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Development of an Educational Kit Using CAD Software for Simple Machine Learning

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ABSTRACT

Traditional simple machine topic is frequently theoretical and does not provide enough hands-on practise. Students may as a result fail to comprehend the fundamentals of simple machines and their applications. This research presents an innovative educational kit for simple machine learning. Students can utilize this kit to understand the fundamental concepts behind simple machines like levers, gears, and pulleys. This study investigates the creation of a simple machine kit using CAD software as a teaching tool for fundamental mechanics. A survey study is employed as part of this technique in order to ascertain audience needs and expectations. Beginning with idea generation and followed by rigorous evaluation, the process of developing the kit focuses on aligning pedagogical viability, marketability, and profitability. The selected concept is then transformed into a detailed technical drawing specifying dimensions, components, and assembly instructions, ensuring coherence between educational goals and machine learning integration. Iterative prototyping and testing further refine the kit's design, ensuring seamless interaction between machine learning elements and LEGO-based components. This approach culminates in an innovative educational kit that effectively imparts foundational machine learning principles through an engaging platform. The simple machine kit made through this research can then be utilized as an educational tool in primary, secondary, or higher education environments to facilitate students' grasp of basic mechanics. Students learning product design may find this novel approach both enjoyable and useful in their studies.

1. Introduction

In the dynamic landscape of education, there is a need to bridge the gap between theoretical learning and practical application. This holds particularly true for fundamental scientific concepts like simple machines [1], where traditional teaching approaches often struggle to offer students a comprehensive understanding that extends beyond theoretical frameworks. The detachment between theoretical concepts and real-world relevance poses a significant challenge to effectively

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conveying the essence of simple machines and their practical utility [2]. To address the pedagogical gap, this research introduces an innovative educational kit for simple machine learning, designed to provide students with an immersive and hands-on exploration of the foundational principles that govern levers, gears, and pulleys. By fusing the interactive potential of LEGO-based construction with the theoretical underpinnings of simple machines, new approach seeks to revolutionize the learning experience, offering students a unique opportunity to engage deeply with mechanics.

This study aims to bridge the divide between theoretical knowledge and practical skills by developing an educational kit that seamlessly integrates the concepts of simple machines with the interactive engagement offered by LEGO components. The significance of this endeavour lies in its potential to transform the way students understand and apply mechanical principles [3,4]. Traditional teaching methods often leave students with a conceptual understanding that may not translate into effective problem-solving in real-world scenarios [5,6]. Hence, the main objective of this study is to create an educational kit that aligns with the needs of various educational levels, from primary schools to higher education institutions. This inclusivity caters not only to students but also extends its benefits to educators seeking innovative tools to enhance their pedagogical strategies. The versatile nature of the developed educational kit enables its integration into diverse learning environments, ranging from conventional classrooms to specialized STEM workshops and collaborative maker spaces. By offering a dynamic platform that merges theoretical understanding with practical application, this study aims to empower learners with a well-rounded grasp of basic mechanics.

Commencing with the generation of ideas and proceeding with a thorough evaluation, the developmental process of the kit is dedicated to match the pedagogical feasibility, market acceptance, and economic viability. The chosen concept is subsequently translated into an elaborate technical illustration, followed by precise measurements, constituent parts, and step-by-step assembly guidelines. This thorough alignment ensures the congruence of educational objectives with the integration of machine learning components. Through a sequence of iterative prototyping and comprehensive testing, the design of the kit is continually refined, guaranteeing a seamless synergy between the elements of machine learning and the LEGO components. This method finalized in the creation of an inventive educational kit, adeptly conveying fundamental machine learning principles through an immersive LEGO-centred platform.

Overall, the introduction of this CAD-based simple machine kit presents a significant advancement in basic mechanics education. By bridging the gap between theory and practice, it is hopefully may empowers students to grasp the principles of simple machines more effectively, promoting a deeper comprehension and fostering enthusiasm for the subject matter.

2. Methodology

In the context of developing a LEGO-based educational kit for simple machine learning, the product design process encompasses a systematic approach as represented in the following flow chart as shown in Figure 1. It is a common practice of innovation and product design, as well as the development of educational kits, this research employed the Double Diamond Design Process Model [7]. This established model, as conceptualized by The Design Council UK, outlines a structured approach involving distinct phases characterized by divergent and convergent cognitive processes.

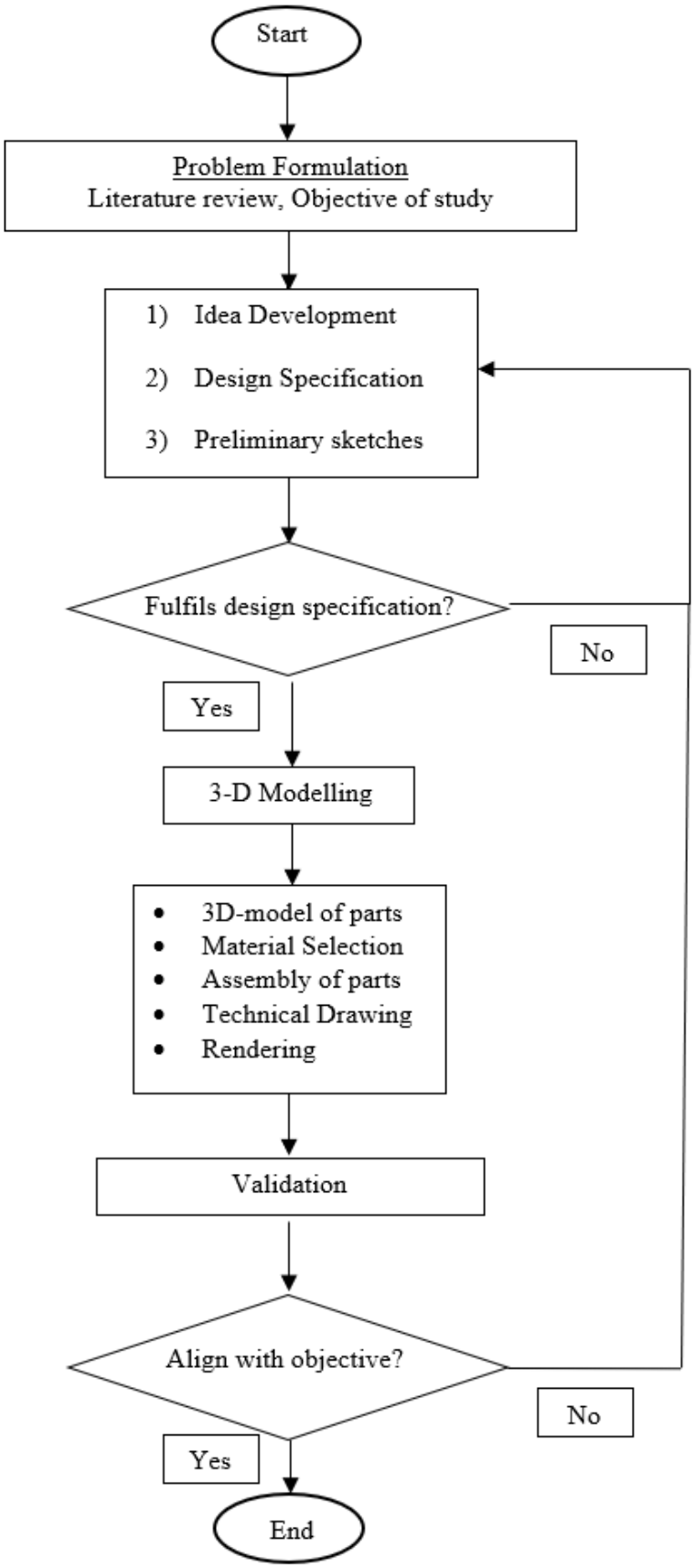


Fig. 1. Methodology flowchart of developing simple machine educational kit

The present exposition expounds upon the adaptation of this model for the purpose of designing educational kits, with specific reference to Figure 2. The following sections provide a brief explanation of each phase and its associated activities intrinsic to the particular development of the LEGO-educational kit.

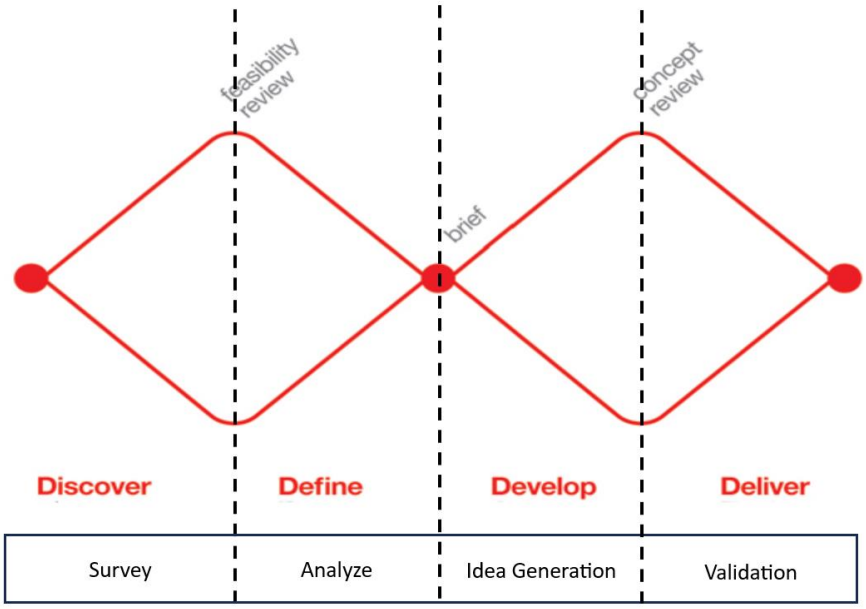


Fig. 2. 'Double Diamond' Design Process Model (Adapted from Design Council UK, 2005)

2.1 Discover: Survey

In the initial phase, this research focuses on comprehending customer needs related to the educational product, specifically centred around basic concepts of simple machines. This involves conducting a survey among primary school students and teachers to gather preferences regarding the educational kit's features. The survey incorporates a mix of closed and open-ended questions to quantitatively and qualitatively capture participant insights, respectively. This survey will further be needed for sketching the product according to the customers need based on the questions. Moreover, result from this survey will pave a crucial foundation for subsequent design stages, guiding the creation of a targeted and effective educational kit.

2.2 Define: Analyses

This phase involves analysing the findings gain from the questionnaire. For open ended question, the result was analysed using thematic analysis.

2.3 Develop: Idea Generation

Figure 3 provides an encompassing overview of the third phase: Develop - Idea Generation. This phase is focused on the generation of ideas to effectively tackle the identified problem. Within this phase, the team engages in the creation of numerous concepts, subsequently fashioning prototypes to undergo testing.

Sketches > Idea Selection > 3D modelling > Prototyping

Fig. 3. Activity in Developing Phase

This process encompasses the transition from conceptual sketches as shown in Figure 4, to the realization of three-dimensional forms. Following this, the ideas undergo a screening process to facilitate idea selection. The initial step in this phase is ideation, a process that involves the generation of a diverse array of concepts. The wide range of ideas presented here aims to examine many possible approaches for incorporating LEGO construction with key concepts in machine learning. Following the aforementioned creative process, the proposed concepts are transformed into tangible form by employing Computer-Aided Design Software. Many researchers used CAD software to visualize their designed products and components [8]-[14]. In this research, the selected type of simple machine with its design concept was sketched and visualized by 3D model drawing using Autodesk Fusion 360 software.

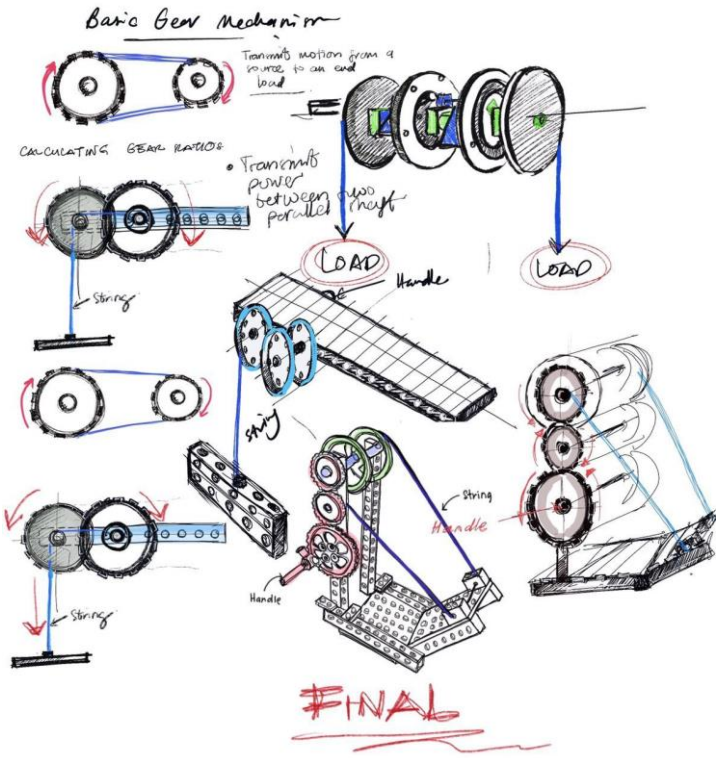


Fig. 4. Conceptual sketches

2.4 Deliver: Validation

The following crucial stage includes the transformation of the selected concept into a tangible product. This involves the development of a thorough technical illustration that outlines technical particulars, including measurements, components, and instructions for construction. The primary difficulty resides in successfully integrating the design components with the deeper educational objectives, while also assuring a smooth integration of machine learning principles. The technical drawing functions as an extensive layout, providing guidance for the succeeding phases of the development process. During this phase, the iterative aspect of product design becomes apparent when the next phases of prototyping and testing are undertaken. Prototypes are fabricated in accordance with the technical drawing, facilitating a practical evaluation of the feasibility and efficacy

of the projected teaching kit. Thorough testing procedures are implemented to ensure smooth interaction between the machine learning components and the LEGO pieces, hence promoting a learning experience that is user-friendly in design. This iterative loop between design, prototyping, and testing is vital to refine the educational kit, ensuring that it not only imparts machine learning concepts effectively but also aligns with the practical constraints and expectations of the target audience. The final validation phase involves testing among the students and validation of the educational kit among the experts. This educational kit was submitted in Invention, Innovation and Design on e-Learning 2023 (IIDEL2023) where it was a great opportunity and platform to gain feedback on the usability and the marketability of the educational kit.

2.4.1 Usability

Since the usability were test out among the students, to make the process of gaining the input is enjoyable, stickers were provided for them to stick at the evaluation board. The evaluation board as shown in Figure 5 was designed to assess the student perception towards their experience while playing the educational kits. They need to paste the sticker at specific criterion of five (5) Likert scale; ranging from 1(very poor) to 5(excellent). The simple survey was comprised items related to the student's overall satisfaction towards the experience while assembly the drawbridge and effectiveness of the module provided.

Fig. 5. Evaluation Board

2.4.2 Marketability

The validation phase involved asking jury's opinion and feedback toward the marketability of the educational kit. Figure 6 is the form were use in the validation phase.

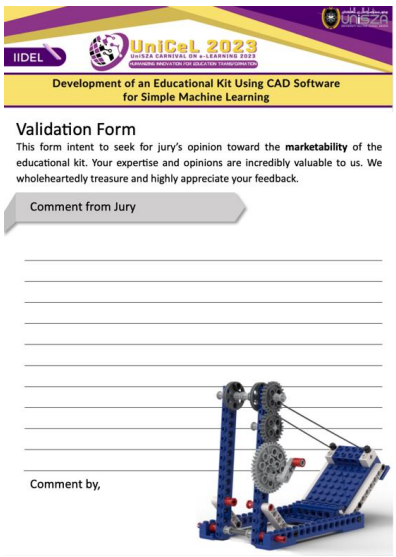


Fig. 6. Validation Form

3. Results and Discussion

3.1 Survey Analysis

Based on a survey conducted with 41 respondents, including teachers and primary/secondary school students, various ideas emerged for the development of a LEGO-based educational kit. Majority of respondents, 92.7% were familiar with the topic of simple machines, while 7.3% were not. The survey results, presented in Figure 7, reveal the most suitable concept of on the LEGO-based educational kit. In terms of suitable concepts, pulleys and wheels/axles received the highest percentage at 80.5% followed by gears while levels and screws with the same 18% percentage of preference. The least preferred concept was the inclined plane, chosen by 39%. All respondents agreed that the kit would enhance students' psychomotor learning. Overall, the toolkit aims to enhance hands-on learning, promote STEM education, and foster critical thinking and problem-solving skills in students.

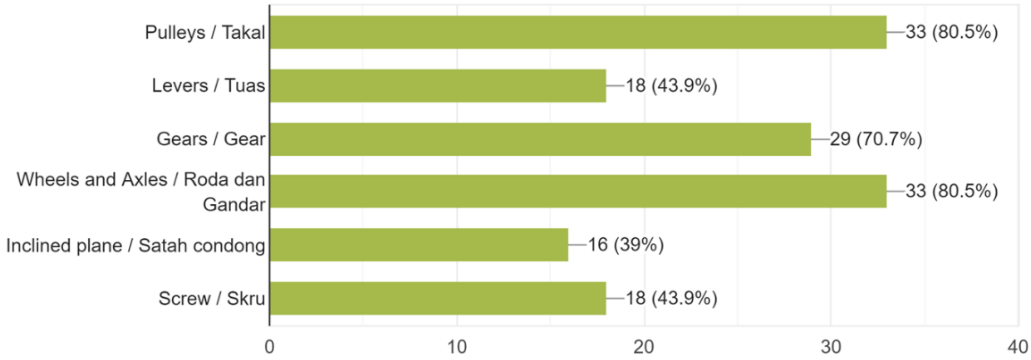


Fig. 7. Survey results on most suitable concept of LEGO- based educational kit

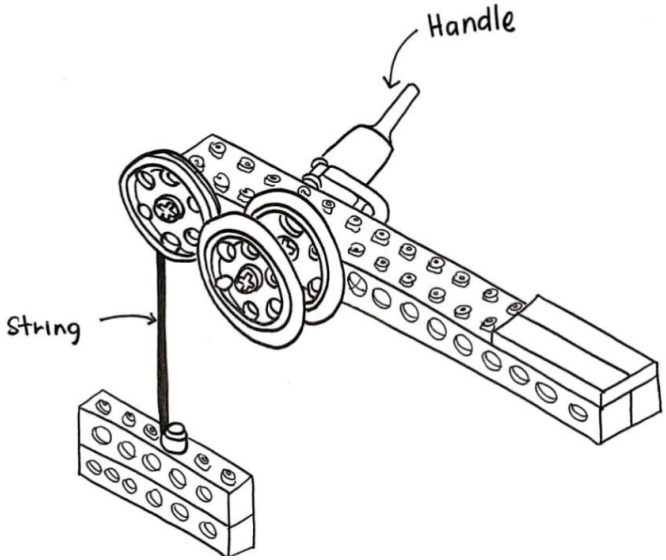
3.2 Simple Machine Educational Kit Ideation

The outputs from the survey are included into the following concepts, which include a thorough instructional guide in the educational kit design. This will necessitate the creation of a thorough instructional manual that offers detailed directions for constructing a range of small parts components. The instruction manual should contain simple graphics, explanations of fundamental concepts, and suggested activities to encourage students to investigate various ideas and do experiments with the kit. Three sketches of hand pulley (Design 1), crane (Design 2), and drawbridge (Design 3) were come out with particular concepts with additional of ecstatic value.

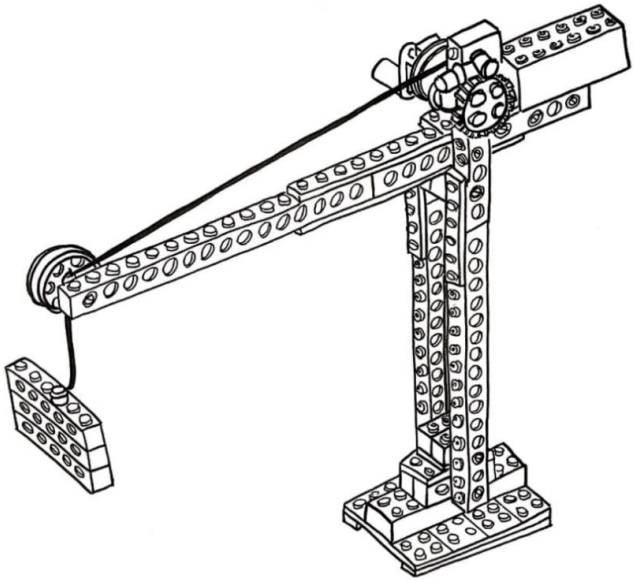
The instructional kit equipped with a modular building system that makes it simple to create and modify simple machines in addition to addressing the drawbacks of conventional learning techniques in basic mechanics education. Li asserts that a modular design for instructional kits gives students flexibility and fosters creativity by enabling them to experiment with various configurations and comprehend the effects of design modifications on machine functionality [2,15]. The use of LEGO-based components is consistent with research from Mazumder, who emphasises the importance of practical construction activities for improving students' comprehension of mechanical principles [16].

Apart from that, it motivates students to actively participate in the creation and modification of simple machines by utilising a modular building concept. They can experiment with various component arrangements, investigate how modifications impact mechanical operations, and track cause-and-effect connections. Students can gain a stronger knowledge of the fundamental ideas behind basic machines thanks to this hands-on approach, which encourages experiential learning

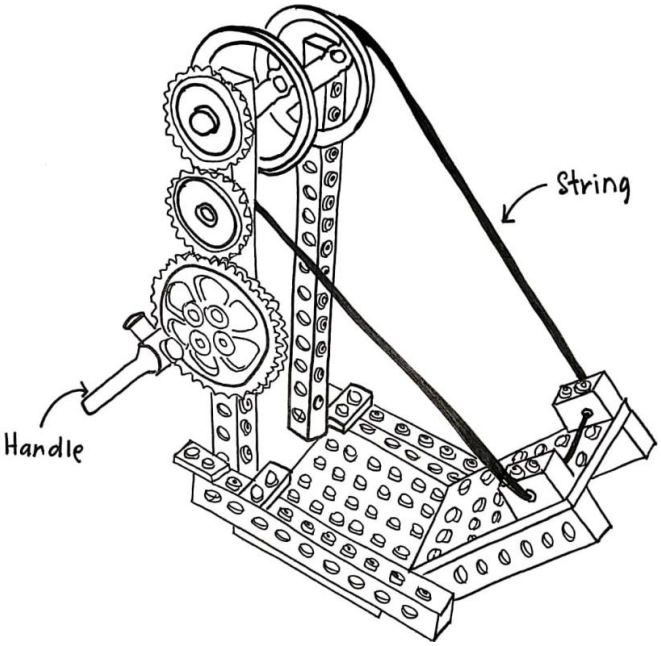
[17,18]. This adaptability facilitates diversified learning experiences and takes into account the various learning styles and capacities of students, as proposed by Lopez [19,20]. Figure 8 shows three design ideations of Hand Pulley, Crane and the Drawbridge.



(a) Design 1 (Hand Pulley)



(b) Design 2 (Crane)



(c) Design 3 (Drawbridge)

Fig. 8. Hand Sketches of a. Design 1 (Hand Pulley) b. Design 2 (Crane) and c. Design 3 (Drawbridge)

3.3 Idea Selection

The idea selection phase plays a pivotal role in shaping the design of the LEGO educational kit for integrating simple machine learning concepts involving pulleys, levers, and wheels. The selected concept must effectively communicate core mechanical principles, offer a progression of difficulty, and seamlessly integrate into the LEGO educational framework. Once the concept was refined, then only the basic prototypes was further developed. Ultimately, the chosen concept becomes a representation of pedagogical innovation, delivering an immersive educational journey that interprets the mechanics of pulleys, levers, and gears. The idea selection was done by screening and scoring concepts as shown in Table 1 and Table 2, respectively.

Table 1
Concept screening

Selection criteria	Design 1	Design 2	Design 3
Safety	+	-	0
Easy to assemble	+	0	0
Able to attract students	-	+	+
High quality	+	+	+
Size	-	+	+
Ergonomic and suitable for use by students	+	-	+
SUM +'S	**4**	**3**	**4**
SUM 0'S	**0**	**1**	**2**
SUM –'S	**2**	**2**	**0**
NET SCORE	**2**	**1**	**4**
RANK	**2**	**3**	**1**
CONTINUE?	**Yes**	**No**	**Yes**

Table 2
Concept Scoring

		Concepts			
		DESIGN 1		DESIGN 3	
Selection criteria	Weight	Rating	Score	Rating	Score
Hands on experience	20%	4	0.80	3	0.60
Enjoyable	25%	3	0.75	3	0.75
Able to attract students	15%	2	0.30	5	0.75
High quality	10%	3	0.30	4	0.40
Size	10%	3	0.30	4	0.40
Ergonomic and suitable for use by students	20%	4	0.80	4	0.80
TOTAL SCORE		3.25		3.70	
RANK		2		1	
CONTINUE?		No		Yes	

Based on the screening and scoring, the third ideation had the most matching criteria for the LEGO simple machine product followed by the first and second ideation. The priority in criteria selection was based on less easiness of assembly and interesting. The model was then created with 3D modelling and technical drawing as shown in Figure 9 and Figure 10, respectively.

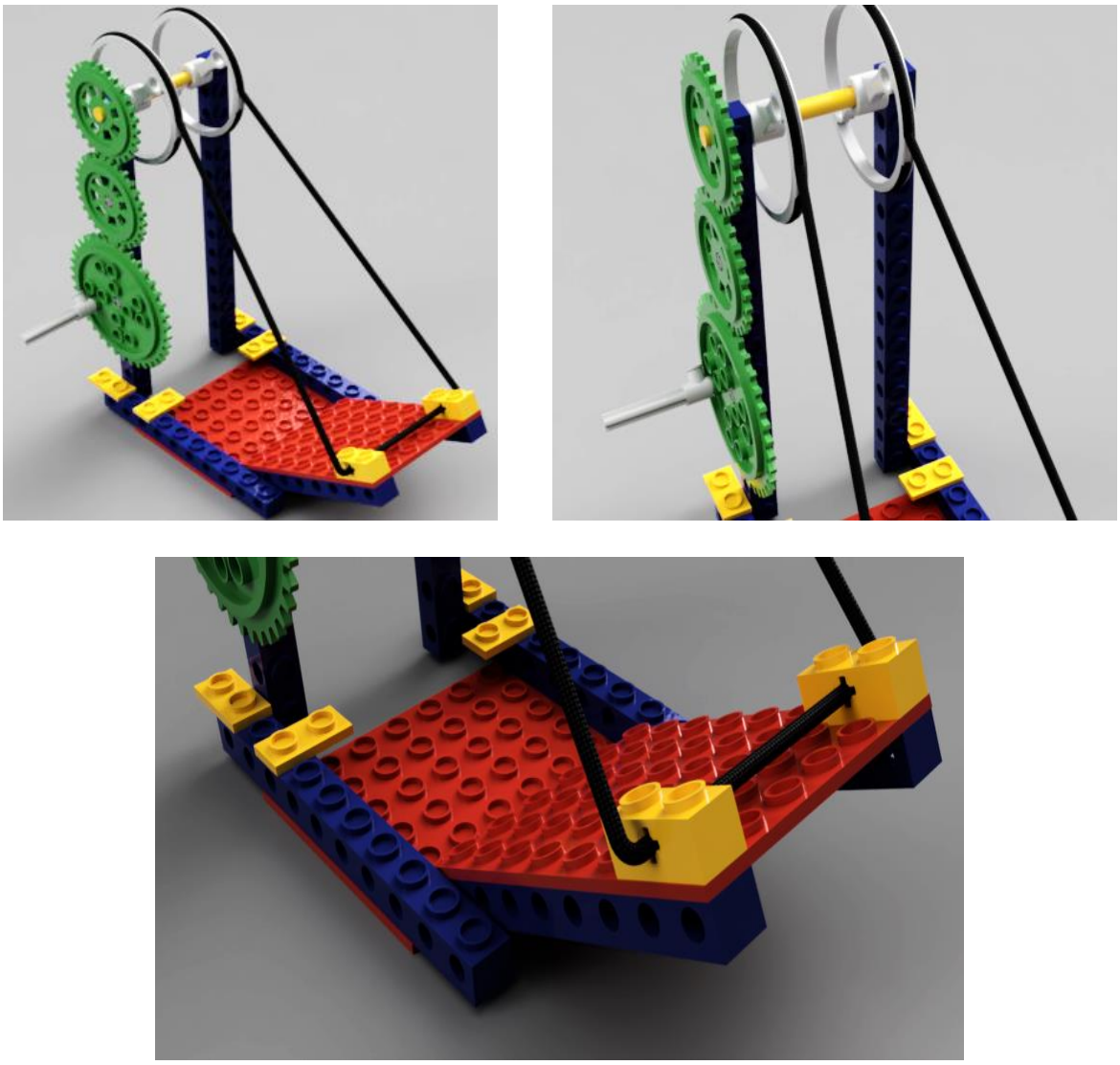
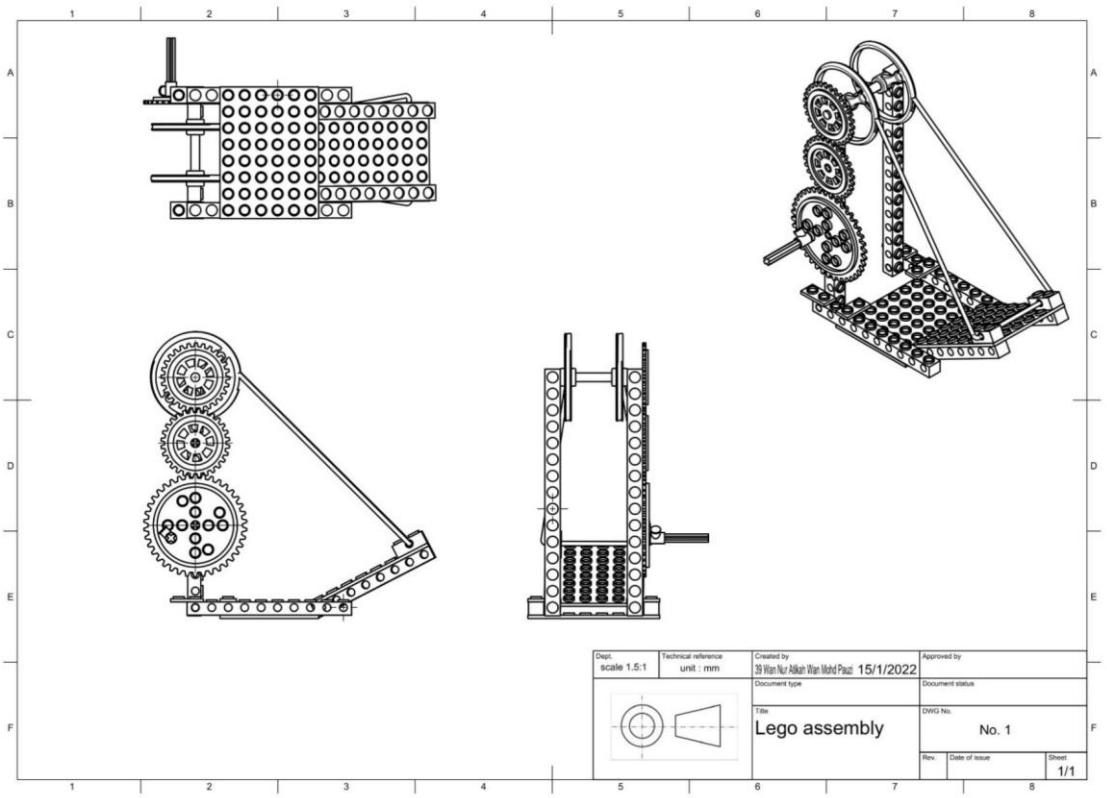
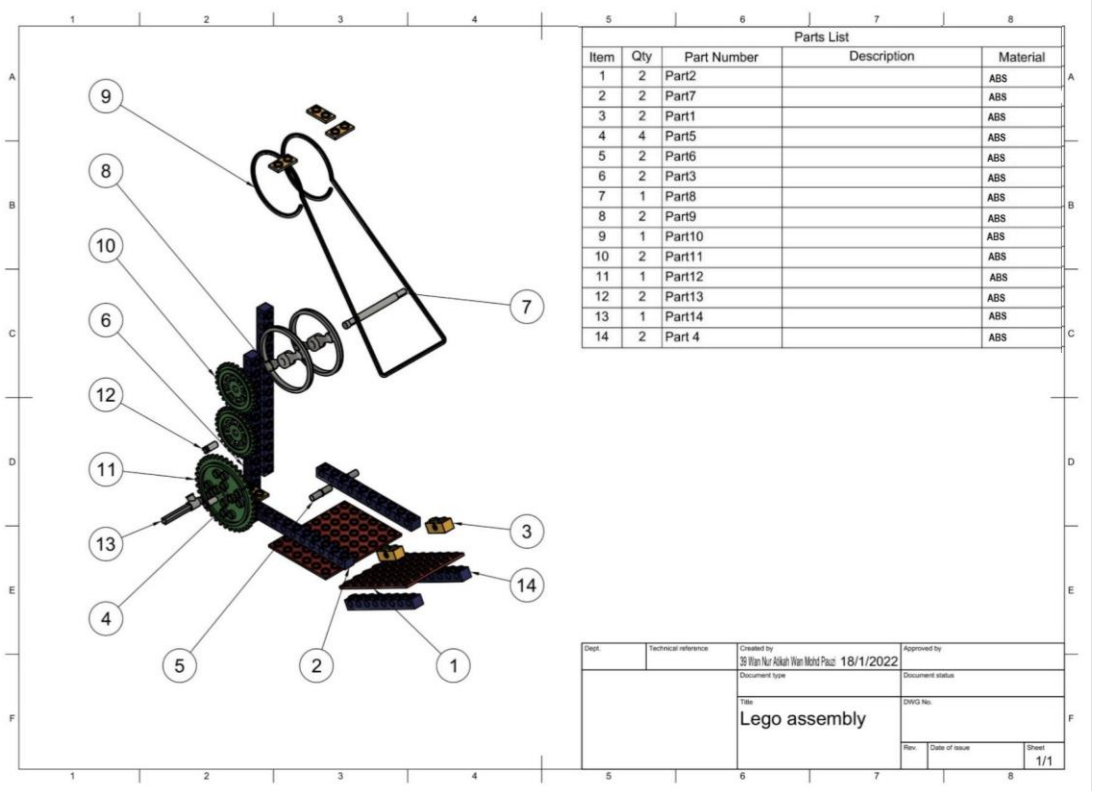


Fig. 9. Final design ideation



(a) Isometric view of final design



(b) Exploded view of final design

Fig. 10. Final design (a) Isometric view (b) Exploded view

3.4 Validation

Figure 11 shows the chosen conceptual design that was transformed into a tangible educational kit product and complete with module instructions and fundamental of simple machine learning. This proves the comprehensive previous stage of technical drawing, 3D modelling that outlines intricate details, such as dimensions, components, and assembly instructions. The challenge of effectively aligning the design elements with the overarching educational goals was addressed. The integration of simple machine learning principles is seamlessly incorporated into the design to ensure that the kit fulfils its intended educational purpose. Prototypes was constructed based on the technical drawing, allowing for a hands-on assessment of their feasibility and functionality. This helps ensure that the envisioned educational kit can be practically realized and used effectively. Rigorous testing ensures that the machine learning components interact harmoniously with the LEGO elements. This interaction is critical to fostering a user-friendly learning experience that effectively imparts simple machine learning concepts.

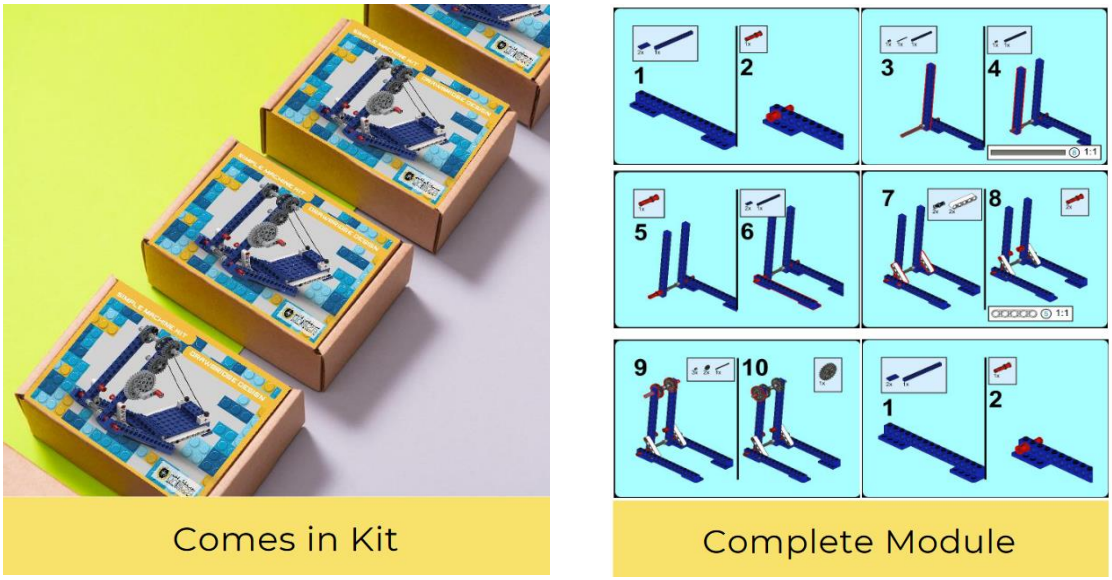


Fig. 11. Conceptual design of LEGO-based educational kit

The final validation phase involves testing the educational kit among students and obtaining validation from experts during the Invention, Innovation, and Design on e-Learning 2023 (IIDEL2023) event as shown in Figure 12. This process gathers insights and feedback on the kit's usability and effectiveness from both end-users and knowledgeable individuals. Submission of the educational kit to IIDEL2023 provides an opportunity to engage with the educational community and receive valuable feedback on various aspects, including usability and marketability. The conceptual design's successful translation into a usable educational product, alignment with educational objectives, seamless integration of simple machine learning principles, iterative refinement, and validation from students and experts within the context of an educational level.

Fig. 12. Students and expert validation process of simple machine educational kit during IIDEL 2023

4. Conclusions

The present research has successfully developed a comprehensive educational kit for simple machine learning using LEGO-based components. The utilisation of computer-aided design (CAD) modelling and a systematic design approach in the creation of an instructional kit. The design of the kit prioritises inclusion as its primary objective, aiming to provide advantageous resources for both students and instructors. These tools encompass state-of-the-art advancements that enable their seamless incorporation into various educational settings, encompassing both conventional teaching spaces and specialist instructional sessions. Consequently, they strive to assure inclusivity and foster active engagement. The aim of this study is to augment learners' understanding of the principles underlying basic mechanics, such as levers, pulleys, and gears, through a comprehensive integration of theoretical concepts and practical application. The development method of the kit is guided by pedagogical feasibility, market acceptance, and affordable, as it was designed with a hands-on and compact size. The applied strategy followed a structured design process consisting of several steps, including sketches, idea selection, 3D modelling and prototyping. From validation, students enjoy the experienced learning with a more effective approach to comprehending the fundamental concepts underlying basic machines. As a result, the kit has the potential to cultivate a deeper understanding and enthusiasm for the subject matter, so enriching the educational experience and promoting the growth of a more empowered comprehension among students.

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