms, they have difficulties in applying this knowledge to a real design project. Thus, there is a need for a new teaching model of mechanism for ID students combining theoretical and practical knowledge with an applied learning style.

Design of New Teaching Model of Mechanisms

Methodology

The implementation was conducted at Gazi University, the department of Industrial Product Design within second-year ‘Product Design II’ course. The aim of this application was to improve ID students’ learning experience on mechanisms by utilising an applied learning style and to enable them to transfer their knowledge of mechanisms into the design project.

In consequence of the above discussions, a new teaching model of mechanisms that combines different styles but mainly based on an applied learning style covering two stages of Kolb’s learning cycle: active experimentation (learning by doing) and concrete experience (learning by experiencing) was designed. This teaching model was integrated to design project and conducted thoroughly within product design-studio course.

The new teaching model consists of three main phases: Improving theoretical knowledge of mechanisms and possible applications, in-depth practical knowledge of specific mechanisms and application of mechanism into the design process (Figure 2).

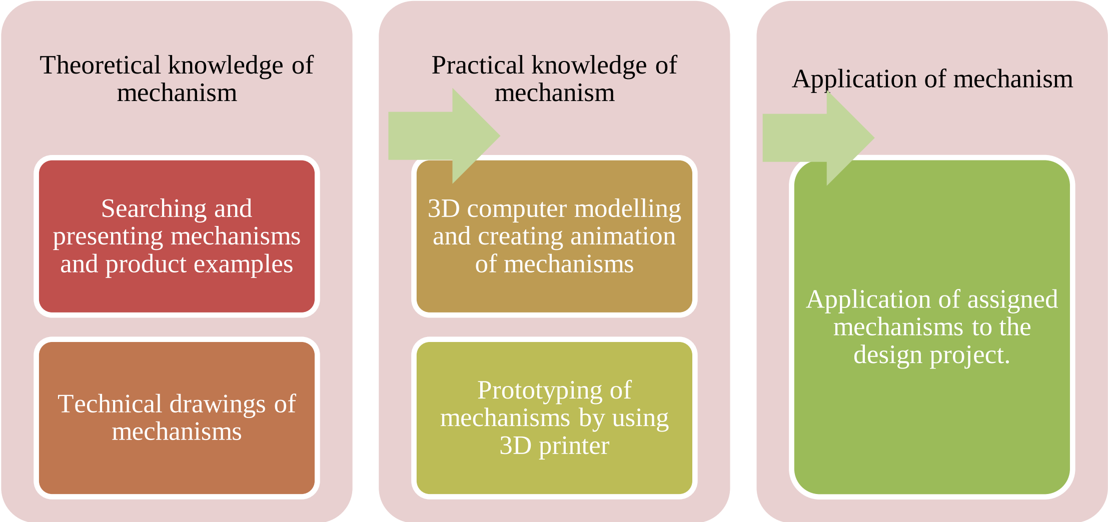


Figure 2. Phases of new teaching model of mechanisms

Improving theoretical knowledge of mechanism and possible applications.

This phase consists of searching and presenting a working system of mechanisms and mechanism-based product examples including the technical drawings and related 3D animations. The teaching method specified a series of reference materials for students' self-study to improve and revise their knowledge obtained in previous courses. Concrete outcome oriented presentations were requested and apart from the recommended self-study materials, students are allowed to show all related information about assigned mechanisms for reinforcing their knowledge through drawing different perspectives. Some amount of the mathematical content was removed except for two sections related to planar linkage degrees of freedom and transmission system speed ratios that are essential for the holistic approach of the final product. Mechanical applications in industrial design are mainly concentrated on the motion mechanisms. Therefore, most of the assigned mechanisms classified based on their level of complexity were focused on planar mechanisms and transmission systems. The functions of the planar mechanisms were requested to be solved in terms of their operative systems such as copying, changing direction, scaling and other basic operations. Students abstracted general principles of the assigned mechanisms around their environment in order to build mechanical knowledge through their initiative in studying everyday objects. Afterwards, the students are guided toward drawing conclusions on theoretical knowledge through practical life conditions. During the studio criticisms, combined applications in problem-solving are carried out to give students experience in analysing situations while, at the same time, seeking solutions to problems through theoretical principles.

Within this process, their skills in applying knowledge were strengthened and their analysis was encouraged with additional 3D animations and video presentation of typical mechanical products as well as necessary detailed technical drawings including perspectives, different views, and sectional views.

In-depth practical knowledge of specific mechanisms

This phase consists of 3D computer modelling and animation of the assigned mechanisms and creating the prototype of the mechanisms by using the 3D printer. The ultimate goal for industrial design students, who study courses on mechanical design, is to increase their advantage in product design and to eliminate the biased common impression that industrial design is just styling (Liu and Wu, 2013). The authors' department was equipped with 3D printers, allowing students to turn their modelled mechanisms into concrete models, which greatly enhances also their knowledge of modelling obtained in computer aided design courses. In this stage, students actively learn mechanisms by doing and experiencing. In case of false scaling, the students re-model the assigned mechanism until it matches with the appropriate output from the 3D printer. They test and improve the design of the mechanism by modifying the scales, features and mechanical functions of the virtual models by adjusting the parameters. Thus, the modelling and testing capabilities of the students were increased in terms of developing a full understanding of their own mechanisms, both theoretically and perceptually.

Application of mechanism into a design process (action learning)

In this phase, students apply the mechanisms in a specific real design project. Students are requested to develop a product including their assigned mechanism after the completion of phase 1 and appropriate modelling in phase 2. Thus, the better comprehension of creating a functional prototype through the active application of the assigned mechanism was the main learning outcome of this final phase. In some drafts of the integrated design cases, the training and implementation were even carried out on combined applications of more than one mechanism.

According to the above-mentioned phases of the proposed teaching model, design brief and assignments were formed as indicated in Section 3.

The Project Brief: Mechanical Game Design

To apply the new teaching model of mechanisms to the design-studio project, many product ideas were discussed while preparing the design brief in terms of their suitability to assigned mechanisms, complexity, and approximate duration. Since the main purpose of the project was to provide students to gain practical knowledge of mechanisms, the mechanism should not have played a recessive role in the product. Therefore, it was decided to constitute a project brief for a mechanical game design. It was thought that a mechanical game design project allowed more alternatives for the students in terms of both creativity of the final product and appropriate application of mechanisms.

The anticipated steps while preparing design brief and assignments are as follows:

Specifying mechanisms

Mechanisms assigned to the students were judged according to their suitability to the mechanical game design project. As product designers generally utilise movement mechanisms in their products (Liu et al., 2013), this type of mechanism was chosen to assign to the students. These mechanisms were distinguished into three categories in terms of their relative complexity (Table 3).

	Less complex	*Complex*	*More Complex*
1	*Worm Wheel*	*Crankshaft-Rod*	*Cardan Gear*
2	*Sprocket Wheel*	*Bellcrank*	*Universal Joint*
3	*Belt-pulley*	*Camshaft*	*Geneva Drive*
4	*Bar-Pendulum Linkage*	*Drop/Snail Camshaft*	*Internal Geneva Drive*
5	*Double Pendulum*	*Scotchyoke*	*Planet Gear*
6	*Hoekens Linkage*	*Ratchet Wheel*	*Looney Gear*
7	*Ball Joint*	*Scissors Mechanism*	*Chuck*
8	*Gear Train*	*Scissors Jackscrew*	*Iris Diaphragm*
9	*Elliptical gear*	*Bevel Gear*	*Variable Speed Gears*
10	*Torsion Spring*	*Helical Gear*	*Anchor Escapement*
11	*Archimedes' Screw*	*Tusi-Couple*	*Ferguson's Paradox*
12		*Centrifugal Governor*	*Withworth Mechanism*
13			*Barrel/Cylindrical Cam*

Table 3. Three categories of movement mechanisms

Forming teams

A total of 41 industrial design sophomores attending a 'Product Design II' course participated in the project. The demographic makeup included 34 females and 7 males. Students were formed into teams consisting of three members.

Assigning mechanisms

All teams chose one mechanism from each of three mechanism categories. All the members of each team were responsible for the detailed analysis of three mechanisms that they chose for the first phase of the training process.

Phase 1: Improving theoretical knowledge of mechanisms and possible applications

Assignment 1: Teams were asked to search mechanisms assigned to them (three mechanisms ranging from less complex to more complex). Searching included materials describing the principles of mechanisms via both visual (technical drawings, renders of 3D computer models and pictures) and video-based approaches as the details are mentioned in the section of methodology. In addition, to gain concrete knowledge about mechanisms, the products or systems around their environment that these mechanisms are utilized were also searched. Teams were also asked to make a technical drawing of all three mechanisms. They submitted and presented all assignments to the instructors. At the end of this phase, three mechanisms assigned to the teams were reduced to two for further in-depth analysis and 3D modelling based on their exhibited competencies and their interest in the mechanisms through the samples of real life conditions indicating that interest is the main motivator in stimulating students' passion for learning and research.

Phase 2: In-depth practical knowledge of specific mechanisms

Assignment 2: Basing on the selection of two mechanisms per team, the students started in-depth analysis on the mechanism systems. Each team created 3D models of these mechanisms by using Autodesk Fusion 360. Teams also set up a motion study in Fusion 360 to analyse their operative systems and movements (rotations, translation, transmission, changing directions etc.) of the parts of mechanism and tested whether it worked appropriately or not. The methodology of the process was fulfilled as mentioned in the previous section.

After the presentations of the 3D models and motion studies of the two mechanisms of each team, the instructors, based on the interest, motivation and previous studies of the students for providing a gap with their environment, chose and assigned one mechanism to each team (Table 4) for the further 3D printing process.

Teams	*Mechanisms*
Team 1	*Centrifugal Governor*
Team 2	*Drop/Snail Camshaft*
Team 3	*Scotchyoke*
Team 4	*Worm Wheel*
Team 5	*Crankshaft-Rod*
Team 6	*Universal joint*
Team 7	*Archimedes' Screw*
Team 8	*Planet Gear*
Team 9	*Ferguson's Paradox*
Team 10	*Iris Diaphragm*
Team 11	*Camshaft*
Team 12	*Geneva Drive*
Team 13	*Cylindrical Cam*
Team 14	*Withworth Mechanism*

Table 4. Mechanisms assigned to teams

Assignment 3: 3D models created in Fusion 360 were examined by instructors to make them ready for 3D printing. The thickness of the parts, tolerances between the parts and overall scales of the models were optimised according to existing 3D printer features. All prototypes of mechanisms were created by using Zortrax M200 within the GAZİ D-LAB (Digital Design Laboratory of Gazi University).

Phase 3: Application of mechanism into a design project (action learning)

Mechanical Game Design: After assigning the mechanisms that each team was responsible for, the process for designing a game based on the assigned mechanism was initialised. This process is also called "action learning" and the project subject was chosen in order to minimise the possible negative pressure and impacts on the students' creative thinking.

The main specifications for the mechanical game design were as follows:

- Teams have to apply the mechanism assigned to them at least once in the active systems of their designs. In a case of more complex system designs, they can add additional mechanisms where required.
- The product should be manually operated or powered.
- There is no limitation on material usage and scale of the product.
- The product can be designed for different age groups.

Working in teams of three students, each team had a total of 5 weeks (Total 40 hours of active studio hours and approximately 70 hours of work outside studio hours including research, case studies, and practices) to finalise the product design. Within the first 4 weeks, teams developed design ideas and formed them as design proposals through studio critiques. They presented their two design proposals including research report, technical and perspective drawings and 1/1 physical mock-ups in the preliminary jury. Instructors chose one of two proposals for teams to continue to improve until the final jury. Each team finalised and presented their mechanical game designs at the end of fifth week.

Project management

To manage the project lifecycle the students' submissions and timing were important. The sequence of the submissions was arranged parallel with the project brief. The duration of each submission was developed by regarding the students' previous project performances. All submissions and timing of the stages are demonstrated in Table 5.

Project Phases	*Week*	*Submissions*
	1	*Team member selection*
Improving theoretical knowledge of mechanisms and possible applications		*Assignment 1* *-Research report on 3 mechanisms* *-Presentation of detailed technical drawings of mechanisms* *-Selection of 2 mechanisms per each team for further phase*
In-depth practical knowledge of specific mechanisms	*2*	*Assignment 2* *-3D modelling of two mechanisms in Fusion 360* *-Motion study of two mechanisms in Fusion 360* *-Selection of one mechanisms per each team for 3D prototyping*
	3	*Assignment 3* *-3D printed prototypes of the selected mechanisms*
Application of mechanism into a design project (action learning) Mechanical Game Design	*4*	*Preliminary Jury* *-Presentation of research, technical and perspective drawings* *-1/1 physical mock-ups*
	5	*Final Jury* *-Presentation of research, technical and perspective drawings* *-1/1 physical model*

Table 5. Submissions and timing

Evaluation of the New Combined Model

To be able to evaluate the teaching model effectively, the project was conducted during the second semester of the 2016/2017 academic year since the participating students taking Product Design II course had studied the Mechanisms and Detail course in the previous semester. Therefore, it was anticipated that they would appropriately evaluate their learning outcomes and compare their practical improvements and competencies with respect to the gained knowledge and skills in the previous related courses. To evaluate the proposed new teaching model, two data acquisition techniques were utilised:

- Process observations and analysis of the submissions
- Post-project questionnaire

Process observations and analysis of the submissions

During twice a week studio critiques (10 hours per week), teams received evaluative feedback for their design ideas. Feedback was beneficial for both learning and application of mechanisms in the design process. Studio critiques were important to record the attendance and the progress of each team and to analyse the appropriateness of the proposed teaching model.

The process observations and analysis of the submissions were conducted each week after 10 hours of studio critiques basing on the expected learning outcomes and competencies for each phase foreseen by the project instructor team while creating the methodology. As mentioned before, the proposed new teaching model of mechanisms combined different learning styles but was mainly based on an applied learning style covering two stages of Kolb's learning cycle: active experimentation (learning by doing) and concrete experience (learning by experiencing). In addition to these aspects, the professional competencies that Liu et al. (2013) suggested (aesthetic literacy, design expression, creativity, planning and integration capability, engineering capability, computer application skills and ergonomics knowledge) skills were considered through different rates while determining the process based on the nature of the established methodology.

Consequently, the structure of the expected learning outcomes and competencies in each of the three phases of the methodology that are the base of the process observations and submission analysis, were determined as follows:

Phase 1: Improving theoretical knowledge of mechanisms and possible applications:

- Research, analyse and synthesise knowledge about specific mechanisms for the development of a design response (engineering capability, design expression)
- Understand the fundamental concepts of the given mechanisms through technical drawings including perspectives, different views and sectional views (engineering capability)
- In-depth analysis and 3D modelling (engineering capability, computer application skills, planning and integration skills)
- Understanding the role of the assigned mechanisms through the samples of real life conditions (design expression, aesthetic literacy)

Phase 2: In-depth practical knowledge of specific mechanisms:

- Active learning of the assigned mechanism by doing and experiencing (computer application skills, engineering capability, planning and integration capability)
- Test and improve the design of the mechanism by modifying the scales, features and mechanical functions of the virtual models by adjusting the parameters (computer application skills, creativity)
- Appropriate modelling and obtaining output from 3D printer / understanding the mechanism perceptually (planning and integration capability, engineering capability, computer application skills, design expression)

Phase 3: Application of mechanism into a design process (action learning):

- Apply fundamental design principles (primary elements, composition of form, proportion and scale) to their work (aesthetic literacy, design expression, creativity)

- Explore creative processes and idea generation and demonstrate critical evaluation of these processes in the assessable work (aesthetic literacy, design expression, planning and integration capability, creativity, engineering capability, ergonomics knowledge)
- Communicate critical design thinking according to disciplinary conventions, drawings, models, mock-ups and other presentations (design expression, aesthetic literacy, planning and integration capability)
- Work productively in a studio environment and, in turn, develop inter-personal skills, verbal communication skills and critical thinking through small group activities and studio exercises (planning and integration capability, creativity, design expression)

Post-project questionnaire

The post-project questionnaire was administered following the final assignment. 37 participants completed the questionnaire during the final day of the project. To get evaluative feedback about the effectiveness of the new teaching model, a 4-part questionnaire was developed using a Likert scale. In the first part of the questionnaire, the impact of the project phases (research, technical drawings, 3D computer modelling, animating, 3D printing, creating concept ideas, and application of mechanism in product) on learning mechanisms were rated, with 1 corresponding to “minimum” and 5 corresponding to “maximum”. In the second part, participants were asked to explain which phase of the project was the most challenging. In the third part, participants were asked to rate their level of knowledge on Autodesk Fusion 360 and 3D printing for before and after the project. In the final part, participants were instructed to rate the acceptability of the given sentences on a Likert scale of 1 to 5, with 1 corresponding to "strongly disagree" and 5 corresponding to "strongly agree". Basic statistical values were calculated for all parts of the questionnaire. In addition to that, in part 3 paired sample t-test was applied in order to observe the improvements in Autodesk Fusion 360 and 3D printing before and after the use of the teaching methodology.

Results

41 industrial design students attending ‘Product Design II’ course participated in the mechanical game design project, resulting in 14 student teams. All teams finalised the mechanical game design project to different levels of different aspects. The results were gained from two data capture techniques: project observations gathered by instructors throughout the process and the post-questionnaire conducted with participating students at the end of the project.

Results of the process observations

To analyse the appropriateness of the phases of the project separately, the project is discussed for each phase through the process and the submissions.

Phase 1: Improving theoretical knowledge of mechanisms and possible applications

As mentioned before, in this phase, teams were asked to search mechanisms and make technical drawings of these mechanisms (3 mechanisms ranging from less complex to more complex) assigned to them. The aim was to gather information about mechanisms and how these mechanisms are utilized in products. While some teams’ research was limited to the proposed reference materials and internet search, some started to work with physical mechanisms. Physical mechanisms allowed teams to comprehend motion of the mechanisms more easily. The majority of research presentations were limited to only google images and texts. Through detailed technical drawings, it was aimed to enable students to learn the parts composing the mechanisms and comprehend the motion and transmission system. It was observed that teams with insufficient research had trouble while making technical drawings especially in dimensioning and scaling of the parts of the mechanisms. Although these applications were not sufficient for fully understanding motions of the mechanisms, students had improved their general knowledge of mechanisms at the end of this phase. After appropriate guidance, most of the students were able to abstract general principles of the assigned mechanisms around their environment and tried to provide a gap between the mechanism and practical life conditions. Approximately, half of the student groups even tried to analyse situations that need combined applications that require at least two or more mechanisms in a relatively complex system.

Phase 2: In-depth practical knowledge of specific mechanisms

As mentioned before, teams were assigned to create 3D models and animation of their mechanisms by using Autodesk Fusion 360 in this phase. Teams struggling while dimensioning the related parts of the mechanisms also had trouble while 3D modelling in Autodesk Fusion 360. Deciding wall thicknesses, tolerances between the parts and calculating gear ratios were some of the challenges teams faced. With instructors' directions, each team revised their Fusion models. The most challenging stage for teams was animating of the mechanisms as they had not sufficient knowledge on making animation in Fusion 360. Despite these difficulties, nearly all teams succeeded in making an animation of their mechanisms at the end. Some examples of teams' 3D models created by Autodesk Fusion 360 are demonstrated in Figure 3.

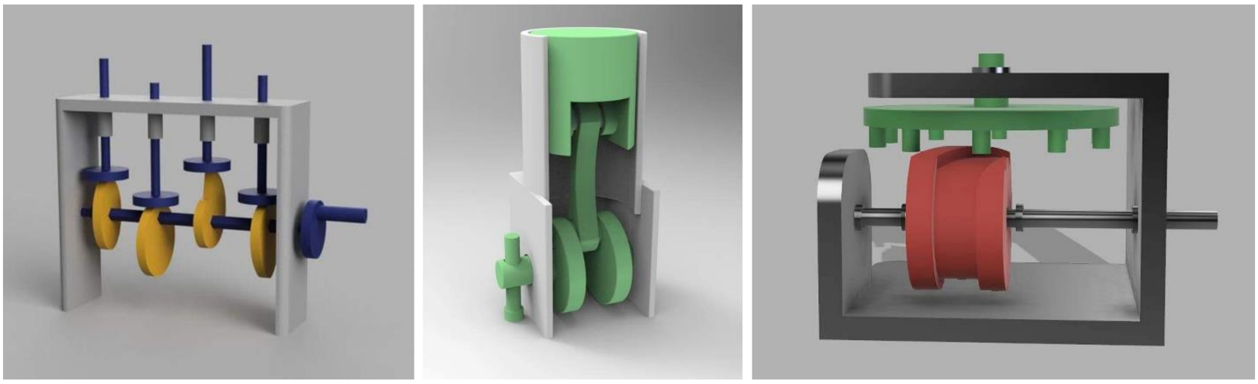


Figure 3. Examples of teams' 3D models created by Autodesk Fusion 360

Following 3D modelling, again with the support of instructors, models were optimised for 3D printing. Wall thicknesses and tolerances of the models were revised according to the features of the 3D printer. In spite of all these optimisations, some errors occurred while 3D printing. Some parts of the models could not fit together due to insufficient tolerances. In addition, low wall thicknesses of some parts resulted in breaking these parts. However, these problems encountered during 3D printing allowed students to concretely see their mistakes made during 3D modelling. All teams' final 3D printed mechanism models are demonstrated in Figure 4.

In this phase, the aim was to apply knowledge acquired during phase 1 and 2 to the design process and action learning. Each team created mechanical game design ideas depending on mechanisms assigned to them. All students engaged in the process using design techniques by making sketches and mock-ups. It was observed that although students were generally motivated by the project, they found the process challenging. Student comments revealed that most of them comprehended the principles of the mechanisms but had difficulties to apply the mechanisms to the product design. They thought that by being limited with a specific mechanism also limited them in creating product ideas. In fact, this limitation enabled them to focus on a specific function and created a starting point for them. During the initial phase, the most common mistake was inappropriate application of mechanisms to the design. They struggled to create product ideas relevant to their mechanisms. During studio critiques, some of their design alternatives were eliminated and they were directed to develop appropriate concepts. This helped remove their uncertainty and focus. Physical models developed in this process also allowed students to evaluate their design decisions. Eventually, students understood the importance the transferring theoretical knowledge to practice and apply this in a relevant way to a real product design process. Working in a team helped them to learn to share a responsibility and develop a working discipline. These all were significant outcomes that were expected from this new teaching model. Despite the difficulties of the process, all teams succeed in finalising their product designs and fulfilling all the requirements.

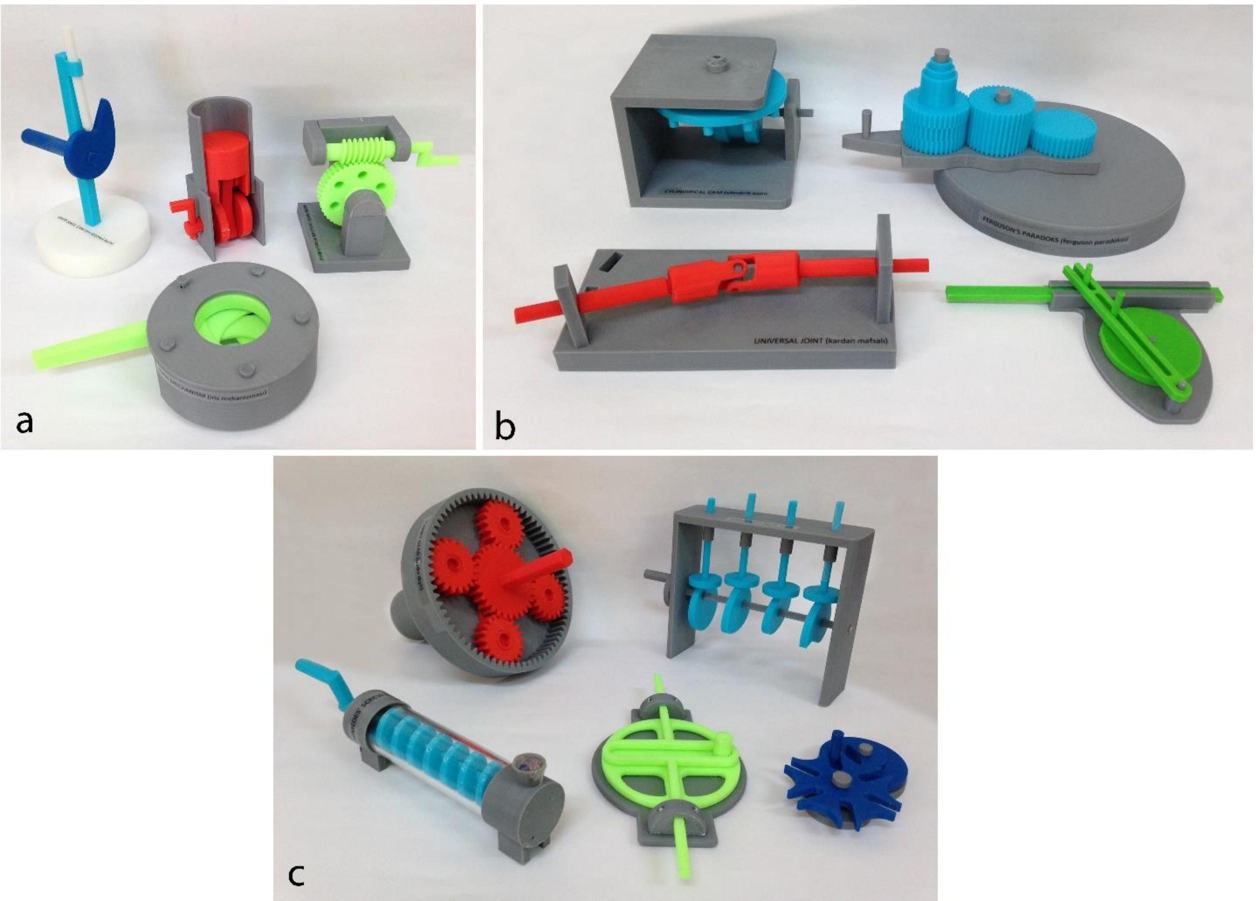


Figure 4. Teams' final 3D printed mechanism models a) Drop Camshaft, Crankshaft-Rod, Worm Wheel, Iris Diaphragm b) Cylindrical Cam, Ferguson's Paradox, Universal Joint, Withworth Mechanism c) Planet Gear, Camshaft, Archimedes' Screw, Scotchyoke, Geneva Drive

Phase 3: Application of mechanism into a design project (action learning)

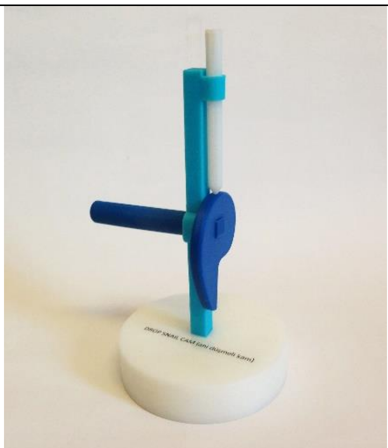
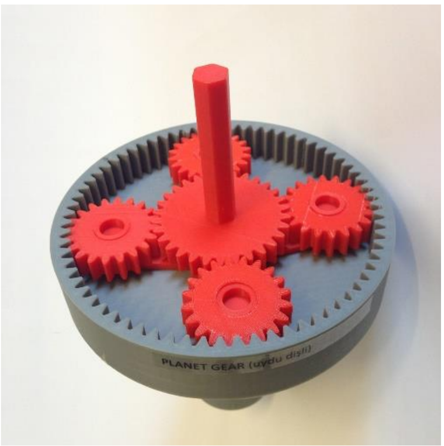
Some of the final products of the teams are shown in Figure 5 and summarised as follows:

Team 2- The Earthquake

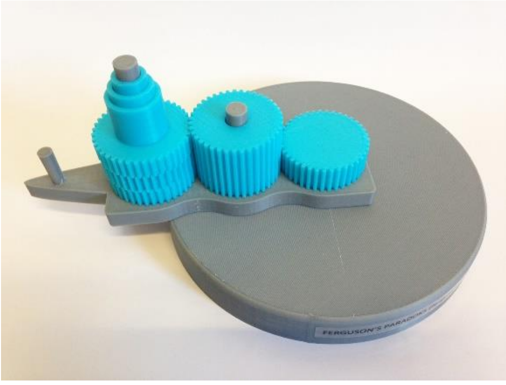
this is a board game utilising a drop camshaft mechanism. It can be played with two or in teams. The aim of the game is to create an arrangement on the card drawn by the competitor with the blocks within a certain period of time. The player selects a card from the decks and opens the card as soon as the timer attached to the platform is set. He tries to align the blocks as in the card. When the time is up, the platform suddenly falls and knocks over the blocks. If the game is completed correctly in time, the player gets the point written on the card.

Team 8- Complete the shape

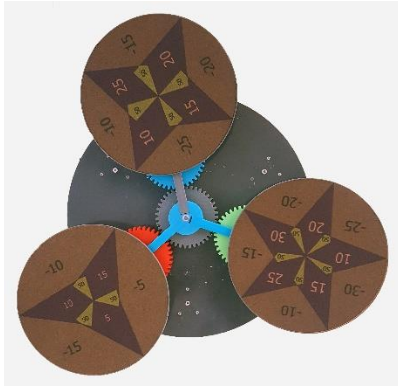
This one-player game is based on a planetary gear mechanism consisting of one environment, one sun, and three pinion gears. With the principle of the planetary gear mechanism, the two bearings always rotate together, depending on the rotating bearings. The goal of this game to complete the shape by rotating the disks attached to the gears.

	3D printed mechanism models	***Final Products***
Team 2	 Drop Camshaft	 The Earthquake
Team 8	 Planet Gear	 Complete the shape

Team 9

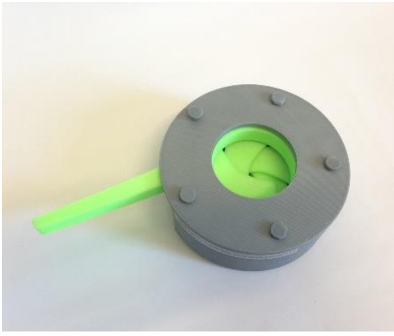


Ferguson’s Paradox



The Paradox Dart Board

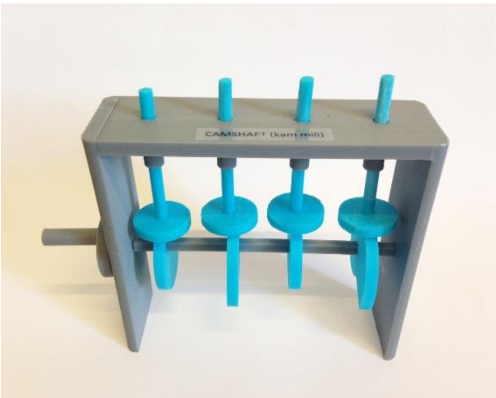
Team 10



Iris Diaphragm

The Brain Pit

Team 11



Camshaft

The Climbing Game

Figure 5. Some of final products of the teams together with their mechanism models

Team 9- The Paradox Dart Board

Differently from dart board game, this has three rotating boards, which makes it more challenging. Ferguson’s Paradox mechanism allows rotating boards in different speeds and directions. It can be played with two or in teams. The game consists of two parts. In the first part, the players try to shoot in positive areas to get points. In the second part, the players try to shoot in negative areas to reduce the score of the opposing players. The players with the highest score win the game.

Team 10- The Brain Pit

This game contains a perforated board and an iris diaphragm mechanism under it. Each player selects a pawn to start the game from the outer of the board. The player who cannot answer the question in the cards correctly move his pion one-step further. At the end of each tour, the iris diaphragm opens which means the nearest the player to the centre, has the highest risk to fall in the brain pit. The last player not falling in the pit wins the game.

Team 11- The Climbing Game

This game has a two-sided platform, which consists of stairs. The stairs attached to the camshaft can raise and lower pressing the button. The players try to get the balls to the top of the platform by raising and lowering the stairs. The balls reaching the top are added to the opposing player's ball pool. The player who finishes the balls first wins the game.

Post-project questionnaire results

From 41 students participated in the project, 37 completed the questionnaire. The 4-part questionnaire results are as follows.

Part 1: In this part, students rated the impact of project phases (research, technical drawing, 3D computer modelling, animating, 3D printing, creating concept ideas, and application of mechanism to design project) on the learning outcomes regarding mechanisms.

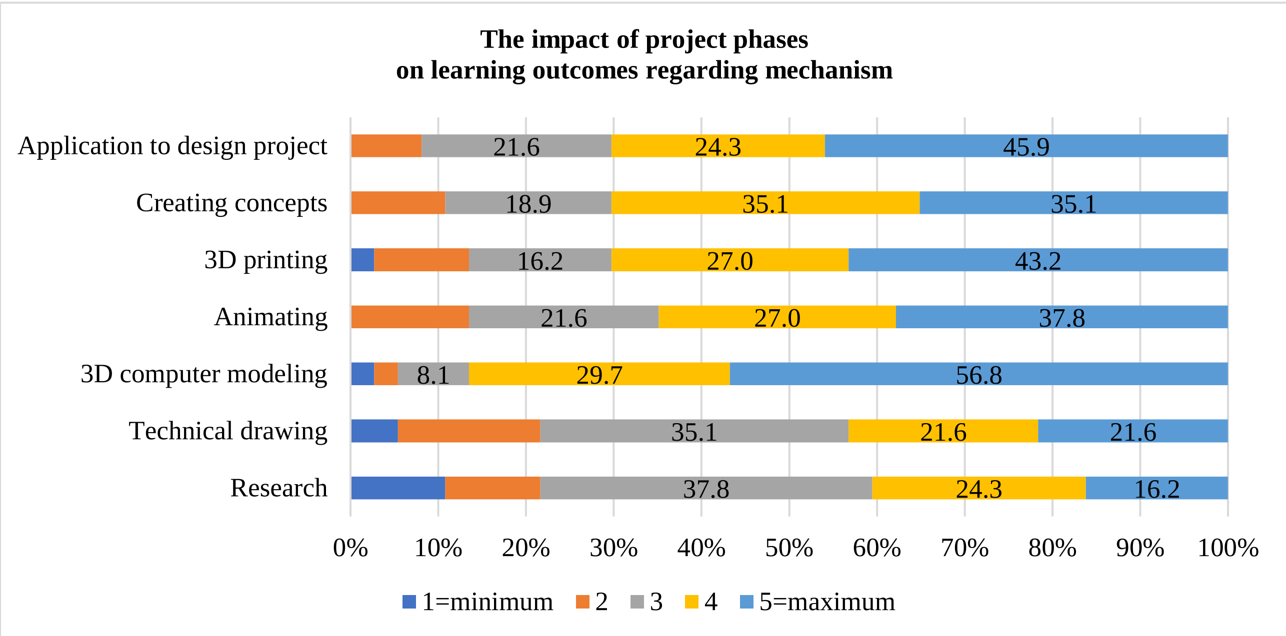


Figure 6. Results of post-project questionnaire part 1

As seen in Figure 6, "3D computer modelling" and "Application to design project (action learning)" received the most 5=maximum responses with 56.8% and 45.9% respectively. The impact of "3D printing" evaluated as 5=maximum with 43'2%. The mean of the all the responses to "3D computer modelling" was 4.35 (highest in the data set) with a standard deviation of 0.949. "Technical drawing" and "research" received the lowest 5=maximum response with 21.6% and 16.2% respectively (Table 6).

	Total (n)	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Total (%)	Mean	SD
Research	*37*	*10.8*	*10.8*	*37.8*	*24.3*	*16.2*	*100*	*3.24*	*1.188*
Technical drawing	*37*	*5,4*	*16.2*	*35.1*	*21.6*	*21.6*	*100*	*3.37*	*1.163*
3D computer modelling	*37*	*2.7*	*2.7*	*8.1*	*29.7*	*56.8*	*100*	*4.35*	*0.949*
Animating	*37*	*0*	*13.5*	*21.6*	*27.0*	*37.8*	*100*	*3.89*	*1.075*
3D printing	*37*	*2.7*	*10.8*	*16.2*	*27.0*	*43.2*	*100*	*3.97*	*1.142*
Creating concepts	*37*	*0*	*10.8*	*18.9*	*35.1*	*35.1*	*100*	*3.94*	*0.998*
Application to design project	*37*	*0*	*8.1*	*21.6*	*24.3*	*45.9*	*100*	*4.08*	*1.010*

Table 6. Basic statistics of the results of post-project questionnaire part 1

Part 2: In this part, the students were asked which were the most challenging phase of the project together with their reasons. The results of responses to the most challenging phase of the project were demonstrated in Figure 7. As seen in the pie chart, the most frequently occurring response was “application of mechanism to design project (action learning)” with 64,9%. “Research” and “technical drawing” received the lowest rating with 2,7%.

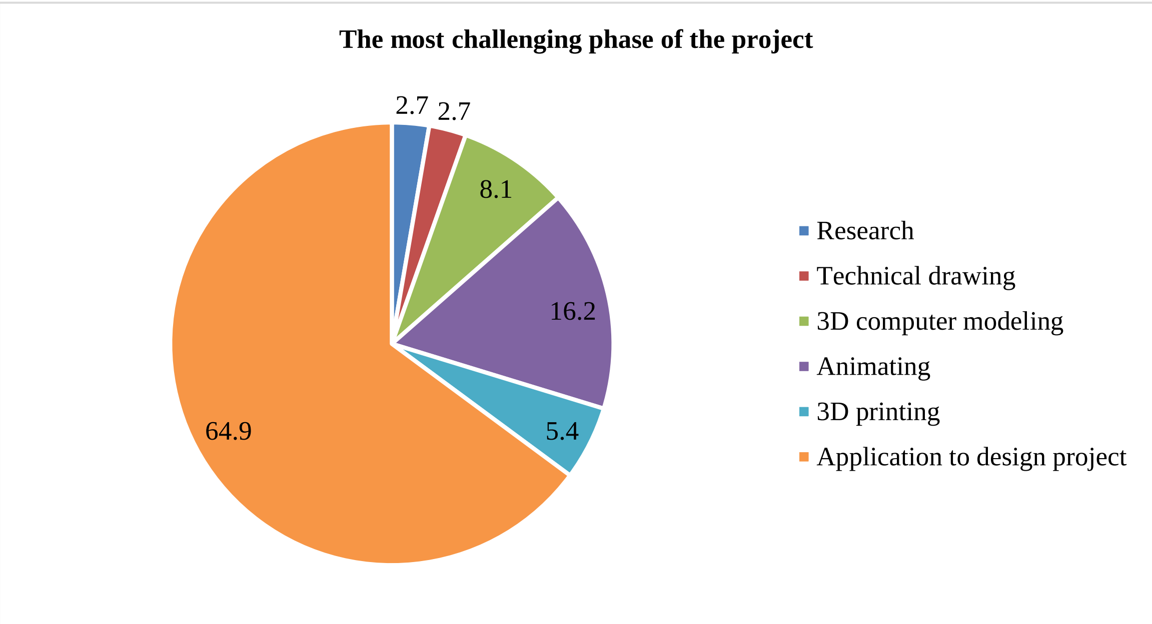


Figure 7. Results of post-project questionnaire part 2

The reasons given by the students who marked “application of mechanism to design project (action learning)” as the most challenging phase of the project are summarised as follows:

- It was challenging that we have to apply assigned mechanism to design project.
- Due to the complexity of the mechanisms, it was difficult to apply the mechanisms to the design project and this made the process more exciting and ambitious.
- We had to create too many design concepts to apply the mechanism appropriately; therefore, it made the process difficult and more intensive.
- Creating the form of a mechanical game design depending on an assigned specific mechanism was difficult thus we had to implement all motional characteristics of the mechanism through various drafts in order to provide a creative game design.
- Teamwork led to contradictory and challenging design ideas.
- Explanations of the students who provided “animating” as the most challenging phase of the project are summarised as follows:
- Since I have not enough knowledge and skills on animating, it was challenging to create motions of mechanisms leading to specific competencies.
- I had trouble while animating motions of mechanism on Autodesk Fusion 360

Part 3: In the third part, students rated their level of knowledge on Autodesk Fusion 360 and 3D printing for before and after the project.

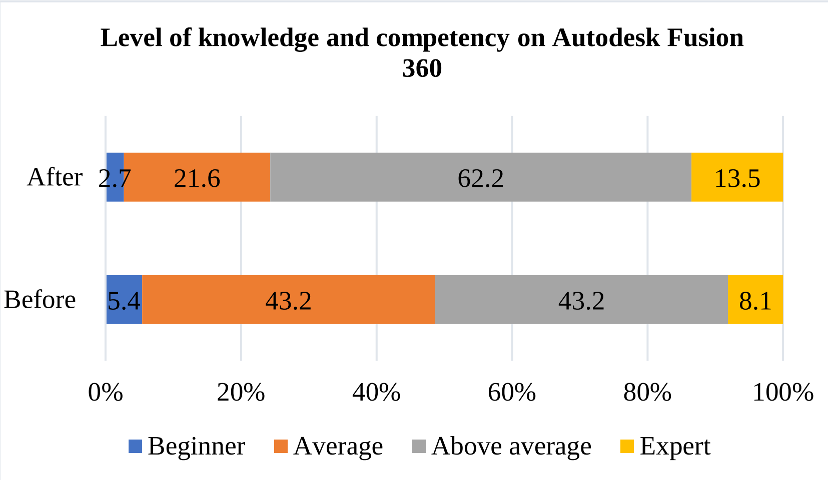


Figure 8. Results of post-project questionnaire part 3 about the level of knowledge and competency on Autodesk Fusion 360

As seen in Figure 8, before the project, knowledge of students on Autodesk Fusion 360 was centred upon average and above average level. After the project, the majority reached the above average level (62.2%). A paired-samples t-test was conducted to compare the level of knowledge on Autodesk Fusion 360 before and after the project. There was a significant difference in the responses for before (M=2.5405, SD=0.730091) and after (M=2.864865, SD=0.673390) situations, p = .000 (Table 7).

	Total (n)	Beginner (%)	Average (%)	Above average (%)	Expert (%)	Total (%)	Mean	SD	Sig. (2-tailed)
Before	37	5.4	43.2	43.2	8.1	100	2.5405	0.730091	.000
After	37	2.7	21.6	62.2	13.5	100	2.864865	0.673390	

Table 7. Results of paired-samples t-test of post-project questionnaire part 3 (level of knowledge and competency on Autodesk Fusion 360)

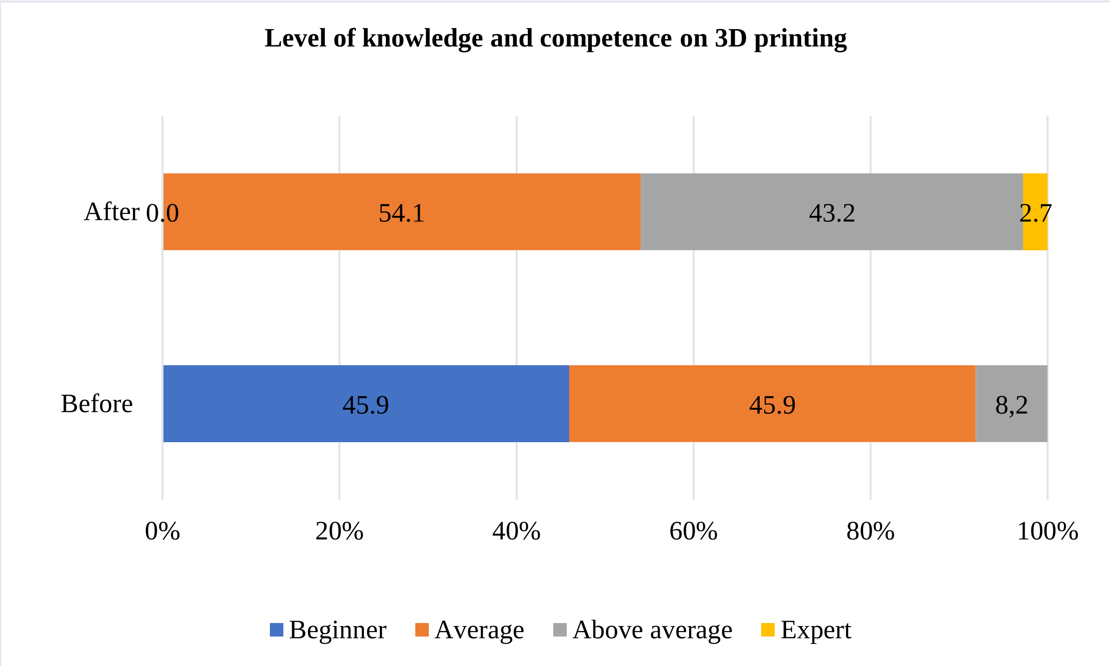


Figure 9. Results of post-project questionnaire part 3 about the level of knowledge and competency on 3D printing

As seen in Figure 9, before the project, knowledge of students on 3D printing was centred upon beginner and average level. After the project, the centre shifted towards average and above average level with 54,1% and 43,2% respectively. A paired-samples t-test was conducted to compare the level of knowledge on 3D printing before and after the project. There was a significant difference in the responses for before (M=1,6216, SD=0,63907) and after (M=2,4865, SD=0,55885) situations; p = ,000 (Table 8).

	Total (n)	Beginner (%)	Average (%)	Above average (%)	Expert (%)	Total (%)	Mean	SD	Sig. (2-tailed)
Before	37	45.9	45.9	8.1	0	100	1.6216	.63907	.000
After	37	0	54.1	43.2	2.7	100	2.4865	.55885	

Table 8. Results of post-project questionnaire part three (level of knowledge and competency on 3D printing)

Part 4: In this part, students rated the acceptability of the 10 questions related to the project process on a Likert scale of 1 to 5, with 1 corresponding to "strongly disagree" and 5 corresponding to "strongly agree". The results of the fourth part of the questionnaire are demonstrated in Figure 10 and basic statistics were presented in Table 9.

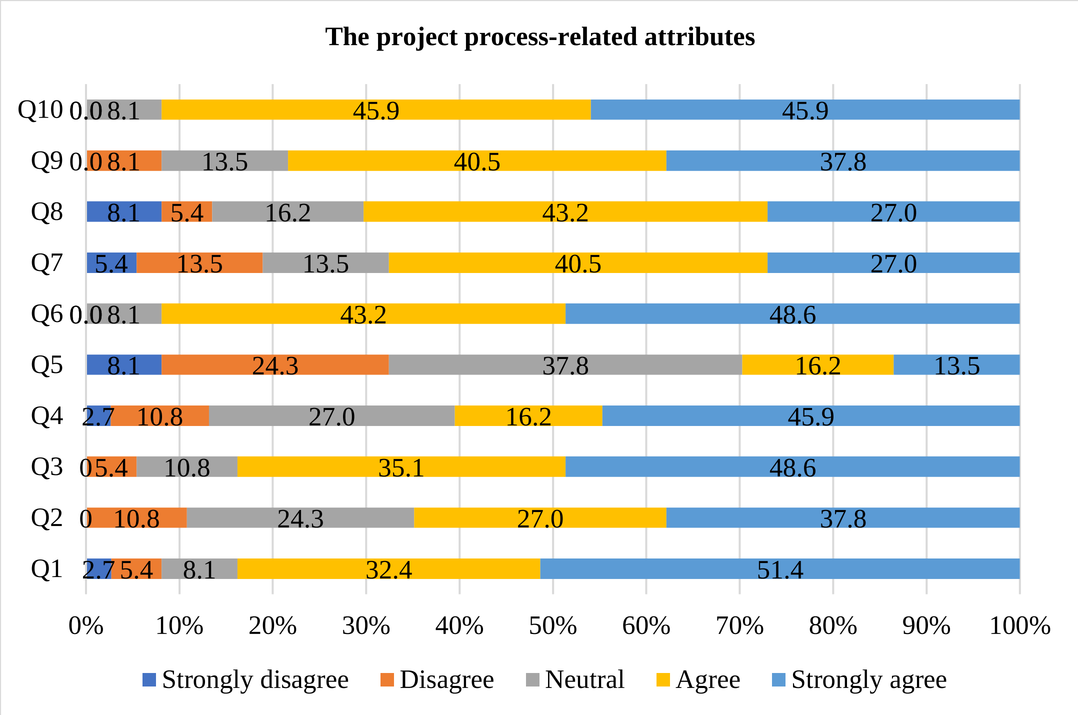


Figure 10. Results of post-project questionnaire part 4

The questions that students rated are as follows:

Q1: 3D printed motion mechanisms allowed me to learn easier.

The responses to this question were largely positive with 51.4% strongly agreeing and 32.4% agreeing and received the fourth highest overall mean of 4.24.

Q2: 3D printed motion mechanisms allowed me to learn other teams' mechanisms.

The responses to this question were mixed with 10.8% disagreeing and 24,3% of the responses being neutral. The mean of all the responses was 3.91.

Q3: 3D printed motion mechanisms provided me to notice the mistakes made in 3D computer modelling.

The responses to this question were mixed but largely positive with 5.4% disagreeing and 10,8% of the responses being neutral and received third highest overall mean (4.27) and third lowest standard deviation (0.871).

Q4: The knowledge of mechanisms gained throughout the project allowed me to create product design ideas easier.

The responses to this question were also mixed with 2.7% strongly disagreeing and 10.8% disagreeing and an overall mean of 3.73.

Q5: Obligation to use the assigned mechanism limited my creativity in the design process.

The responses to this question were largely neutral (37.8%) and received the lowest overall mean (3.03).

	Total (n)	*Strongly disagree (%)*	*Disagree (%)*	*Neutral (%)*	*Agree (%)*	*Strongly agree (%)*	*Total (%)*	*Mean*	*SD*
Q1	*37*	*2.7*	*5.4*	*8.1*	*32.4*	*51.4*	*100*	*4.24*	*1.011*
Q2	*37*	*0*	*10.8*	*24.3*	*27*	*378*	*100*	*3.91*	*1.037*
Q3	*37*	*0*	*5.4*	*10.8*	*35.1*	*48.6*	*100*	*4.27*	*0.871*
Q4	*37*	*2.7*	*10.8*	*27*	*29.7*	*29.7*	*100*	*3.73*	*1.097*
Q5	*37*	*8.1*	*24.3*	*37.8*	*16.2*	*13.5*	*100*	*3.03*	*1.142*
Q6	*37*	*0*	*0*	*8,1*	*43.2*	*48.6*	*100*	*4.41*	*0.644*
Q7	*37*	*5.4*	*13.5*	*13.5*	*40.5*	*27*	*100*	*3.70*	*1.175*
Q8	*37*	*8.1*	*5.4*	*16.2*	*43.2*	*27*	*100*	*3.76*	*1.164*
Q9	*37*	*0*	*8.1*	*13.5*	*40.5*	*37.8*	*100*	*4.08*	*0.924*
Q10	*37*	*0*	*0*	*8.1*	*45.9*	*45.9*	*100*	*4.38*	*0.639*

Table 9. Basic statistics of the results of post-project questionnaire part four

Q6: I can utilise the knowledge of mechanisms gained for further projects.

The responses to this question were largely positive with only 8.1% of the responses being neutral and received the highest overall mean of 4.41 and the second lowest standard deviation of 0.644.

Q7: Teamwork allowed us to create diverse creative product design ideas.

The responses to this question were mixed with 5.4% strongly disagreeing and 13.5% disagreeing and 13.5% of responses being neutral. The mean of all responses was 3.70 (the second lowest in the data set) and the standard deviation was 1.175 (the highest in the data set).

Q8: This project has increased my motivation to work as a team.

The responses to this question were again mixed with 5,4% strongly disagreeing and 18.9% disagreeing and 18.9% of responses being neutral. The mean of all responses was 3.76 (the second lowest in the data set) and the standard deviation was 1.238 (the highest in data set).

Q9: This project increased my motivation to the product design studio.

The responses to this question were largely positive with only 8.1% disagreeing and 13.5% of responses being neutral.

Q10: The project process was useful for me in general.

The responses to this question were again largely positive with only 8.1% of responses being neutral. The mean of all the responses was 4.38 which is second highest in the data set and received a standard deviation of 0.639 which is the lowest in the data set.

Conclusion

Although it is reported that knowledge and principles of mechanical designing is an important item for industrial designers (Liu et al., 2013), the studies on the teaching of mechanical mechanisms to ID students are limited. In spite of its importance, mechanics-based courses are generally taught through traditional lecture-based style in ID departments in Turkey. In addition, there is no integration between mechanics-based courses and design studio courses, which makes difficult for students to apply the knowledge of mechanisms to the design projects.

This paper has proposed and presented a new teaching model combining three main phases: Improving theoretical knowledge of mechanisms and possible applications, in-depth practical knowledge of specific mechanisms and application of mechanism into design a process (action learning). Integration of this teaching model to the design project aimed to improve ID students' learning experience providing transference of theoretical knowledge into practice. Furthermore, this combined teaching model covered all learning styles of K-LSI although focused on learning by doing and experiencing. Thus, it supported the notion that "design students learn in diverse ways". (Carmel-Gilfilen, 2012; Demirbas and Demirkan, 2003, 2007; Demirkan and Demirbas, 2008; Demirkan, 2016; Kvan and Yunyan, 2005). The evaluation of this teaching model focuses on project observations and post-questionnaire to analyse objectively the appropriateness of it.

Observations of project process and submissions revealed that in all three phases of the project the expected outcomes were highly obtained. All phases fed each other and the knowledge of mechanisms cumulated from the first phase to final phase. Research and technical drawings of mechanisms provided students with sufficient theoretical knowledge for utilising in the phase of practical knowledge. The practical knowledge phase reinforced the knowledge of mechanisms by transferring theory to practice with 3D computer modelling, 3D printing and animating. 3D computer modelling enabled students to comprehend the parts of the mechanisms and the relations between them. Having to model for 3D printing provided the opportunity to learn about the optimum wall thicknesses of the parts and tolerances between them. It also contributed to gaining concrete experience about manufacturing principles. These applications increased the students' practical knowledge of 3D modelling and printing. Cumulative knowledge gained throughout the project facilitated the application of mechanisms to mechanical game design project.

The results of post-questionnaire indicated that the students thought that although the most challenging phase was the application of mechanism, it was also the second most effective phase on their learning of mechanisms. Therefore, application of mechanism to a design project is vital to gain sufficient competencies for comprehending the function of the mechanisms. Studies indicate that design students are found in all stages of Kolb's learning cycle. However, diverging and accommodating learning styles (learning by doing and experiencing) are dominant and a better fit for design education (Carmel-Gilfilen, 2012). In addition, design students prefer sensing, visual and active learning styles; that is, learning facts and concrete materials, visual information and hands-on activities (Demirkan, 2016). Accordingly, mechanics-based courses in ID departments must be revised in terms of design students' learning styles. They should introduce the concept of problem-based action learning (learning by doing and experiencing) inside the learning system since this style emphasises direct utilisation of the otherwise very abstract knowledge of scientific theories. Apart from that, such courses should collaborate with design studio courses within a problem-based action-learning environment. Therefore, the further step of this combined teaching model will be the extension of the applied model of action learning model to problem-based learning through simultaneous or consecutive mechanics related course and product design studio.

The studies suggest that design students show a preference to work in teams (Nussbaumer and Guerin, 2000; Bender, 2004; Carmel-Gilfilen, 2012; Demirkan, 2016). The findings also support that teamwork increases design students' creativity and motivation. Similar to design-studio projects, collaborative projects might be adapted to mechanics-based courses.

The results revealed that 3D computer modelling was the most effective phase during the process. It supports the fact that designers are visual and active learners. Thus, assignments could be designed mainly based on visual information and hands-on activities like drawing, 3D modelling and testing. It also supports that design students prefer a sensing learning style like facts and concrete material rather than theories. The study also revealed that designers prefer visual information rather than verbal ones. As Demirkan 2016 stated, designers learn better with pictures, schemas and videos. Moreover, it is found that design students are active learners; they prefer teamwork and hands-on activities, like sketching or constructing a 3D model. They learn better by doing and applying.

The results of post-questionnaire also indicated that students agreed that the project was effective in terms of their motivation to the course and useful for further projects. Thus, the first thing to do in the product design studios is to motivate students' interest. An emphasis on case studies in practical design greatly improves industrial design students' abilities in applying mechanical design theory.

The curriculum of an industrial design programme consists of various courses; namely fundamental courses, technology-based courses, artistic courses and design studio courses (Demirbas and Demirkan, 2007; Demirbas, 2001; Uluoğlu, 1990). Since courses have different dynamics, appropriate learning styles might differ according to the type of courses. Studies found that there is a significant correlation between learning style and students' academic performance in design education (Demirbas and Demirkan, 2007; Kvan and Yunyan, 2005). Therefore, instructors should be aware of learning styles and place emphasis on specific exercises accordingly.

This study was based on data collected from 41 students and limited to one University; hence, for generalisability of results in design education larger samples are required. However, overall results of the project established that this combined teaching model of mechanisms improved ID students' learning outcomes and competencies in terms of transferring the gained theoretical and practical knowledge to the action learning through creating a game design including the concrete function of the mechanism inside the system.

Although this study focuses on the teaching of mechanisms, the general approach on implementation and evaluation could be extrapolated to other ID courses.

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