UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

QUANTITATIVE CONTENT ANALYSIS OF THE IMPACT OF UTILIZING THE “VIRTUAL-OBJECT” ON THE ENGINEERING STUDENTS’ PEDAGOGY

A THESIS

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

Degree of

MASTER OF SCIENCE

By

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Norman, Oklahoma

2020

QUANTITATIVE CONTENT ANALYSIS OF THE IMPACT OF UTILIZING THE “VIRTUAL-OBJECT” ON THE ENGINEERING STUDENTS’ PEDAGOGY

A THESIS APPROVED FOR THE

SCHOOL OF AEROSPACE AND MECHANICAL ENGINEERING

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This thesis is dedicated to

my Cadence

Acknowledgments

I would like to express my sincerest appreciation to my advisor Professor Siddique; he backed me up when it really counted! I am especially grateful to him for believing in me and supporting me while I pursued my interests in the new field of engineering. It was his thoughtful guidance, extensive knowledge, and positive energy, which inspired me throughout my master's study. I will always be honored to have his signature under my degree throughout my professional career. I learned a lot from his exemplary leadership, professionalism, and high standards of ethics. He is a noble professor who taught me lessons of honesty, dignity, and sympathy, and I will be his student all over my life.

I want to give my special thanks to Professors Dr. Shabgard and Dr.Liu for serving on my committee. Without the support of Dr. Shabgard and his valuable advice and considerable patience, this research could not be accomplished. I am thankful for his encouraging attitude, sincere collaboration, and honorable character. My mechanical engineering foundations established in the “Design Mechanical components” course under professor Liu’s education. His genuine advice and outstanding knowledge were the first spark that heartened me to believe that success is achievable for me in the engineering field.

I would like to express my solemn gratitude to Dr. Marilyn Korhonen and Professor Dr. Lloyd Korhonen, for their precious counsel and unlimited support throughout my research. Moreover, their friendship is the exquisite treasure for my family and me and is the reason that I believe in miracles!

I am thankful to Professor Sahabeh Tabrizy for his professional advice regarding the statistical evaluation of the data in this research. I am grateful to know Dr. Sahabeh Tabrizy and his wife, dear Shima Shahahmadi, and honored to have their friendship.

I would like to express my eternal love and gratitude to my parents, Mr. Hashem Mobaraki and Mrs. Azam Mahmoodi-Ashan for unconditional love, sacrifice, and timeless support which makes the distances meaningless. As my first teachers in life, they taught me to love and respect humanity and honesty, which is my primary life goal to follow their advice. Furthermore, I want to express my thanks to my husband, Dr. Farid H Omoumi, to be my friend and reliable support. His unlimited love, outstanding solidarity, and bright wisdom over the years encourage me to overcome any challenges. I am grateful to my little angle, the meaning of my life, and the vivid origin of happiness, my lovely Cadence. Her presence is my hope for the future, my ambition, and the strength to fulfill my dreams. As a mother, I want to be her inspiration and to show her that being her mom was and is an endless source of divine energy to empower me in a path of success.

I want to give my thanks and most profound love to my dear sister Dr. Solmaz Mobaraki and my brother, Dr. Babak Mobaraki, for being my pure friends, ever-present supports, and unlimited source of kindness and positive energy.

I also would like to use this opportunity to express my sincere gratefulness to my first teacher in the United States, life tutor, and my sagacious confidant, dear

Betty Brown. I always feel honored and indebted to Betty and her husband, Jim Brown, for their genuine love and support.

I also want to acknowledge the faculty, staff, and the students of the University of Oklahoma, especially the department of Mechanical engineering, who helped me to accomplish in my study, additionally I want to appreciate Dr.Diana Bairaktarova and her students in Virginia Tech University for their contribution in this study.

I want to express my gratitude to National Science Foundation (NSF) for their support. This thesis is based upon work primarily supported by the NSF under NSF Award Number DUE 1712103/1712210. Any opinions, findings and conclusions, or recommendations expressed in this thesis are those of the author(s), and do not necessarily reflect those of the NSF.

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Abstract

Undoubtedly, “Knowledge” is the most precious heritage passed through generations. “Learning,” the ability to acquire, internalize and improve knowledge is the critical factor helping human beings to prevail in challenges, solve complicated puzzles and adapt to new situations or regulate conditions to sustain their existence and have a comfortable and dominant life in the universe. Therefore “Education,” as the instrument of learning, is the initial requirement for human to promote his quality of life. Education is emphasized in all epochs, and the demands and facilities of each era characterized the evolving feature of educational techniques.

Today’s era of exponential technology expansion demands adjustments in educational practice. New designing software, data analyzing, and coding, artificial intelligence, and internet-based facilities are a few examples of the latest technology that can be utilized in this field. New demands, like online education, arose from the faster pace of life, which have been escalated by the recent COVID-19 pandemic, are also emphasizing in the importance of the modifications in education.

The engineering field as a part of STEM education is not an exception to all these adjustments. Moreover, engineering, as a practical field, demands learning skills and should be collaborating with rapidly changing industry needs. A decade ago, to address future challenges and needs in engineering education, the National Engineering Education Research Cocliques (EERC) is founded.[1] The EERC suggests that engineers need to continually learn about the new discoveries and innovations in the engineering field, and because of this, engineering education needed to be transformed [2].

Virtual laboratories are the facilities provided by technology in recent years and can be used as a valuable educational instrument in practical learning settings. They are

interactive environments enabling simulated experiments and especially advantageous when the real laboratories are so complicated or difficult to use. Virtual objects are experimental units, and their educational potentials have been argued in many researches [3,4,5].

The objective of this study is to assist the learning process in engineering education by utilizing a "Virtual-Object" that is designed specifically for one of the fundamental courses, Thermodynamics. The virtual-object is developed for a project-based instruction by using theoretical materials, graphics, diagrams, and animations to enable students to process the theoretical content by visual thinking method, which facilitates the comprehension of the material.

To investigate the effectiveness of the Virtual- object on students' performance and answer the research questions a study designed. Our population groups were the students enrolled in the thermodynamic course at the Sophomore level at the University of Oklahoma for three consecutive years, 2017, 2018, and 2019. They were asked to participate in a class project to design an imaginary power plant in one of the three offered countries. In the last two years (2018 and 2019), students were provided with the specially designed Virtual-Object, while our control group, the 2017 class, used traditional resources like course materials, books, and online information. Additional assessment methods were applied for the 2019 class.

Two different evaluation methods were used to analyze the data. At first, the assignments of all three years were graded based on a holistic rubric system, and the results were verified by statistical analysis. But because the feature of the project that was assigned to the students was practical whilst the outcome was written assignments, we consider the probability of some observer-based errors when using pre-defined rubrics in evaluating the students' discussions and ideas. Therefore, the Quantitative data analyzing method that provides more precise verification of the written contents was employed as a second evaluating method. We hypothesized that Quantitative data analysis is a preferable method in evaluating the written outcomes of the practical project and provides a detailed and categorized information in glossing the effectiveness of Virtual-object on student performance.

The statistical analysis of the results obtained from grading based on the pre-defined rubric verified a significant improvement in the 2018 class performance comparing 2017. The data from 2019 produced better results as compared to 2018 or 2017, explaining the benefits of additional assessment techniques and cumulative effectiveness of Virtual-objects in students' learning process, respectively.

Moreover, the quantitative content analysis results were consonant with the results of Rubric based grading and supported the improvement in class 2018 and 2019 performance comparing with the 2017 class in many aspects. However, the difference between 2018 and 2019 was not statistically significant, based on this analysis method. The quantitative content analysis, which divides the assignments to different categories and analyzes them separately, provided evidence that some aspects of the project, which would be necessary for the practical setting, were not discussed sufficiently by students in their assignments in all three classes.

This research supports the effectiveness of utilizing Virtual-objects in students' performance. The effect of assessment methods is controversial and needs to be analyzed in future studies. Quantitative content analysis provides more precise information by evaluating the level of learning based on the criteria obtained from the performance of the students. It highlights the imperfect aspects and strengths of practical accomplishment, which suggests considering industrial and professional perspectives in engineering students' educational projects with a well-defined approach.

Chapter 1. Introduction

1.1. Background of the study

Higher education or postsecondary education begins after finishing high school and includes non-degree programs. It leads to certificates and diplomas plus six degree levels: associate, bachelor, first professional, master, advanced intermediate, and research doctorate. The U.S. system does not offer a second or higher doctorate but does offer postdoctoral research programs [6].

Based on the U.S. Department of Education, bachelor’s degree as the most common first degree in U.S. higher education and is the degree that gives access to advanced studies. U.S. educators and employers expect that the bachelor’s degree should prepare students for entry-level jobs as well as for possible advanced education [6]. Whether students continue their studies or enter the labor market, they will need to understand the basic principles of fields other than their narrow specialization, and they will need skills – such as languages, I.T., and computational skills – that cannot be obtained exclusively in their major field.

To fulfill the abovementioned goals, the degree programs need to provide additional knowledge supplemented by skills as their primary educational purpose for the students of bachelor’s degree or undergrad level. This aim looks easily achievable in some majors or fields as they need impractical skills besides the theoretical materials. However, for some areas like engineering, which need hands-on skills, it turns to a big challenge.

Engineering education, as a part of STEM, is one of the fundamental factors in defining the improvement of infrastructures and the successful reforms in society. STEM is critical for human life to protect them, help them with their challenges, to provide the new and healthy resources, to enhance the economy, and to keep their environment safe.

The challenges that educators face in the engineering field in the ever-changing world is a priority that crosses the government's scientific and educational agencies:

- In December 2018, the U.S. Department of Education designed a new strategic plan "North Star" and set out a five-year Federal implementation strategy. The plan is making an urgent call to STEM collaborators nationwide to chart a course for success in STEM education, aiming that all Americans will have lifelong access to high-quality STEM education, and the United States will be the global leader in STEM literacy, innovation, and employment [7].
- In 2018, the National Science Foundation (NSF), in consultation with the Department of Education, NASA and the National Oceanic and Atmospheric Administration (NOAA) announced a new STEM education advisory panel created to encourage U.S. scientific and technological innovations in education, as authorized by the American Innovation and Competitiveness Act. This advisory panel authorized by congress and is called the Committee on Science, Technology, Engineering, and Mathematics Education (CoSTEM) on matters related to STEM education [8].
- In November 2019, the Department of Education announced that it invested nearly $540 million to support STEM education through research grants in Fiscal Year 2019 [7].

Based on the U.S. National Academy of Engineering (2008), engineering education has a pivotal part in making the world a better place by addressing two significant challenges to maintain equity and sustainability: a growing population and decreased renewable resources [9]. Furthermore, education at the undergrad level is the basis of students' knowledge and success in their future careers; either they decide to go to the industry or to continue their education in graduate programs, although the majority of the engineering students choose to go to the labor market after completing their bachelor's degree [10].

During the undergraduate program, students should become motivated and educated listeners, learn the necessary knowledge and engineering ethics, skilled to design, and analyze with emphasizing the importance of time and trained for group works and projects [11]. Moreover, educators in undergraduate engineering programs should keep pace with the evolving digital world and adapt their teaching method by taking advantage of these developments. The industry needs engineers to be creative problem solvers, innovative, and possess the latest knowledge and skills. The students are future engineers, and their prospective employer's expectations should be considered as well. Teaching the complex theory materials, including combined high-level physic, math, and chemistry science with abstract concepts, is another challenge that the engineering educators face. Training the students to develop contemporary skills, for instance, getting familiar with field related software like designing, analyzing, and coding is the other one. However, the most important and complex one is bringing the learned theory and developed skills to the practice. Furthermore, the educator needs to develop a course plan which meets all the goals and address all the challenges.

The Accreditation Board of Engineering and Technology (ABET) introduced some standard criteria for different degree levels for various program areas, which is updated annually. These criteria set up in four different areas of applied and natural science, computing, engineering, and engineering technology. All the programs have been asked to help the students to develop the specific competencies for their future professional practice of engineering. For example, in the student outcome section of the defined criteria by accreditation engineering commission (AEC) for bachelor degree for the 2020-2021year, seven different abilities which a student graduated from an engineering program expected to fulfill are identified as [12]:

1. Problem-solving ability by applying the principle of mathematics, science, and engineering.
2. Product designing ability considering public health, safety, and social, cultural, economic, and other factors.
3. An ability to communicate with different audiences
4. An ability to understand ethical and professional responsibilities, making judgments, and to provide solutions considering the impact of them in different aspects, i.e., environmental, economic, and social.
5. An ability to work collaboratively in a group
6. An ability to design experimentation and to analyze the data
7. An ability to continue their learning and apply their knowledge to solve contemporary problems.

There are also many researches have been done to identify the gap between engineering education and competencies required for an engineering career. This information is helpful in designing an engineering curriculum. For example, Honor J.Passow et al. described that theoretical and practical contexts should be taught in parallel. Also, the social and technical aspects of engineering practice should be considered from the first day of education [13].

Besides the impact on the future engineering career, practical learning and practicing the theoretical material will help in digesting complex and abstract concepts too. It is known that the idea and observation are the foundation of science, and the important impact of practical work is to help students develop links between ideas and observation [14]. This linkage can help to solidify the theoretical knowledge. Because of this reason, experiential learning is one of the methods that has been used in many fields, especially engineering helping in retaining knowledge [15].

To provide a practical environment for engineering students, instructional laboratories are the valuable traditional instruments that are in use for a long time. There are three different types of laboratories: development, research, and educational laboratories. Development laboratories are designed to answer a question of immediate importance, provide the experimental data to design or develop a product, and analyze if the performance of the product is desirable. Research laboratories are used to answer the broader questions and usually provide additional new knowledge in the field. Educational laboratories can be designed based on the goal of the course to help the students relate their knowledge to the practice, which increases their motivation also [16].

However, educational laboratories can have limitations when a physical resource cannot support the learning objective due to the abstract or complex nature, value or size, or danger associated with the physical model. In these situations, Virtual laboratories can model the real environment to combine energy, material, knowledge, and to acquire data, compute and correlate them, analyze and test, design, and simulate. They provide the opportunity for students to experience their future career setting, the problems they will face, demanded skill and knowledge to solve the problems, and analyze their solutions impact virtually.

Simulation is a method to illustrate the experience and help the students to comprehend the theoretical concepts by visualizing the abstract and complex data, for instance, deformation under different loads, different stress patterns, different types of fluid flow, and heat transfer through materials [17]. Starting in 1940 as Finite element modeling (FEM) to solve the critical and complex problems in the civil and aerospace engineering field, Finite element analysis (FEA) is one of the most valuable simulation software. FEA is fast and flexible with decreased approximation error, which helps to save time and money in many engineering projects.

The ongoing demand for distance learning, which fitted more in the current busy life schedule is another reason which emphasizes the virtual learning importance. Of course, online engineering education is not an exemption. However, distance education does not mean hands-off learning for engineering students because engineering feature is practical. Using online videos to provide the students sense of presence in the real physical environment and employing the virtual laboratories which students can involve in the quasi-real experiment are two worthy instruments in online education.

Virtual laboratories like real laboratories should follow the fundamental objectives of engineering laboratories. These objectives are[16] a)Instrumentation, b) Identifying the limitation and strength of the Models, c) Experiment: specify the components, process, analyzing the results, d) Data analysis, e) Design: by using specific materials, equipment, and methods, f) Analyzing the outcome and detect the unsuccessful points, g) Creativity, h) Psychomotor, i) Safety, j) Communication, k) Teamwork, l) Ethics, and m) Sensory awareness to use the information in engineering conclusions.

One of the engineering courses which can be benefitted from virtual laboratories is Thermodynamics. It is one of the sophisticated courses that contain abstract information that is challenging to be comprehended. Founded in 1824, with a discussion about steam engine efficacy, Thermodynamics is a fundamental science and an essential course for some of the undergrad engineering programs. Currently, it is a wide field and divided into branches. For instance, while classical thermodynamics applied to mechanical heat engines, chemical thermodynamics studies about entropy and chemical reactions properties.

Although the universally valid laws of thermodynamics look easy to learn, applying them to a system brings up some confusion. Different cycles of thermodynamics, their characteristics, their goals, and differences are other examples of this course complexity.

Because it is one of the most present science in life and its wide variety of applications, most of the engineering students will face the practical aspects of the thermodynamics course in their future career. All types of engines of the vehicles work based on the Carnot cycle and 2nd law of thermodynamics. Heat transfer science, either via conduction, convection, and radiation are used in a variety of devices, for instance: coolers, heaters, condensers. Thermodynamics also is applied in various types of power plants, which is the inseparable frame of technological development of each country.

To understand the power plant and its function, students should learn most of the thermodynamics concepts thoroughly and combine the underlying data, cycles, diagrams, and formulas to have a comprehended view of a power plant. They also need to test different parts with different characteristics and analyze the outcome in order to learn the function. All of these are applicable in a laboratory. However, power plants are too large in size to be used in real laboratories. Therefore, the virtual laboratory, which contains all the information including diagrams and formulas, provides the facility of choosing and visualizes the powerplant, compartments, and function, also tests the outcome would be a very useful tool in teaching thermodynamics.

1.2 Research questions and methodology

Grounded on all the abovementioned information, the researchers decided to design a virtual laboratory to illustrate a powerplant, including all the needed data, components, and function, aiming to help undergrad students and the professors in fulfilling their educational goals. Subsequently, an analysis plan proposed to evaluate the efficacy of the designed virtual-object by utilizing project-based learning principles. Project-based learning is a student-centered method that focuses on a specific context or problem, and students are actively involved in the learning process[11]. An instructional class project which required the participants to propose an imaginary powerplant in one of the three offered countries was designed.

Researchers tried to resemble the real-world problems and desired the students not only visualize the powerplant but also to practice their role as an engineer and involve in the environment of their future career. Therefore, all aspects of the powerplant project were emphasized, aiming to help students to have a better view of their challenges in their future job and strengthen their practical and cognitive skills in managing projects like this. The aspects that were pointed out in the project were observing the demands, resources, and the various reciprocal impacts of the powerplant on the selected geographic area. Considering all of these features, strengthen the students' reasoning about their choice in their arguments and helped them to select the most effective technical solution and the most proper powerplant type.

To answer the first question of the research, “if the Virtual-object can enhance the undergrad engineering student’s education in thermodynamics,” a research study was planned. Three groups of sophomore students of Mechanical and Aerospace engineering department at the University of Oklahoma enrolled in the thermodynamics course for three consecutive years 2017,2018, and 2019 had been chosen. All three groups were asked to participate in the instructional class project. The students in the year of 2017 were not provided the Virtual-object, while students of both 2018 and 2019 years had access to the Virtual-object all over their semester. The project was appointed in four different assignments with the same time intervals. Some formative assessment methods like peer reviews, feedbacks from the researcher after each assignment, and some summative assessment methods, for instance, a feedback was applied in the class of 2019.

After finalizing the project, a researcher evaluated all the assignments of the three classes based on two analyzing methods. Firstly, the assignments graded based on the same holistic rubric, and the data were verified by statistical analysis to answer the first and second questions of the thesis:

- Is utilizing Virtual-object enhance the learning process in engineering students or not?
- Is complimentary assessment methods contain additional benefits in the students' performance or not?

Afterward, the need for a complementary and detailed analyzing method was determined because:

- The feature of the powerplant project was practical, but the outcome was written assignment, and the rubrics designed for a written assignment could miss some aspects of practical work.
- Deep analyzing the outcomes could be helpful to understand that if the students involve with virtual laboratory properly and apply all the categories in their project or not.

As a practical based learning method, it was essential to know which categories were mostly used or were ineffective in the learning process.

The quantitative content analyzing method was the one that fulfilled the mentioned goals. In this method, the students' assignment has an essential role in designing the rubrics. The researcher should read the assignments several times to get aquatint with the students' discussions and also find the distinctive pattern, repeated interpretations besides the unique ones to categorize the assignments. Subsequently, he/she revise the assignments considering the created categories in order to assign subcategories to each class, then find the repeated words or statements which related mostly to that particular subcategory and called "codes." Codes, subcategories, and categories are the rubric for content analyzing methods. Moreover, the researcher evaluates the assignments based on them. At the final step in the quantitative content analysis, by using the numerical statistical methods researcher would be able to verify the findings

Quantitative content analysis was used in this thesis in order to genuinely evaluate the impact of the Virtual-object in the learning of the students, to compare both analyzing methods, and to challenge the designed virtual laboratory and realize its strength and weak points. All of this information can be used in future works designed in the educational field and to study the virtual laboratory or different analyzing methods.

1.3 Research significance

This research investigated the effectiveness of utilizing Virtual-objects as a practical learning method in engineering students' performance. Some assessment methods and their efficacy in assisting the pedagogical process was studied as well. Two different methodologies were applied to evaluate the data, and the competence of these analyzing methods was verified and discussed. Both Rubric-based grading and Quantitative analyzing results indicated the positive impact of virtual-object on learning outcomes. However, the effect of assessment methods is controversial and needs to be analyzed in future studies. Quantitative content analysis provides detailed and categorized information in analyzing the arguments and reflected ideas, based on the criteria obtained from the performance of the students. The results obtained from quantitative content analysis underlined the importance of considering the practical features of the engineering profession in their educational instructions.

1.4 Thesis outline

In this chapter, the motivation and theoretical framework of the research are discussed. Furthermore, the purpose of the study, research questions, and methodology are identified. Chapter.2 provides a literature review covering the current research pertaining to the background and relevancy of this research. The literature is divided into three main sections: 2.1 Learning, 2.2 Different assessment methods, and 2.3 Content analysis. In Chapter 3, the design and methodology of the research, also the data analyzing procedures to answer the questions of the study are described. Chapter.4 discusses the results, numerical data, and statistical verification. Finally, in Chapter.5, the findings are summarized, and conclusions are drawn accordingly. The questions of the research have been answered with two different analyzing methods and the results compared to identify the best evaluation method for each level of the learning goal.

Chapter 2. Theoretical discussion

2.1 Learning

2.1.1. Learning and educational goals

In 1956 Benjamin Samuel Bloom and his team classified the educational goals and objectives based on a rubric in his first published work as “Taxonomy of Educational Objectives: The Classification of Educational Goals,” which is cited as Bloom’s Taxonomy. They were trying to develop a method of classification of thinking behaviors related to learning to explain what the educator intends or expects students to learn as a result of instructions [18].

In 1990, Dr.Lorin Anderson, one of the former students of Bloom, published an updated version of Bloom’s Taxonomy, arguing that the factors that are affecting the learning process are broader than what classified in the previous version, hoping to make the taxonomy more suitable for his current age [19].

In Bloom’s taxonomy, they organized the list of cognitive skills in the hierarchy, from simple to complex and from concrete to abstract ones, and it assumed that getting skillful in previous steps is a prerequisite for higher categories. There are six levels in this taxonomy, and the teacher should try to help students go up as they acquire more knowledge. The groups are Knowledge, Comprehension, Application, Analysis, Synthesis, and evaluation [19].

1.Knowledge: In the knowledge level of Bloom’s Taxonomy, the teacher tests whether a student has gained specific information or the main ideas from the lesson.

2.Comprehension: The comprehension level of Bloom’s Taxonomy tests the students’ understanding of the data. In this level, they could be able to interpret the facts.

3.Application: In this level, students can apply their knowledge to solve the problems being asked.

4.Analysis: In the analysis level, students would be able to analyze and find the patterns to have a discussion and explain the situation.

5.Synthesis: With synthesis, students can imagine, predict, and give new theories.

6. Evaluation: The top level of Bloom's Taxonomy is evaluation. Students are expected to evaluate information and discuss the actual value or the bias behind the sources.

Except for Application, each category is divided into different subcategories.

Table 2.1- The subcategories for knowledge

Knowledge	Knowledge of specifics	Knowledge of terminology
		Knowledge of specific facts
	Knowledge of ways and means	Knowledge of conventions
		Knowledge of trends and sequences
		Knowledge of classifications and categories
		Knowledge of criteria
		Knowledge of methodology
	Knowledge of universals and abstractions in a field	Knowledge of principles and generalizations
		Knowledge of theories and structures

In the revised version, the number of categories retained, but three of them were renamed, and the other retained nouns changed to verb form; also, the order of two last ones were interchanged, and creating is considered as the final stage of the learning process after evaluating. Like the original taxonomy, the new revised version is also a hierarchy in a sense based on their complexity with more flexibility between the frontier of categories for teachers to use [19].

1.Remembering: recalling and recognizing relevant knowledge from long term memory

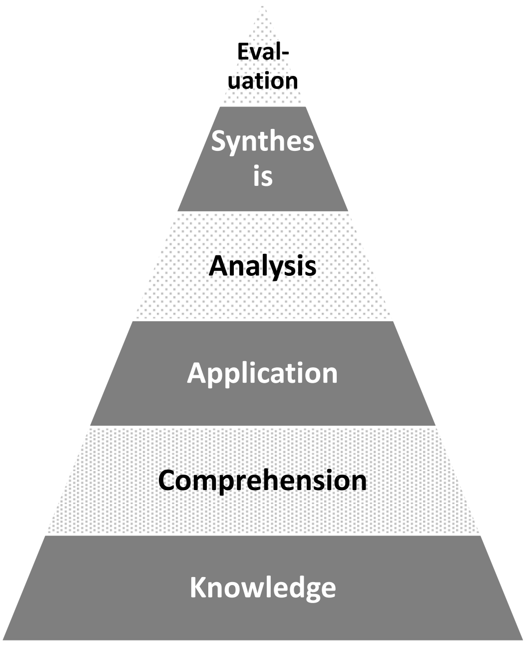
2. Understanding: oral, written, and graphic massages turn to be meaningful through classification, comparing, inferring and summarizing

3.Applying: implementing a procedure

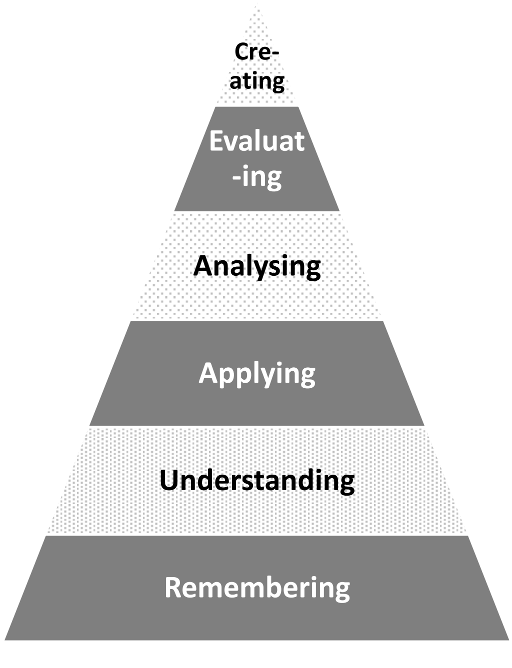
4. Analyzing: cracking the material into the parts, organizing them, and relating them together.

5.Evaluating: being able to check based on criteria and make judgments

6. Creating: re-organizing the pattern to create a new profile or structure.



Original version



Revised version

Figure2.1-Comparing pyramids of Bloom’s Taxonomy and the Revised Version

Besides terminology change, the original one-dimensional noun or verb cognitive taxonomy changes to two- dimensional one, which is demonstrated in Table 2.2 The nouns provides the basis for the Knowledge dimension and describe the knowledge that should be learned, in contrast, the verbs form the basis of the Cognitive process and defined as the process used to learn, consisting of 6 levels, which discussed earlier.

The knowledge dimension consists of 4 different levels instead of three in the original one. The four different levels of the Knowledge dimension are defined as Factual, Conceptual, Procedural, and meta-Cognitive. The fourth level, Metacognitive knowledge is the new and distinctive one is added to the revised version and involves the knowledge about cognition in general plus self-awareness about own perception [20].

Similar to the original version, each process of both dimensions is subdivided into different subcategories. For example, the Factual category can be divided into the knowledge of terminology and knowledge of specific details and elements, or the newly created group "Metacognitive knowledge" includes three subgroups:) Strategic knowledge, b) knowledge about cognitive tasks, including appropriate contextual and conditional knowledge and, and c) Self-knowledge. Each level of the Cognitive dimension subdivided into 3 or 8 subcategories. For example, "Remembering" is divided into remembering, recognizing, and recalling.

To apply the new two-dimensional taxonomy, it is easy if we construct a two-dimensional table, with the Knowledge dimension forms the vertical axis of the table. In contrast, the Cognitive dimension forms the horizontal axis.

Table 2.1- Two-dimensional approach in the revised version: Knowledge and Cognitive

	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual knowledge						
Conceptual knowledge						
Procedural knowledge			**Technology to apply**			
Metacognitive Knowledge						

For example, in our research in the 3rd assignment, we want the students to choose a particular technology to apply in their project. The keyword is the "*technology*" which is asking about the knowledge of subject-specific techniques and fits in the second subcategory of "Procedural knowledge" of the Knowledge dimension. The principal verb is "*to apply*" which is evaluating the students' knowledge about implementing the procedure, which fits in the "Apply" level of cognitive dimension in revised Taxonomy.

In this thesis, the highest levels of the revised taxonomy, "Creating and Evaluating" were targeted as the initial objective.

2.1.2. Learning styles

In education, the learner has a critical contribution to the accomplishment of the process of learning. Many factors related to the learner like her/his mental ability, personality, previous knowledge are the primary factors that could not be altered by the educator and are not directly interacted with the teaching process but should be considered. However, one of the essential characteristics of the learner, which directly involved with the process, is her/his learning style. A vast number of researchers have a focus on this topic because of the critical impact of the different manners which individuals have when they want to learn on their final achievement. Consequently, there exists a variety of definitions, classifications, interpretations, and models in this regard.

In 1987 Neil D. Fleming and Coleen E. Mills created a learning style inventory that is known for the VARK model and describes the four modalities as *visual, auditory, reading/writing, and kinesthetic*. He developed a questionnaire based on his model that was designed to identify the particular style for each student.

Visual learners think in pictures and prefer to learn through depicted meaningful symbols or graphics. They prefer holistic information rather than piecemeal one, so the summarized charts and diagrams are the most helpful educational tools for them to use.

Auditory learners prefer to learn through listening to lectures, discussions, and recorded audios. The unbroken auditory attention is their learning strategy, so they may benefit group activity when they discuss the material or read the material aloud to themselves.

Readers or Writers are the ones who prefer taking notes in the class and use books and handouts because the written words are their learning instruments.

Kinesthetic Learners should engage in the learning process physically, and they learn better when they utilize something like flashcards or involving in skill-based activity and laboratory-based instructions [21, 22].

Kolb's Experiential Learning Model (ELM) and Learning Styles Inventory (LSI) proposed in 1977 consider learning as a continuous interactive process. He defined four different types of learners across two dimensions of the learning process:

how people receive the information (concrete vs. abstract) and how they process information (active vs. reflective).

Concrete experience is based on experiential learning, while Abstract conceptualization is about analytical thinking to understand. Active experimentation involves trial and error learning, whereas reflective observation considers potential solutions. *Convergers, Divergers, Assimilators,* and *Accommodators* are the four distinct learning styles based on Kolb's learning theory.

Convergers receive the information via abstract conceptualization to drive active experimentation. Therefore, they are good at the practical use of ideas and doing technical tasks. In contrast, *Divergers* are creative learners who combine concrete experience and reflective observation, so they observe and use their imagination to find multiple potential solutions for the problems. *Assimilators* tend to be informed by abstract conceptualization and process it via reflective observation and theoretical reasoning. *Accommodators* who are famous for their adapting ability to diverse situations, prefers hands-on training and practical projects because they better receive the information by real experience and process them by active experimentation [23,24].

Felder-Silverman learning style model (FSLSM) (Felder & Silverman, 1988), defines four dimensions for learning based on the specific areas of personality. They are *Active or Reflective, Sensing or Intuitive, Visual or Verbal, Sequential, or Global.*

Active learners prefer to learn by working and applying the materials, so they are favor group working and discussions. In contrast, *Reflective* learners prefer to work alone and think about the material to have a reflection.

Sensing learners are the realistic ones who like to learn concrete materials and facts and relate them to the real world. They usually follow the standard to solve the problems while the *Intuitive* learners are the innovative ones who enjoy learning abstract materials such as theories and discover the possible relationship.

The third dimension, visual or verbal learners, are distinguished by the material they usually remember the best. *Visual* ones learn better through seeing, and *Verbal* ones prefer to learn written or spoken materials.

The final dimension is based on the learners' understanding. *Sequential* learners follow a logical stepwise process to solve the problems. In contrast, *Global* learners prefer to learn randomly from a whole picture and overview of the content, so they are better at finding connections between different aspects of the learning materials [25].

There are several other models in defining learning styles. However, many studies estimate that 50-70% of the population are multimodal learners and engage in the learning process using different styles alternately or in coordinately [26].
Considering all of these, preparing an educational strategy for a group of students enrolled in a course with different preferred learning styles is a complicated process. However, more diverse educational tools will comply with more different styles, and more students will be benefited. In this research, the virtual-object is provided in project-based learning instruction. Therefore, the following learning styles would be more benefitted from the virtual laboratory:

- Visual learners and Kinesthetic learners of the VARK model because they would be able to visualize the materials and interact with the project in a laboratory setting.
- In Kolbe's experiential learning model, diverges and accommodators who prefer concrete experience to receive information.
- In the Filder-Silverman model, Active learners who learn better by applying the theoric materials or Visual learners who have better graphical memory.

2.1.3. Neuroscience and active learning

Learning is one of the functions of our brain. The human brain has different sections anatomically, with separate functions for each of them. However, all the parts are connected with each other, also with the brain stem and with the peripheral nervous system. The brain should receive various stimulations, process, and comprehend them, and relate them to produce the output, which is “Learning” itself or a function due to learning.

The frontal lobe of the brain controls critical thinking and problem-solving skills besides language (left lobe), judgment, personality. The Broca area of the frontal lobe is responsible for speech production and any action associated with speech [27].

The parietal lobes function is processing the numbers and math. This lobe primarily processes the information relating to the sense of touch and visuospatial data. Also, these lobes are involved with analyzing the information from different internal and external sources [28].

Temporal lobes receive auditory information and comprehend them to meaningful data such as speech and words. Also, it is involved by high-level visual stimuli interpretation and both auditory and visual comprehension, making object-recognition possible. These lobes are also the field of new memory [29].

The Wernicke’s area located between partial and temporal lobe is one of the parts of the cerebral cortex involved with comprehension of written and spoken language; the damage in this area in dominant lobe(usually left) cause fluent aphasia which means the patient can speak fluently but will have a hard time understanding speech and texts, which is precisely the opposite of Broca aphasia which patient can read and understand the spoken language but is not able to produce speech [30].

The occipital lobe is the visual processing center and categories different data like colors, sensing motions, spatial situations, and imagination [31]. The limbic system, which is located beneath the temporal lobe, supports a variety of activities involved in the learning process. The Hippocampus has a significant role in forming long term memory by consolidating new memories of experienced events. Alzheimer's disease and other pathologies, which result in dementia are related to hippocampus disorders [32]. In interesting neuroscience research, Curlik and Shors show the relationship between learning and cognitive skills with neurogenesis in the hippocampus [33].They claim that physical activity increases the number of new neurons produced in the Hippocampus. In contrast, mental training via skill learning increases the numbers that survive, because almost half of the generated neurons undergo programmed cell death in one or two weeks after their birth. The Hippocampus also involved in spatial memory or cognitive map and make locating and navigating possible. The other part of the limbic system, Amygdala, is associated with emotional memory, face evaluation related to social processing, and inattention.

Attention, which defines as the ability to be focused on the desired stimulus, plays a vital role in learning. The small amygdala volume and abnormal connectivity between Amygdala and prefrontal cortex are associated with ADHD (attention deficit hyperactivity disorder) [34]. The active learning can reduce the attention lapses, which starts almost fifteen minutes during the lecture [35] by engaging with a subject in different ways, and the brain can retain the information [36].

Intelligence is defined as mental ability involved in calculating, reasoning, perceiving, learning quickly, storing, retrieving information, using language fluently, classifying, generalizing, and adjusting to new conditions. (Columbia Encyclopedia, sixth edition,2006). Therefore, the intelligence is the product of our brain and involves different parts and functions of the brain. However, different studies show that intelligence is associated with some specific parts of our brain. For example, the parieto-frontal integration theory claims that the parietal and frontal cortex are the central region involving intelligence [37]. The vast majority of researchers are working on intelligence neuroscience are trying to address the questions that if other parts of the brain involved in the brain and how by using fMRI, EEG, and other diagnostic processes. Youngwoo et al. supports the parieto-frontal theory and shows that the maintaining structural network of parietal and frontal lobes with the cerebellum and temporal lobe respectively is also essential in intelligence [38].

The principle of this research was to provide a practical environment for engineering students to enable them actively involved with the learning process and enhance their cognitive skills. Although learning is a complicated function of our brain, the active learning methodology activates the hippocampus specifically, as we discussed. Hippocampus is the center of long-term memory, and this illustrates the positive impact of practical learning when aiming for education, the future engineering career.

Active learning

Bonwell and Eison defined Active learning as a method of learning in which students are actively or experientially involved in the learning process and where there are different levels of active learning, depending on student involvement [39]. In active learning, students involved in the learning process by not just listening but also reading, writing, discussing, or solving problems. There is an important point in active learning; it relates to all levels of the learning taxonomy, and students should engage even in higher levels of learning, such as evaluation and synthesis [40]. There are other definitions and terms of active learning.

Collaborative learning refers to a learning method in which students working together in a small group and interact with each other [41]. While in the *Cooperative* learning method, the group work is more structured and evaluates each student separately while they are working on the same goal. Such activity needs interpersonal skills, mutual interdependence, and cooperative interaction rather than the competition [42].

Problem-based learning (PBL) is an instructional method in which the related problems are presented at the beginning of the class to provide the goal and motivation for the following learning materials. This method focuses on self-directed learning [36]. Project-based learning is an active student-centered learning method that provides real-world practices as inquiry-based projects to create a learning experience. [43,44,45]

It has been argued that the freedom and challenge that students experience as a result of solving the problems that arise in designing and building their projects result in high levels of student engagement [43]. A well-designed project should initiate the cognitive challenge as well as holding the substantial effective, ethical, and aesthetic dimensions [44].

Thomas John et al. identified five essential characteristics of projects: (1) Centrality, (2) Driving question, (3) Constructive investigations, (4) Autonomy, and (5) Realism, with the importance of student collaboration, reflection, redrafting and presentations emphasized in other publications[45,46].

The uniqueness of PBL is the construction of an end product, a 'concrete artifact' [47], which represents students' new understandings, knowledge and attitudes regarding the issue under investigation often presented using videos, photographs, sketches, reports, models and other collected artifacts [48].

2.1.4. Psychomotor learning and its importance

2.1.4.1. Theoretical vs. Practical learning

Theoretical knowledge means learning everything via textbooks by seeing the context and processing it to reach deep comprehension. Theoretical knowledge teaches through the experience of others, providing the whole picture, and complement it by adding details. In contrast, *Practical* knowledge is learning via practical experience and hands-on training in the real world. Both are valuable educational methods, but their priority or importance can be varied depending on the field or the type of knowledge that wanted to be learned. For example, in Philosophy, theoretical knowledge has far more critical than practical learning. At the same time, in the Engineering field, where the complicated concepts and skills are the end goal of training, practical knowledge is essential almost the same as theoretical education. Another example is the medical field, which needs hands-on training parallel to theoretical knowledge. In one study which has been done to evaluate the effect of the use of theoretical versus theoretical-practical training on the quality of CPR (cardiopulmonary resuscitation) performed by nurses, the researchers showed that although theoretical training beside CPR videos can improve cognitive knowledge, but did not improve psychomotor ability to perform good quality CPR[49].

2.1.4.2. Psychomotor learning

Psychomotor learning is the relationship between cognitive functions and wide range of organized patterns of muscular activity. Coordination, speed, the accuracy of the movements demonstrates the learning quality. Learning motor skills involves both mental and physical activity. In 1964 Paul Fitts defined the three stages in which learners progress through them during psychomotor learning.

In *the Cognitive phase*, the initial phase of learning, before each movement, the learner should think about it and produce the clumsy and slow movement. In this stage, the learner tries to understand the structure of motion.

In the second stage, *the Associative phase,* which is the practical and fixing phase, the learner tries to associate the movement with other ones who already know. The movements are smooth, but still, it is not a permanent part of the brain, and the leaner should think about each movement before performing it.

Finally, in *the Autonomous phase,* the movement is a habit and performed spontaneously. The body and mind become one, and the learner should not think about the movement [50].

Teaching psychomotor skills should consider the hierarchy classification of psychomotor learning, so preparing an instruction for teaching this type of knowledge is not an easy task, and many researchers have been working in this field to provide different methods and ideas. Francis Quinn believes that skill is beyond just doing a particular task, and it also involves understanding and comprehended knowledge behind it. He defined six different phases for transferring a psychomotor skill.

1. Preparative phase: investigate the entry-level of the learners and their previous knowledge about the task and classify them as a novice, advanced beginner, competent, proficient, and expert

2. Constructive phase: constructing the plan and demonstrating the skill at a slow pace, break down the skills into components so the learner can observe the stages of the process, outline the learning outcomes, and create motivation

3. Coaching phase: observe the learner practicing sub-skills and help them change sub-skills into smoother psychomotor skills by providing feedbacks and prompts

4.Fading phase: the learner moves from dependent to independent by gradually withdrawing prompts and feedbacks

5.Practice phase: the learner practices the skill because kinesthetic feedback will be missed without practice. In this phase, cognitive learning is faster than motor learning

6. Reflective phase: self-assessing phase, the learner may articulate reasoning and critical thinking skills, increase the complexity and diversity of the task.

The rapid development of technology-enhanced learning provides the opportunity for virtual laboratories and online learning. Nevertheless, the capability of these learning procedures in learning psychomotor skills is a very complicated topic related to a variety of factors. Still, there is considerable controversy in answering this question. However, most of the researchers agree on the benefit of virtual laboratories on enhancing the cognitive level of psychomotor learning [51].

2.2. Different assessment methods in the educational field

Assessment is the process of gathering and evaluating data about student's performance in the educational field in order to utilize this information to design better qualified educational methods and help the students to comprehend the complicated concepts [52,53,54].

There are three general types of assessment: *Diagnostic, Formative, and Summative*.

Diagnostic: This type of assessment is done before the trial starts or at the very beginning of the research and provides the information about students' current knowledge, skill sets, and capabilities before the course or training starts. Diagnostic assessments guide the instructor in designing the proper educating method for that specific class and further assessment types. She/he can use pre-tests, interviews, self-assessment methods as diagnostic assessment techniques.

Formative assessment: The main goal of this type of assessment is to monitor the learning process and identify areas that may need improvement and more practice. They are performed during the learning process, and while the instructional process is taking place and would not necessarily grade. By providing feedback and information, it is an excellent technique to measure the students' progress or weakness points and teaching effectiveness. There are different kinds of formative assessment tools like Clickers, Homework, and Quizzes as a review before the exam, Discussions, or any question and answer session; Feedback and self-assessments and peer reviews.

Summative assessment: like final exams and final projects takes place after the learning has been completed and gives information about the educational process that has been done. Rubrics can be used for this reason and can be provided before the final test to give the students a better idea of what the expectations are from them. Grades are the outcome of this kind of assessment besides course evaluation by students, and self- assessment by the instructor can assess the course and teaching effectiveness. This type of assessment provides valuable information in future educational process designing and would be helpful for instructors to use this experience to modify his/her expectation and teaching procedure.

Rubrics for assessment

The rubric can be used to evaluate any kind of student's work like essays, oral presentations, or final projects. The rubric is a simple scoring tool that identifies the various criteria relevant to the learning outcome [55.56]. There are different types of rubrics:

1. Holistic rubric: it means considering all evaluating criteria and assign a single score.

2. Analytic rubric: the separated criteria listed and scaled in different levels to evaluate the students' performance by weighting the strength and weakness.

3. Developmental rubric: is a subset of analytic rubrics that are not evaluating the homework instead of analyzing the developed skills or ability.

4. Checklists: It is useful when every decision about the performance is binary.

In this thesis, some formative assessment methods were applied in the educational instruction of the class of 2019, and to evaluate their efficacy, a statistical t-test performed to compare the performance of classes of 2018 and 2019, which their only difference was utilizing the formative assessment. A feedback survey assigned to the students in the 2019 class as a summative assessment method and the results provided valuable information that assists the researcher in clarifying the findings of the study.

Grading based on the holistic rubric was one of the main evaluating methodologies in this research, followed by statistical analysis to verify the obtained results.

2.3 Content analysis

Content analysis is a unique research method to investigate the documented texts, audio, or visual data and infer a specific pattern or hidden relationship with special concepts. It is defined as: "the systematic reading of a body of texts, images, and symbolic matter, not necessarily from an author's or user's perspective" [57].

Content analysis history dating back to the 18th century in Scandinavia. In the United States, it was first used at the beginning of the 20th century by Barcus, as a study of mass communication and described a family of analytic approaches ranging from impressionistic, intuitive, interpretive analyses to systematic, strict textual analyses which depends on the particular problem being studied and the theoretical and primitive interest that researcher has[58,59,60].

The content analysis primarily categorized into ***Qualitative method***, which gives qualitative inferences by analyzing the meaning and semantic relationship of words and concepts and ***Quantitative analyzing method*** that quantifies the occurrence of certain words, phrases, or concepts in the set of data. Each of these procedures has been employed in different studies.

2.3.1 Qualitative content analysis method

Qualitative analysis is a widely used analytical method and has an important role in defining and discovering valuable information in different scientific fields and defined as:

- A multi-method in focus, involving an interpretive, naturalistic approach to its subject matter. This means that qualitative researchers study things in their natural settings, attempting to make sense of or interpret phenomena in terms of the meanings people bring to them. Qualitative research involves a variety of studies and empirical materials, for instance, case study, personal experience, life story interview, observational, historical, interactional, and visual texts that describe routine and problematic moments and meaning in individuals' lives [61].
- A research method for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns [62].

In contrast to its Quantitative counterpart model which is a deductive method to test a hypothesis by giving some numerical outcomes as incidence, prevalence, percentage; in the qualitative process, the researcher is trying to offer a hypothesis by defining a special pattern or theme elicited from profoundly analyzing a large amount of text data and literal content. Table 2-3 shows some fundamental differences between 2 methods

Table 2.2-The basic differences between Qualitative and Quantitative content analyzing methods

Quantitative	Qualitative
Deductive-confirmatory	Inductive-exploratory
Assume a stable reality	Assume a dynamic reality
Outcome-oriented	Process-oriented
Obstructive and controlled measurements	Naturalistic and uncontrolled observation
Aiming to validate a hypothesis to quantify variation and explain relationships	Try to explore a hypothesis about probable patterns or links.
Stable approach	Flexible approach

Terms commonly adapted from Reichardt and Cook as cited in Nunan [63]. However, sometimes researchers need to combine these two paradigms to design their study. Burgess describes these methods as "multiple research strategies" and argues that researchers should be flexible when the sampling looks inadequate and need to be done with a wide range of investigation methods [64].

The process of qualitative content analysis often begins during the early stages of data collection and writing the findings, which could help direct the subsequent steps based on the developing concept to address the research question [65].To support a valid inference, the Qualitative content analysis should be designed carefully and follows some general and some unique steps. Regardless of its modality, it usually proceeds the following steps [66].

1st step: data preparing

Qualitative data analysis can be used to analyze different types of data, but the data need to be transformed into written text. Interviews are one of the most used methods in this analysis, and a complete transcript is the most desired and useful recording steps in this type of data gathering.

2nd step: define the coding unit

Codes are labels that are used to represent a specific feature of data and could be *Semantic or Latent.*

Semantic codes describe the content of the data and participant meaning and are the summary of the information in the analysis. However, *Latent* codes can provide interpretation about data and clarify the meaning behind the data surface [58].

In Qualitative content analysis, the coding unit is independent of its size and a single word, a phrase, a sentence, a paragraph can be used as a coding theme unit, which primarily is the expression of the idea [67]. and representing the issue relevant to the research questions

3rd step: Develop Categories

In the studies that intend to offer a theory, the categories would be developed inductively using different sources: the data, previous studies, and theories. When developing categories inductively from raw data is the case, it is useful to follow the Constant comparative method [68]. The basics of this method are: (1) the systematic comparison of each text assigned to a category with each of those already assigned to that category, in order to fully understand the theoretical properties of the category; and (2) integrating categories and their properties through the development of interpretive memos[66].

For other studies, in which there exists the previous model or theory, the researcher can adapt the coding categories from them as an initial list and then modify it during the analysis. In this case, there is an advantage of supporting the results in comparison across different studies.

4th step: Assess coding consistency and code all the text

The data should be read word by word and usually several times to derive exact words that reflect the principal thoughts or concepts and revise the list of the expected information categories by adding or changing them to more relevant ones. As this process continues, the categorized labels for sorted concepts will emerge and make the coding more meaningful.

Meanwhile, it is wise to test the coding consistency in the sample of the data at the beginning of the process as a method to help the researcher get a better view of how practical the categories are.

Although the researcher needs to test and revise the codes iteratively to achieve a sufficient one finally [60]. All the categories and codes should be finalized, and all the texted data should be coded at the end of this step.

5th step: Assess Coding Consistency at the end

Because of the probability of making any mistakes and because it is possible to researcher that change the understanding of the categories by the time, it is wise to evaluate the coding consistency after coding the entire texted data [60].

6th step: Draw the conclusion

In this critical step, the researcher tries to infer the themes and categories properties and dimension, identify any relationship between them, discover any special pattern based on his/her reasoning.

Validity:

Because of the interpretive feature of this analyzing method, the general validating criteria are not able to evaluate the quality of the research. For this purpose, other criteria were proposed in 1985 by Lincoln and Guba to assess the qualitative research work [69].

Credibility, which means “adequate representation of the constructions of the social world under study” [70] can be improved by researcher’s knowledge and experience enhancement, persistent observation, triangulation, negative case analysis, checking interpretations against raw data, peer debriefing, and member checking [69].

Dependability refers to “the coherence of the internal process and the way the researcher accounts for changing conditions in the phenomena” [70].

Confirmability refers to “the extent to which the characteristics of the data, as posited by the researcher, can be confirmed by others who read or review the research results” [70], analyzing the meaningfulness of interrelationship of the data, inferences, and results.

Transferability, which means the provided hypothesis should be efficient, consequential, and worthwhile enough to be extended in future works.

Different approaches of Qualitative Data Analysis:

Qualitative data analysis contributes to many types of research in different fields because of its flexibility and follows three distinct approach methods: *Conventional, Directed, and Summative.*

In a conventional method, coding categories are derived directly from the text data. In a directed approach, the analysis starts with previous relevant research findings, and in the Summative technique, usually, keywords are used and correlated with the underlying meaning of the context [61].

Conventional method: Conventional content analysis is generally used with a study design that aims to describe a phenomenon and uses direct information from the participant as a primary source of the categories. In this method, the researcher allows the categories and codes schemes to emerge from the data by iteratively reading and listing the texted data based on his/her own perception. For the report, the researcher demonstrates any relationship between subcategories and categories.

Directed method: In this approach, the researcher uses an existing theory which should be completed or can be benefited from further analyzes or need to be proved by other researches as a model for ongoing research. Using existing theory or prior research, researchers begin by identifying key concepts or variables as initial coding categories [71]. The final finding can be supportive or non-supportive for the antecedent theory. The evidence can be presented by descriptive documents, incidence, or percentage of the matched and un-matched codes and results, which eventually confirm, contradict, or shows further evaluation needs for the primitive phenomenon.

Summative: in this method, analysis begins with quantifying specific contents or words, usually keywords, to identify the frequency of their usage but unlike the quantitative content analyzing method, the summative analyzing method does not pause in this point and continue to discover the underlying concept and interpret what these quantified data were implying. In this analysis, the focus is on discovering the underlying meanings of the words or the content [72,73,74]. The advantage of a summative approach is an unobtrusive and nonreactive way to study the phenomenon of interest [72]. On the other hand, its limitation is the connotation of the presented data could be unconsidered. Weber, in 1990 claims that credibility can be used to demonstrate the trustworthiness in this type of study by showing the consistency of the textual evidence and interpretation.

2.3.2. Quantitative data analysis

Quantitative content analysis is a deductive approach that tests the hypothesis by using statistical analysis. In this type of analysis, the researcher should identify the pattern, relationship among the data, categories, and even previous studies and uses statistical approaches to test these findings. As the final step, data should be summarized, restated, and be adjusted with research questions and based on the hypothesis.

The steps are similar to qualitative data analysis by some small differences. In this method, categories are created before coding, and as they are evident in definition, they also should contain relevancy and validity features. Relevant means that schemes can test hypotheses and validity mean they enable the analysis to result in the intended concept [75]. Code scheme can be derived from previous similar analysis and can be modified, which in this way, the interpretation would be more straightforward based on the comparison of many results. Also, the contents and categories should be mutually exclusive.

Quantitative content analysis has been used in different research fields to evaluate a special phenomenon or a hypothesis by applying statistical analysis. Therefore, measurement as a linkage between conceptualization step and analyzing involved in quantitative content analysis with all its features like variables and scales. Some objects that have quantitative nature are easy to be measured, whereas objects like thinking, inferring, and feeling are difficult to be scaled. Variables are the codes created in this method and can be anything that represents the intended content. There are four scales of measurement: *nominal, ordinal, interval, and ratio* [76,77,78].

The nominal level of measurement is essentially a level of classifications and words, letters, alphanumeric symbols that can be used in this level.

Ordinal level of measurement indicates the ordering of the measurements like ranking the data.

Interval level of measurement which at this level, the distances between each interval on the scale are meaningful.

Ratio level of measurements: the direct comparison is possible, and unlike previous methods, the Zero value is defined.

Errors are a feature of any measurement, regardless of its scale. Random errors are inevitable, but the errors generated by human or instrument can be minimized. Errors are divided into two groups: *within errors* derive when a single instrument or a researcher reaches different results in similar instances or studies, while *between errors* happen when two different instruments or two researchers obtain different results while working on the same case or study. Therefore, like any other analysis method, the researcher tries to minimize any kind of error and provide a reliable and valid analysis.

Reliability indicates the consistency of the technique, which if it is applied to similar data under the same condition, the results should be almost the same. There are three steps in achieving reliability in content analysis. It starts with defining the categories and subcategories pertaining to research goals. Afterward, by applying these definitions to the content, the proper codes inventory would be created by coders. And in the final step, the coder reliability test qualifies the coverage of the content by the defined categories and subcategories and codes. In the case of a single coder, she/he should test the reliability against herself/himself in two points in time.

There are four main types of reliability which show if the analysis is replicable under different conditions, for instance, different time intervals, by other observers or concerning other tests [79,80,81,82]:

Test-retest reliability: in order to minimize the subjectivity in the research, this type of reliability tries to measure the consistency of the same method on the same sample over time by calculating the correlation between results.

Inter-rater reliability: provides the same results when the analyses conducted by different researchers and tries to measure the agreement between different observers' results by correlation.

Parallel form reliability: by using two equivalent versions of the test on the same data and making sure that tests are based on the same theory, this type of measurement tries to minimize the objective and trial method error.

Internal consistency: measures the correlation between multiple items in a test that are intended to reflect the same concept. It means the design of the test should be in a way that all the materials in the test, for instance, the questions in the survey, maintain the same concepts, and the results should be the same on average at the end. There are two different ways to measure this kind of reliability:

- *Average inter-item correlation*: which means calculating the average of correlations between the results of all possible pairs
- *Split-half reliability*: randomly split a set of measures into two separate sets and calculate the correlation between them.

Validity has many definitions, but in general, valid means that the data refers to a fact or evidence. Internal and external validity are the concepts verifying the trustworthiness of a method or study. Internal validity focuses mainly on the research procedure and reflects the ability of the test to illustrate the cause and effect relationship by eliminating other sources of influence. Internal validity is necessary to condition for external validity, which refers to how generalizable these causal relationships are in the real world. External validity derives from the judgment of scientific peers if they find the research significant, meaningful, and relevant by reviewing it or by applying the outcome to their research and comparing the results. There are four different methods of measuring the internal validity [82,83]:

Face validity: The most common validity test which has been used in content analysis, and it measures the correlation of the test and the aims of the study.

Concurrent validity: Correlates the measure of the study with a similar one applied in another study.

Predictive validity: Correlates the measure with some predicted outcomes. If it satisfies the expected results, the measure assumed a more valid one.

Constructive validity: Correlates an abstract concept which exists but is not observable directly to the observable measure, which presumes the existence of the concept. For instance, intelligence is an abstract concept and cannot be observed but can be measured by related indicators.

In this research, a quantitative content analysis was performed to evaluate the hypothesis of the study and provides the answers. This methodology was also advantageous in providing detailed and categorized information, which was critical in accentuating the strength and weaknesses features of the students' performance, which correlated with the design of the study, powerplant project, and Virtual-object and provided valuable information for future studies.

The reliability of the quantitative content analysis in this thesis met a parallel form reliability test comparing with Rubric based grading method applied to the data in parallel to the content analysis. (Pearson’s correlation coefficient, r=.42, p value=.000781)

The results obtained from quantitative data analysis led to convincing answers for research questions and were in coordination with the predicted answers based on the previous researches and the other evaluating methodology which has been used in this study. Both of these cases are testimonies of the face validity and predictive validity of the content analyzing method in this research, respectively.

Chapter 3. Use of virtual-objects in Thermodynamics - Experimental design

Thermodynamics is the science of energy conversion and transfer, and its effect on the physical properties of substances. It is one of the most present science in life and one of the basic courses in most of the engineering programs. However, students usually found it complicated because of its conceptual and discursive nature, which is difficult to be visualized. So many efforts have been going on to help the students in their learning process, especially in complicated concepts and courses like Thermodynamics, by using different technics and embedding a variety of factors like technology.

Using educational laboratories is a method that shows the effectiveness of enhancing the learning process, especially in intricate concepts. Visualizing the theoretical knowledge in the laboratory provides the opportunity for the students to observe the characteristics of the components, their function, and their relation [16]. They understand the importance of the theoretical material, and it would help them motivated. Moreover, the combination of theoretical knowledge and all the experiences in the laboratories will help them to obtain cognitive and practical skills. Also, in this way, learning would be solidified by enhancing psychomotor ability. It would help to progress from the cognitive phase of psychomotor learning to the autonomous phase, which is a permanent skill [84,85].

Also, interacting with different visuals, audio, and other stimulatory tools in the laboratory will activate different sections of the brain and triggers more neurological pathways and utilize a variety of neuroscientific aspects to facilitate and increase the quality of learning.

However, sometimes physical objects cannot be used in the laboratory because of many reasons, for instance, being dangerous, too large, or too expensive. In these cases, Virtual-objects are a qualified substitute, and even in some cases, they are better choices based on their feasibility.

Grounded on all of the reasons, we planned a study aiming to help undergrad students who enrolled in the Thermodynamics course to understand the complicated material of the course by providing them a specifically designed virtual-object. Different videos, animations, tables, and graphs were used in developing the virtual laboratory in order to crack down the fundamental of concepts like the Rankin and Brayton cycle, which tend to be misunderstood.

The research was designed based on the Project-learning method because, as discussed in the previous chapter, PBL is a student-centered method that can enhance cognitive ability by encouraging students' engagement and challenging their critical thinking, problem-solving and skill-enhancing abilities[43,44].

Both PBL and virtual laboratory can satisfy more students with different learning styles by providing additional learning tools. For example, based on the Felder-Silverman learning style model (FSLSM), active learners prefer to learn via involvement in the process directly, which PBL provides this opportunity for them. Alternatively, for visual learners who prefer to learn by viewing the learning process would be facilitated by using virtual-laboratory.

Some assessment methods, for instance, peer reviews, feedback from the researchers after each assignment, and final feedback survey were applied as complementary educational technics parallel to Virtual-objects to enhance the learning outcome.

In order to evaluate the data, two different analyzing methods were performed: Rubric based grading and quantitative data analyzing. The further one applied to eliminate the possible errors of the grading method when analyzing the practical aspect of the assignments.

3.1.1 Power plant project

Thermodynamics is a science of heat, work, and energy and their relation based on the laws of Thermodynamics. Starting in 1650 with the first vacuum pump invention by Otto Van Guericke, the Thermodynamics evolves through many studies and inventions. Finally, in 1824, Nicolas Leonardo Said Carnot, a French mechanical engineer and the father of thermodynamics, published the first book about the Carnot cycle and Carnot engine and established the basis of modern science [86]. Presently its principles apply to almost every device ever invented, and thermodynamics is one of the fundamental courses which most of the undergrad students in different engineering field should take it.

Four laws of Thermodynamics:

The Zeroth Law: states that if two bodies are in thermal equilibrium with some third body, then they are also in equilibrium with each other. This law establishes the definition of temperature as a fundamental and measurable property.

The First Law: depends on the principle of conversion of energy and taken as a definition of internal energy, which states that the total increase in the energy of a system is equal to the increase in thermal energy plus the work done on the system.

The Second Law: distinguish between reversible and irreversible physical processes and shows that the full conversion of energy to the equivalent amount of work is impossible. It states that heat energy cannot be transferred from a lower temperature body to a body at a higher temperature without the addition of energy.

The Third Law: concerns the entropy of a pure crystal at absolute zero temperature and states that as the temperature of a system approaches absolute zero, all processes suspend, and the entropy of the system approaches a minimum value [87,88].

In powerplant, for example, the first law is used to explain and increase the efficiency of the system. Based on the first law of thermodynamics, there is a balance between the heat transferred to (Qin) and the work done on (Win) the system, and the heat transferred from (Qout) and work done by (Wout) the system. So, for instance, reducing the temperature of the heat transferred from (Qout) the system by adding a condenser to the system, the total work done by the system will be increased.

Or the second law of thermodynamics, which demonstrates the direction of the energy transformation, is used in designing different kinds of cycles in the thermodynamics. Rankine and Brayton cycles are the most used ones in designing a powerplant.

The thermodynamics cycles are classified into two major groups: *Heat pump* cycles and *Power* cycles. Heat power cycles include *Carnot, Ericsson, Rankine, Stirling, Manson* cycles, and examples for power cycles are*: Diesel, Brayton, Otto, and Lenoir*.

The most efficient cycle is the Carnot cycle, and its thermal efficiency depends only on the temperature of the two reservoirs, which transfers the heat. It composed of reversible isentropic compression and expansion cycles [89].

Rankine cycle, which named after a Scottish polymath and Glasgow University professor, William John Macquorn Rankine, is a vapor power cycle. It is less efficient than the Carnot cycle, but more practical includes four different processes:

1. Isentropic compression of the liquid from.
2. Isobaric heating of the liquid, boiling, and super-heating the vapor.

3. Isentropic expansion.
4. And isobaric heat rejection until full condensation of the vapor.

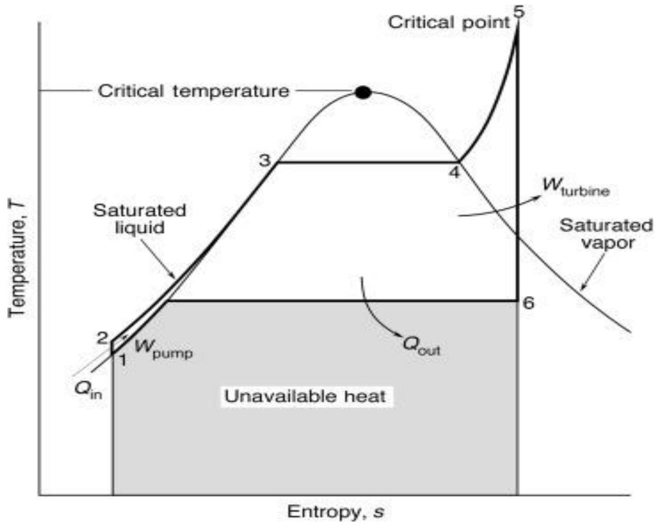


Figure3.1-Rankine cycle

- In the Rankine cycle, water is the only working fluid which is used because of its excellent thermal properties and availability. However, it is not an ideal fluid because its phase changes happen at low temperatures, and also it generates much entropy. The upper limit of the steam power plant temperature depends on the constrained material and is less than 600C, and the maximum pressure for a typical Rankine cycle is 10 MPa. Different variations of the Rankine cycle have been created in order to increase the efficacy of the cycle:
- *Rankine cycle with reheat:* In this variation, by using two turbines, it is tried to increase the average temperature. After the vapor has passed through the first turbine, it enters the boiler again and is reheated before passing through a second turbine.
- *Regenerative Rankine cycle:* in this type, by using the heat transferred from the steam to increase the temperature of the primary liquid or the liquid emerging from the turbine, it tried to regenerate the cycle and increase the efficiency [90].

- *Organic Rankine cycle:* water is not suitable for a small engine with low-temperature heat sources like solar or waste heat because of its low vapor pressure in low temperatures. Typical working substances are hydrocarbons or halocarbons, like toluene [91].

Brayton cycle, for the first time in 1872, applied by George Brayton in his constant - pressure engine, which includes a piston-compressor and a piston -expander. Currently, modern gas turbines and airbreathing jet engines working based on the Brayton cycle. This cycle has four steps [92,93]:

1. Adiabatic compression
2. An isobaric process with heat addition and fuel combustion
3. Adiabatic expansion in the turbine and produce work to generate the power or accelerate the fluid for jet propulsion
4. An isobaric process by heat reduction.

The two factors that affect efficiency are turbine-inlet temperature and pressure ratio, which should be the highest as possible. Like the Rankine cycle, several variations of Brayton cycles are explained to improve the efficacy. For example, in the regenerative variant, heat from the exhaust is used to heat the air before entering the combustion chamber, or it can be used to generate the vapor in combined Brayton - Rankine cycle [94].

Because of the abstract feature of the thermodynamics, which includes different topics and their relation either theoretically or numerically, many students describe this course as one of the difficult courses in which its problems need to be solved attentively. Although it is one of the most present sciences in daily life, many students find the thermodynamics so complicated to be comprehended. It is known that Practical learning is one of the educational methods helping the materials to be learned by visualizing and practicing the theory. Having a practical view of the course materials helps the students to correlate the topics with real-life, understand the usage, benefits, and the importance of the science that they are learning, which enhances their motivation and curiosity, ending in better processing and critical thinking. To provide the opportunity for students to practically involve the concepts of thermodynamics and relevant needed knowledge from other fields and to put all these data together, it would be beneficial if a practical model of learning for different applications of the thermodynamics science is developed. There are many exciting applications of thermodynamics in the real-world, for instance, different kinds of engines, heat transfer, and powerplants. Because the need for powerplants construction is in increase, especially in developing countries, we decided to model a Power plant project in a virtual environment.

As it's known, powerplants are industrial facilities to generate electrical power and can be divided into two different groups: *Thermal* power plants and *Renewable* energy power stations [95,96,97].

In *Renewable* power stations, the energy which transforms into mechanical then electrical power is renewable. Examples are hydroelectric or solar powerplants and wind turbines.

In *Thermal* power plants, the thermal energy transferred through a heat engine and transformed into rotational energy to produce mechanical power. Thermal powerplants also can be classified based on their heat source, for instance: Fossil-fuels, Nuclear, Geothermal, Biomass, solar-thermal power stations.

Heat engines, which transfer the thermal energy to mechanical energy and work, have different types of working based on different cycles with a wide range of efficiency.

In designing the power plant project, besides the scientific aspects of the project, which was the first motivation, other learning goals were targeted by allocating more responsibilities to the students. The study population groups were engineering students, and they will face real-world challenges in their future careers, which will not be just theoretical or scientific indeed. A significant project like power plant projects in the real world contains a variety of aspects that should be considered, studied, and analyzed. Features like economic, geographic, energy, and political will have reciprocal impacts on the project, and an engineer should consider all of them. Therefore, students were asked to consider themselves as a project manager for a fictitious company engaged in the construction of a thermal energy power system that is looking for potential sites for future projects in one of the offered countries. They were assigned to write a proposal report to the company in four divided assignments aligned with all expected aspects of the projects.

The researchers tried to follow the revised Blooms' taxonomy learning steps in these classified assignments. In the first assignment, students were asked to describe the need, resource, and economic situation. The second one asked the description of the economic, societal, and political impact of the project. In these two assignments, the research was evaluating the “understanding,” which is related to the word “description” and is the second level of the learning taxonomy. The technology, specification, and components and their function were the desired learning materials in the third assignment, which place in the third level of the taxonomy. In the final deadline, students needed to justify their choice, analyze, calculate the specifications of the system, and write the abstract, which is aligned with the “evaluating” and “creating” level of the taxonomy and the highest goal in the learning process. (Table 2.1)

3.1.2 Developing virtual-object

To develop the Virtual-object, our colleagues at Virginia Tech University used the LabVIEW tool from National instruments to create a virtual environment based on the engineering and statistical data associated with various considered aspects [64]. Panama, Rwanda, and Jamaica were the three countries offered in this object. Geographic, economic, environmental, and energy aspects of each country provided in charts, maps, and graphics based on the last updated statistical data from governor website of each country under the homonymous categories to guide the students to choose the country and imply the importance of each aspect in the projects. All the windows and subcategories in the tool included the buttons in order to be easily navigated.

As illustrated in Figure 3.2, the data is accessible in each category under the similarly named icon on the left side of the page. These windows included different aspects of each country related to the power plant project and technical description of both the Rankine and Brayton cycle.

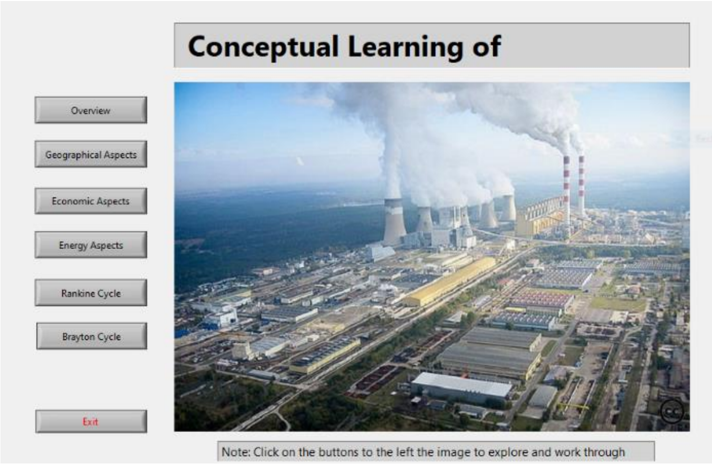


Figure 3.2-Virtual-object

After selecting the location, students should decide about the power plant type based on the predicted demand, available resources, and other conditions like geographic characteristics of the site of choice.

Because most of the power generating methods designed based on the two main thermodynamics cycles: Rankine and Bryton cycles, two different windows were created for each of the cycles, and the characteristics of each component and their functions were provided under separate categories. Related thermodynamics graphs (h-s and p-v charts) used in textbooks provided in animated form to explain the processes clearly. The tables of the properties (temperatures, pressures, and specific volume) of the working fluid, besides all the formula and calculations for each cycle, were provided as well—the calculation results after putting the suitable input obtained by clicking the related key.

The Virtual-object was developed using the Lab view software, which enabled developing animations besides writing equations. Each module was called Virtual Instruments (VI), and all the sub-modules or sub-Vis could be called from the main VI by clicking the key.

Following is some methods that had been used in developing the Virtual-object process [98]:

Ring Control: was used in creating animations by adding the sequences of the images and play them at pre-defined speed.

Event Structure: Event structure was a generic coding method which enabled to navigate to sub-Vis by clicking the button

The ActiveX controller was an add-on to the LabVIEW software, which enabled it to play video files. An additional control file (ctl) needed to be downloaded to allow the basic control keys of ‘Play,’ ‘Pause’ and ‘Stop’ to be used during runtime [98].

As a final step in creating the Virtual-Object tool, the equations and calculations in Rankine and Brayton cycles were validated against standard published results.

And to test the tool’s functionality, undergrad students at Virginia Tech University volunteered to work on the project with the tool. Their feedback had been considered to improve the thermodynamics Virtual-object tool.

3.2 Selecting the population

The students enrolled in the Thermodynamics course at the University of Oklahoma in three consequent years 2017,2018, and 2019 were chosen as the population groups of the study.

All the classes were asked to participate in the power plant project provided in four separate assignments and write their reports considering the questions asked in each of them. Participating in the project was optional, and the participant was asked to sign the consent form before the project starts at the orientation session at the beginning of the semester.

The timeline and rubrics were available from the beginning, and additional three different short discussion session took place in the class to clarify the subjects and issues were coming up during the semester.

For the 2017 class, which was the control group of the research, students engaged in the project did not have access to the Virtual-object and used their course materials, books, internet, and all traditional data sources for their assignments. But the experimental groups, the 2018 and 2019 classes, were provided the tool and being asked to use the tool as their primary source of data.

3.3 Applying different assessment methods

Using additional educational methods as a supplementary method to enhance the virtual-object effect on the learning process was another intention of the research. These assessments that were applied only to the class of 2019 population group were:

- *Peer reviews:* researchers randomly assigned each student to review two other students' reports at each assignment and encourage them to give about ten suggestions every time. In this way, students access other students' assignments and encounter different ideas and compare them with each other and with his/her report. Also, he/she got the feedback from 2 other peers for his/her report and had a variety of suggestions to improve his/her work.
- *Feedback from the researcher after each assignment*: the researcher had access to all data, so she/he can guide the students in their project and help them if they have any questions or problems with utilizing a Virtual-object.
- *Having three short in-class discussion* session
- *Final students' feedback survey*: students of the 2019 class after submitting their final assignment were asked to participate in a feedback survey as a summative assessment method. In this survey, they answered the questions and evaluated the processes, the Virtual-object and power plant project on a scale of 1-5, which 1 is the less helpful method, and five is the most helpful one. (A.3- Students' feedback survey form)

The difference in the student's performance between 2019 and 2018 classes was interpreted as the effect of these applied assessment methods.

3.4 Evaluating students' assignments

3.4.1. Rubric based grading

The assignments were evaluated by using the grading system based on holistic rubrics. Background and technology used to design the powerplant and the project proposing skills were considered in the defined rubric. The explicate criteria were defined for each part, and all the grades were recorded while the best performance assignment score expected to be 20 (A.2-Rubrics table). After finalizing the grades, the statistical analysis has been done to evaluate the data.

The pooled variance t-tests are one of the t-test models, which is used prominently for comparing means between two normally distributed populations if the standard deviations are approximately similar. Un-pooled variance test (or Welch test) is used when the standard deviations of the samples are far different from each other. A more practical but informal way to decide whether to use a pooled variance t-test or not is to calculate the standard deviation ratio between two groups. If this ratio falls between 0.5 and 2.0, the pooled t-test can be used, otherwise using an un-pooled t-test should be considered. The Shapiro-Wilk test, with a 95% confidence interval, was conducted to test the normality of each sample and showed the normal distribution and similar standard deviation of groups. Based on this, the pooled variance t-test was selected as a statistical analysis method to verify the results [99,100,101].

Two pooled variance t-tests were conducted to compare the performances of students in classes of 2018 and 2019 with the control group. To investigate the effectiveness of supplementary formative assessment, a pooled variance t-test was conducted to compare the overall performance of students in the class of 2018 with students in the class of 2019.

3.4 .2. Content analysis

Each educational process contains wide-ranged technics that can be either effective or inefficient in the learning process. The goals in every pedagogical project usually go beyond the only teaching of the relevant material in that pre-defined time. The sophisticated of instruction is to help the students grasp something beneficial for their future life and career because even the small amount of knowledge can have a profound effect and play a critical role in their future.

The Virtual-object project also had its own far-reaching goals and tried to teach useful lessons beyond helping students in learning complicated concepts in thermodynamics. In this project, students were involved with other aspects of the power plants besides the technical part; they understand that for proposing their design in this kind of project, they need to consider many perspectives like economic, geographic, political aspects of the site of choice. They discussed the reasoning of the project in their proposal paper and realized that it should be convincing enough for investors. They perceived the responsibility of an engineer who should evaluate the impact of his/her project, either positive or negative, should predict a timeline, cost, and efficacy, and many other things. Although researchers tried to mention all of these by asking different targeted questions in each assignment, it was difficult to evaluate the learning of all these aspects by the grading analyzing method. The study was practical, but unlike the usual ones, the outcome of it was written assignments by the students. So, it was hypothesized that the grading based on the predefined rubric by the researcher or educator was not sufficient enough in evaluating the discussions inferred by the students and can miss some particular data in practical learning.

Quantitative content analysis was the method fitted in our goals, and it was applied in our study as the second evaluating method. In quantitative data analysis, the researcher is trying to go over all the contents, then categorize, code, and finally interpret the relationship among different categories or between categories, codes, and the previous existence data.

For this reason, after the final submission was made, and after reviewing all the assignments, a researcher created different categories and sub-categories based on her comprehension of all students' homework. Each student used his/her language and a specific way of thinking and rationale in the project. As a researcher, I tried to combine all of these wide-range perspectives and comprehend them carefully to reach the subtle-point of their thoughts to create the categories and related codes. All of the categories, subcategories, and codes were revised several times as research was going on in order to reach the ones which satisfy most of the data correctly. After finalizing the inventory, it is used as rubrics for analyzing the assignments while the existence of a code in the students' homework graded as one and the lack of code in related sub-category rated as zero for that specific sub-category. Because the number of sub-categories was different, all the data in each category was normalized, and the normalized mean of each category was used as a descriptive measure to evaluate the difference between 2019 and 2018 with the control group, 2017. In the end, because the variance ratios between two under-comparison population groups for each category was between 0.5 and 2.0, the pooled variance t-test was applied to verify the significance of the differences. Also, the comparison between 2018 and 2019 was performed to analyze the effect of the assessment method on the performance of the students.

Chapter 4: Results

4.1. Applying assessment methods

Formative assessments are the type of educational assessment design to evaluate the learning process when the process is still going on. This assessment method targets the students' weakness and learning effectiveness problems, and educator usually tries to improve the learning process by providing feedback. Summative assessments are done after the completion of the learning process and usually use a grading system based on the rubrics. Any feedback and quizzes after the final tests consider summative assessment and aim to improve the educational process in the future courses and programs.

In this study, we divide the project into three different assignments without grading them except the final assignment. The assignments revised by the researcher, and the necessary comments and advice were submitted after each assignment. Also, students asked to participate as a peer reviewer in each assignment and encouraged them to provide ten commentary advice. At the end of the semester and submitting the final assignment, students were asked to participate in the feedback questionnaire, which was providing the questions about the project itself, virtual-object, and education, and assessment methods had been used during the course. Thirty students participated in the feedback survey and graded the questions from 1-5, with one being the least helpful and 5 being the most helpful material or method which helped them during the course. The summary of feedback from students is shown in Table 4.1.

Table 4.1-Student evaluation of project and V-Object

Rating	1	2	3	4	5	No answer
Overall Project	%	%	%	%	%	%
Determining what aspects should be considered when managing a project	10	10	30	27	20	3
Project reasoning and discuss the demands and benefits	10	13	33	27	13	3
Recourses which are or are not available	13	17	27	23	17	3
Economic condition and impact of the project	10	13	13	43	17	3
Societal conditions and impact of the project	13	17	17	30	20	3
Geographic and project reciprocal impact	10	7	33	40	7	3
Political and project reciprocal impact	13	37	27	17	3	3
Determining what aspects should be considered about the technology of choice	13	10	20	33	20	3
Virtual tool	%	%	%	%	%	%
Project tool: a profound understanding of the course material	23	17	30	23	3	3
The impact of the project to retain the course material for future use	20	17	20	30	10	3
Project tool: an overview of the energy problem	17	10	43	20	7	3
Project tool: geographic aspect data	17	13	40	17	10	3
Project tool: energy aspects data	13	23	37	13	10	3
Project tool: Economic aspects data	13	23	27	27	7	3
Project tool: Rankine cycle function	17	3	27	37	13	3
Project tool: Rankin cycle processes	10	10	27	30	20	3
Project tool: components & equations	27	3	27	27	13	3
Educational assessment methods	%	%	%	%	%	%
Having access to the top well-done assignments as a paragon	20	7	17	33	20	3
Having the opportunity to receive feedback from the peers	10	3	23	40	20	3
Having the opportunity to give feedback to the peers	13	7	33	27	17	3
Dividing the project into several segments rather than a single final project as a whole.	3	0	10	27	53	7
Hearing the feedback from the researcher	10	3	13	17	53	3

In the Power plant project evaluating section of the feedback survey, overall, 33% of students found this project helping them with a score of 3-4 in all questioned aspects. These questions were evaluating the level of improvement in the knowledge of the students about the aspects that should be considered when managing a project, and what makes a specific technology suitable for a project.

In the V-object tool evaluating section, 27%-40% of the students rate the efficiency of the V-object tool on their learning process of the course material or helping them with their project with the average score (mostly 3-4). They found the data about the Rankine cycle, its characteristics, and function the most helpful category in the V-object tool.

In the Educational assessment methods, among five different types, distributing the project into classified assignments and getting feedback from the researcher were two most helpful techniques during the course, and 53% of the participant students rate these methods with the highest score.

The results show that receiving feedback from peers was more helpful than reviewing and revising peered assignments (20% highest score compared with 17%) and having access to the top well-done assignments almost was as helpful as peer reviews.

4.2. Rubric-based grading of the students' assignments

The use of newly developed technologies is becoming an integral aspect of higher education nowadays. In the engineering field, which is the combination of analytical thinking, designing skills, and creativity, it is critical to utilize the advanced technologic methods and have the evolutionary process to help the students' learning ability.

The leading universities and colleges try to integrate the teaching techniques with virtual reality to embolden the perception and learning processes in their students. The Virtual-objects are defined as 2D or 3D computer-generated environments that simulate the real-world facts that enable users to perform a wide range of interactions with the content of the object and even other users.

In this project, researchers wanted to study the effect of using “Virtual-object” on the performance of engineering students who were enrolled in one of the fundamental courses in mechanical engineering, Thermodynamics.

For this purpose, researchers developed a virtual learning environment by using different informative features such as animations, videos, maps, and charts to explain some fundamental concepts in Thermodynamics. For instance, the Rankine cycle icon, a diagram for the cycle routs, and an animation of the function of the cycle used to illustrate the theoretical data.

Subsequently, we selected three different classes that enrolled in the Thermodynamics course and asked them to participate in the same project in the same time manner. The experimental groups (2018,2019) were provided the V-object in their course, whereas the control group (2017) used the traditional education method with no access to the virtual laboratory.

The project required students to design an imaginary power plant in one of the three offered countries to provide them a high-quality energy resource for their increasing needs considering their geographic, financial, and political situation.

In the end, a researcher collected the data and evaluated the students’ performance based on the pre-defined rubrics. We considered technical knowledge and formal paper writing regulations in the rubrics. To measure the difference between experimental and control groups, we used the mean of each class group, and the numerical statistical method was performed to verify the significance of the difference. The pooled variance t-test is one of the t-test models, which is used prominently for comparing means between two normally distributed populations if the standard deviations are approximately similar. Two pooled variance t-tests were conducted to compare the performances of students in classes of 2018 and 2019 with the control group. To investigate the effectiveness of supplementary formative assessment, a pooled variance t-test was conducted to compare the overall performance of students in the class of 2018 with students in the class of 2019.

The assignments of students in each year are evaluated and graded base on the pooled variance test. Table- 4.2 shows the results for each group of students.

Table4.2 -The statistical evaluation of results obtained from rubric-based grading

Class	*Class size*	*Median grade (out of 20)*	*Mean of Grades (out of 20)*	*Standard Deviation*
2017	*35*	*12.5*	*12.64*	*2.87*
2018	*39*	*15*	*14.27*	*2.62*
2019	*65*	*17.75*	*17.25*	*3.31*

The maximum grade from grading rubrics is expected to be 20, and the mean of grades for 2018 is 14.27, where the mean for the control group is 12.64. The results show that there is a significant difference between the performance of students in 2018 compared with the control group (p-value=0.006, CI=95%, and df=72). The results also show that the average grade (17.25 out of 20) in the class of 2019 is significantly higher than the average grade in the control group (p-value =2.15E-10, CI = 95%, and df =98).

The V-object was introduced to students in both classes of 2018 and 2019, but the formative assessment was also supplemented to the V-object in a later class. The results show that the mean of grades for students in 2019 is higher than the mean for students in 2018, and the difference is statistically significant (p-value = 2.8E-06 , CI = 95% and df = 102).

4.3. Content analysis of students' assignments

In this study, after students' final submission, for evaluation of the impact of the "Virtual-object " on student's performance and learning, a quantitative content analysis was performed. Because the research was designed based on a practical-learning method with the writing report outcome, researchers hypothesized that the grading method based on the pre-defined rubrics may contain some errors and would not be a distinctive method and analyzing the student's approach to the project based on their own words and discussions would be beneficial.

When the project was submitted to the students, besides the main objective of the research, which was helping the students to learn the complicated concepts of the Thermodynamics, our long-term goal was to set a different, practical, and more realistic view of the course material for students. As future engineers, this research provided them an opportunity to involve in an imaginary project proposed based on the real-world problems and their future career environment. For example, in addition to the Rankine cycle and all its characteristics, formulas, and diagrams, we wanted students to learn and think about what and how other aspects like social, political, environmental features of a society can have mutual impacts on their project. They encountered the questions which should be answered, the issues should be predicted, and the possible solutions should be considered.

However, evaluating all the categories mentioned above needed a precise method of analyzing that can evaluate the discussion, interpretations, and ideas of the students. So evaluating by grading method based on the pre-defined rubrics seemed insufficient. Quantitative content analyzing method, which fitted in our goals, have been chosen. Grounded on this analyzing method, a researcher reviewed the assignments several times to get familiar with the content and students' different approaches and various opinions. Then she highlighted any particular pattern on discussed content or specific idea which could be added to the list of categories. Then she tried to classify all the conventional materials for each section, then added the categories which students did not discuss in their assignments to cover all the content. Each category included different sub-categories to cover all essential contents. Following this, the researcher tried to find the code for each sub-category, which is reciprocally related to the content and was the very brief meaning of it. After creating code inventory, every student's assignment was re-evaluated based on the created codes list. If the code exists in their discussion, they graded one versus zero for code inexistence. The researcher was trying to evaluate which aspects are most important for students and which features are being neglected from their sides.

For example, the sub-categories under the "Political aspect" category in which the study asked students to discuss it in their second assignment were: current political condition, the potential effect that the governor or political situation can have on the project and the impact of the project on the political environment. The researcher chose "president, government, system" as codes for the current political situation sub-category. "election, law, policy, popularity" for the second sub-category and "internet, media, public" for the third one.

Results of content analysis

The normalized average of all categories for all three populations calculated. Overall, students of class 2019 had a better performance compared to the 2018 and 2017 classes. However, there were some exceptions too. For example, the 2017 class had better performance in political aspects comparing with 2019 and in resource and political aspects compared with 2018 students.

All three population groups had a higher average score in project design and technology aspects among all categories where the resource and political aspects were the least considered categories. Table 4.3 shows the average scores for each category that is graded between zero and one.

Table 3.3-The normalized average of main categories obtained from content analysis

	Reasoning	economic perspective	considering resource	Geographicperspective	societal perspective	political perspective	project design	technology
2019	0.55	0.55	0.19	0.76	0.45	0.27	0.96	0.88
2018	0.53	0.53	0.1	0.76	0.67	0.26	0.87	0.86
2017	0.36	0.45	0.18	0.61	0.42	0.35	0.68	0.83

A pooled t-test for each category and each pair of years were applied separately. To evaluate the validity of these results statistically,

1.Project reasoning

Both 2018 and 2019 classes had a better performance than the control group in this category. However, comparing 2018 and 2019 showed the same distribution statistically. Almost 50% of expected data was described in students' assignments in 2019, which has the best performance rate among all three-population groups. It means that in this section, there is an average satisfaction toward the project goal, and more efforts and correction would even improve the gained results.

Table 4.4- Comparing the performance of all three population groups in the "Project reasoning" category.

	Mean difference	*df*	*t-stat*	*P-value*
Class 2018 Vs. Class 2017	*0.17*	72	2.90	0.002
Class 2019 Vs. Class 2017	*0.19*	98	3.4	4.9e-04
Class 2019 Vs. Class 2018	*0.02*	102	0.45	0.325

2.Economic aspects

The difference between 2018 and 2019 classes with 2017 in the economic perspective category was meaningful; however, comparing 2018 and 2019 results showed no differences in this category. Almost 50% of the expected content was discussed by the students in all three groups. In 2019, fifty-nine students discussed the country's economic present condition like GDP and poverty. Fifty-two of them conversed about the impact of the project on the employment rate and income, but only ten of them talked about foreign investment and trade, which were the sub-categories of this class.

Table 4.5 - Comparing the performance of all three population groups in "Economic" category

	Mean difference	*df*	*t-stat*	*P-value*
Class 2018 Vs. Class 2017	***0.08***	***72***	***1.82***	***0.036***
Class 2019 Vs. Class 2017	***0.1***	***98***	***2.4***	***0.009***
Class 2019 Vs. Class 2018	***0.02***	***102***	***0.35***	***0.361***

3. Considering the resource

Class 2018 had the lowest performance in this category, and the difference between this class with 2017 class and also with the 2019 class was significant statistically. However, the difference between the 2017 class and 2019 was not valid by 95% confidence Interval. This category was the least considered one in all three population groups. Only fourteen students in 2019 discuss the importance of financial resources and opportunities in their assignments.

Table 4.6 - Comparing the performance of all three population groups in the "Resources" category

	Mean difference	*df*	*t-stat*	*P-value*
Class 2018 Vs. Class 2017	***-0.08***	***72***	***-1.71***	***0.045***
Class 2019 Vs. Class 2017	***0.01***	***98***	***0.29***	***0.384***
Class 2019 Vs. Class 2018	***0.09***	***102***	***2.18***	***0.016***

4.Geographic aspects

The difference between 2017 and 2018 and the difference between 2017 and 2019 class was meaningful In Geographical aspects' category. But there was no significant difference between 2018 and 2019 classes.

Table 4.7 - Comparing the performance of all three population groups in "Geographic aspects" category

	Mean difference	*df*	*t-stat*	*P-value*
Class 2018 Vs. Class 2017	***0.15***	***72***	***3.13***	***0.001***
Class 2019 Vs. Class 2017	***0.15***	***98***	***3.80***	***0.0001***
Class 2019 Vs. Class 2018	***0***	***102***	***0.23***	***0.407***

5.Societal aspects

The 2018 class group had the best performance in this category, and the differences with other classes were meaningful statistically. This class discussed more than 50% of the awaited data. However, the difference between the years 2017 and 2019 was not significant statistically.

Table 4.8 - Comparing the performance of all three population groups in "Societal aspects" category

	Mean difference	*df*	*t-stat*	*P-value*
Class 2018 Vs. Class 2017	***0.25***	***72***	***3.85***	***0.0001***
Class 2019 Vs. Class 2017	***0.03***	***98***	***0.46***	***0.32***
Class 2019 Vs. Class 2018	***-0.22***	***102***	***-4.32***	$1.8e^{-0.5}$

6.Political aspects

Although the students' performance in 2017 class looked better than the other two class groups, and they discussed the political aspects more comprehensively comparing with other population groups, but the difference of 2017 class performance with either 2018 or 2019 was not significant statistically. Even in 2017, almost 35% of expected information was discussed in assignments showing that needed political supports, agreements, and adjustments are the issues that students had not enough knowledge or just could not relate them to this kind of project.

Table 4.9- Comparing the performance of all three population groups in "Political Aspect" category

	Mean difference	*df*	*t-stat*	*P-value*
Class 2018 Vs. Class 2017	***-0.09***	***72***	***-1.12***	***0.132***
Class 2019 Vs. Class 2017	***-0.08***	***98***	***-1.31***	***0.096***
Class 2019 Vs. Class 2018	***0.01***	***102***	***0.12***	***0.452***

7.Project design

This was one of the best-performed categories in all three groups of the population. Both 2018 and 2019 classes had better results than the 2017 class in the project designing section, which has been proved by statistical analysis. The students did not consider only less than 5% of expected data in 2019 comparing with almost 30% in the 2017 class group. However, 2018 and 2019 classes did not have significant differences in this section.

Table 4.10 - Comparing the performance of all three population groups in "Project Design" category

	Mean difference	*df*	*t-stat*	*P-value*
Class 2018 Vs. Class 2017	***0.19***	***72***	***2.85***	***0.002***
Class 2019 Vs. Class 2017	***0.28***	***98***	***3.78***	***0.0001***
Class 2019 Vs. Class 2018	***0.09***	***102***	***0.64***	***0.259***

8.Technology

This category was the other well-performed category by all three population groups. Although the mean of 2017 was lower than the 2018 and 2019 classes, this difference was not significant statistically.

Table 4.11 - Comparing the performance of all three population groups in the "Technology" category

	Mean difference	*df*	*t-stat*	*P-value*
Class 2018 Vs. Class 2017	***0.03***	***72***	***0.7***	***0.230***
Class 2019 Vs. Class 2017	***0.05***	***98***	***1.26***	***0.103***
Class 2019 Vs. Class 2018	***0.02***	***102***	***0.52***	***0.299***

Chapter 5: Conclusion

5.1. Findings regarding the first and second research questions by grading method

The statistical data based on the grading method showed the significant effect of the Virtual- object project in enhancing the students' performance in both 2018 and 2019 class groups comparing with the control group in the class of 2017. Moreover, comparing 2018 and 2019 results, which the only difference between them was using additional assessment tools, showed a significant effect of these methods in students' achievement.

In the feedback survey, students reported an overall score of 3-4 for all the questions in all three categories considered by researchers to be evaluated, the project itself, the v-object tool, and the assessment methods. By the results obtained from this survey, it can be comprehended that all of the categories were helpful in the learning of some of the appointed materials of the thermodynamics. However, still, some adjustments and changes are needed to make them more useful. Also, because only 30 students from 60 students participate in the feedback survey, our conclusion is not expandable, and for example, it cannot be claimed that adding the assessment methods were successful determinedly. However, it can be concluded that they were helpful for at least half of the students of the 2019 population group and has a positive impact on their performance.

The results in the "educational assessment" section of the feedback survey showed that dividing the project in different assignments and receiving feedback from the researcher rated most helpful among all other methods. These results agree with the benefits of the stepwise approach to learning. Receiving feedback after each assignment helped in their stepwise achievement by clarifying the material, correcting the misunderstood points, and giving positive feedback for their good comprehension aspects. Peer reviews are also considered helpful, but they found receiving advice from peers is more helpful than reading and giving some advice for their peers. Receiving feedback makes a valuable supplementary notation, which helps students reflect on the points they previously did not think about them. Nevertheless, giving feedback requires reading, critical thinking, making a judgment, which is not an easy task and has a far-reaching impact on students thinking process. Probably it is the reason that they found it less helpful than receiving the feedbacks, which is easy and has a direct impact on their ongoing course.

In evaluating the "Virtual-object" tool section of the feedback survey, the information provided in the tool was rated reasonably helpful in all the related aspects of the project. However, it was less helpful correlating with course materials. This is an important point that can be considered in future studies—probably adjusting the data in a way that has the specific language of the professor and his/her instruction or adding some initial data about the course and its material would be more helpful. In the Thermodynamics course, the powerplant is an advanced topic and needs students to grasp the basic material profoundly. So probably instead of the powerplant, which is a complicated content for the students in basic Thermodynamics course, using simple topics, for example, different components like turbines, boilers, and generators with various specifications would be a better choice.

It is hopeful when we are looking at the "project impact" section in the feedback survey. Students found the project helpful in identifying what angles they should consider in managing this kind of project and what aspects of the technology that they want to implement. This is one of our initial goals with this project, and although still, it is not entirely fulfilled, but it has some promising results to be a reference for future studies.

5.2. Finding regarding the questions of the study by quantitative content analyzing method

Based on the data which content analysis followed by detailed statistical analysis provided, it could be easily realized that the overall performance in experimental groups is better than the control group, which coordinates with the results obtained from the grading method. The 2019 class has a higher mean comparing two other classes in most of the categories. However, the difference between 2019 and 2018 classes was not strong enough to consider significant statistically in all categories. This finding is different from what we obtained from rubric-based grading, which shows the statistically valid difference between 2018 and 2019 results. We conclude this controversy by taking the two-analysis method difference into account. In the content analysis, we are looking for the developmental process of comprehension in detail by using students' achievement as a reference. By reviewing students' assignments and cracking down their conclusions into different categories and sub-categories, we try to analyze their level of learning based on the criteria that are created by their performance. Also, with the content analyzing method, we can evaluate our project and design by accommodating the strength and weaknesses of the project with the pattern of the students' performance in each category. However, in rubric-based grading, we evaluate students' final performance in various criteria that we defined them based on our learning goals, and we can miss, underestimate, or overvalue some criteria. So, in the grading method, we may have a rough identification of the level of achievement comparing with content analysis, which is a more detailed process. However, future studies needed to answer the question clearly that if assessment methods are useful in enhancing the efficacy of the virtual-objects in students' performance.

By results obtained from quantitative content analyzing, “project reasoning,” “economical,” “geographic,” and “designing” categories are the ones we observed the better performance in both 2019 and 2018 classes in comparison with the 2017 class group. This result can have a possible reason. In the virtual-object, we have created separate icons for economic, geographic, and energy aspects. We can see that each category with an icon in the v-object has a significant improvement in the performance of the experimental groups. Even for “designing the project” category, the Rankine cycle and Brayton cycle icons cause better achievements. This conclusion showed that the categories of the virtual-object with provided data were aligned with the learning goals; however, they still can be complemented and expanded to reach the same amount of improvement in all categories described in content analysis.

In the “project reasoning” section, almost 50% of expected data was described in the assignments of the students in the 2019 class, which has the best performance rate among all three-population groups. It means that in this section, there is an average satisfaction toward a project goal, and more efforts and correction would even improve the obtained results. We observed the same pattern in the “economic” category. Positive local economic effects of the project were described reasonably by the students. In contrast, the possible impact of the project on the import and export of power or other commodities and the economic independence of the country was failed to be well described. It means that students are not fully aware of the economic dimension of the project, which can be considered in future studies. In “geographic” aspects, the pollution and possible solution for it is the clearly explained subjects in all three population groups, which shows the students who are the future mechanical engineers will consider contemporary climate problems in their future practice of engineering. Most of them investigate the possible geographic potentials of the country of choice, which could be proposed as the unique geographic site for their project to make instructing feasible, durable, and financially reasonable.

The "designing" category is the best performed one in almost three class groups with a 30% improvement in 2019 class compared with the 2017 class. If we consider the V-object project as a whole, this result showed a significant achievement in our highest-level goal of learning based on revised Bloom's taxonomy. The "designing and creating" classes are the sixth and final level of learning goal in this taxonomy, respectively, which shows students passed all the preceding steps and now reaches the point that they are able to design.

The "resource" category is the one that has the least satisfactory results in all three groups of the population. In 2019 which has the best performance among all groups, only 20% of the expected data were described in this class. This result is important because for implementing any project in the real world, finding the financial resource, workforce, political, and other supports plays a critical role in the accomplishment of the project, and without defining them, the project will possibly be stopped in proposing step. So, this is the issue that can be resolved in future researches by probably introducing some additional data, choices, or examples.

In "political" aspects, the group of 2017 class has the best mean among all groups. Although this difference was not significant enough to be valid statistically, but if it was meaningful, it could be related to the 2016 election and the political news and following excitement that happened that year in our country. In "societal" aspects, the 2018 class has the best performance among all groups. One possible reason for that can be the societal changes and adjustments that happened after the new political party takes power. This result showed the environmental impact on students' performance in the project. The community and related issues will affect the life of all populations in different aspects and a variety of angles. So, global awareness and information will impact human life even indirectly.

The surprising results were obtained in the “technology” category with quantitative content analysis. The components, their functions, and mathematical calculations are the analyzed data in this class. All three classes showed almost 80% of expected learning performance in this category. There were no differences between the performances of all population groups, which was contrary to the results obtained from the grading method. It is important because this category, like the designing category, is a technical one and is mostly related to the practical aspect of the engineering, which was one of our end goals in improving the outcome of the students. We can conclude this finding in different ways. First, besides the specific information for each cycle route, we provide all the formulas, curves, and other data about each component under the cycle icon. By providing the calculator for each formula, we facilitate the calculations for students. It is possible that students used the calculator only and did not pay attention to the valuable supplementary information provided in this icon. Which if it is the case, it would probably be better to revise this section and instead of a calculator introduce a variety of components with different characteristics and challenge the students to select the best one fit in their design. The second probability is that all three groups of students’ majors are mechanical engineering, and It is reasonable that mechanical engineering students put more weight on technology and design, which is the nature of their field. The students in the 2017 class achieved 83% of our learning goal, which is a satisfying result. Does it show that we can predict the educational field by investigating the more emphasized category in this kind of project? For example, if our population groups were the industrial engineering students, the best-performed category probably would be the resource or reasoning categories?

Moreover, the third possibility is that the content analysis is not a good measure for analyzing this category. In this group, students were describing the predefined data, for instance, the characteristic of each component, and they only should recall them or search the data and then rewrite them. Alternatively, they should put the numbers in the formula and get the result. There were no cognitive or practical skills challenge here, which make the content analysis a questionable method to test it, because this type of analysis, evaluates students learning based on their idea, choices, interpretations, and comprehensions not just recalled and rewritten data. Future studies are needed to discuss and confirm all of these hypotheses.

5.3. Summary

Our research is intended to evaluate the impact of a Virtual-object on the pedagogy of engineering students, emphasizing on the importance of practical learning. A Virtual-object was designed to help students to understand one of the complicated contents in thermodynamics course, a power plant, by visualizing and interacting. We utilized a project-based learning method to design our study and assigned a class project to the students in the Mechanical engineering department of the University of Oklahoma who enrolled in the thermodynamics course for three consecutive years. Different assessment methods added in the last year of the study and their impact on the performance of the students was also evaluated. We used a rubric-based grading method and quantitative content analyzing method to evaluate and interpret our data. The key finding of this study summarized as:

- Utilizing V-object has an augmenting effect on engineering students' learning performance.
- The impact of the additional assessment methods on students learning is controversial based on two different analyzing ways and needs further studies.

- Feedback from the researcher after each assignment, receiving feedback from peers, and dividing the project into four different tasks are the most helpful assessment methods based on the students' survey.
- The result of content analysis is mainly in agreement with rubric-based grading evaluation.
- Content analysis is the preferred method and provides more detailed data in project-based learning when we want to evaluate the cognitive thinking or the high level of educational goals, evaluating or creating.
- Content analysis probably is not a good method in analyzing the basic levels of learning goals like remembering.

5.4. Limitations and future works

The results of this study confirmed the efficacy of Virtual-objects and practical learning in students' educational performance. However, the impact on future engineering career is beyond the boards of this research and needs further studies. The limitation that our study faced was the small population number, the lack of information about students individually who participate in the study, which can affect the final performance, and the unavailability of the direct observation of the usage of virtual-objects. Also, this study was limited to mechanical engineering students in their sophomore level, and future research needed to extend these findings beyond the context of the major of the engineering students and their level.

Researchers presented the quantitative content analysis as a different evaluation method, which is infrequently used in previous studies in the engineering field and discussed the positive effect of the content analyzing method in evaluating the interpretations conferred by the students and their initial ideas. This method provided a clear and comprehensive data of the performance of the students and is a valuable evaluating method in evaluating the practical learning. These results can be used as a model and for comparison in future researches to evaluate and increase the reliability and validity of the studies.

Furthermore, like any other research, some questions were addressed in this thesis, while some others have been raised. The results obtained from content analyzing and feedback survey, generated some hypothesis about some methods which can improve the designing of the instructional Virtual-objects:

1. Choosing the topic considering the level of the complexity of the course, and using the educational material of the curricular created by the professor of the course would be helpful in correlating the project with the course materials.
2. Probably providing separate icons for the materials intended to be learned can help the students' performance in that specific topic.
3. Possibly providing different options in the components section of the powerplant, is more beneficial than a calculator for each mathematical formula involved in powerplant.

All of these can be explored in future design and studies in order to develop more readable educational tools. Finally, it is imperative that new educational devices like virtual laboratories, upgraded on-line teaching facilities, and different evaluation methods continue to be investigated in the practical learning domain, which is the main characteristic of engineering education.

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Appendix A

A. 1-Power plant project instruction

You are a global project manager for Global Energy Systems—a fictitious company engaged in the design and construction of thermal energy power systems around the globe. Your company is looking for new projects, and as a result, you are searching the globe for potential sites for future projects. Write an internal company report proposing a new energy system at a prospective site in Jamaica, Panama, or Rwanda.

Your report must conform to the accompanying template and will be evaluated using the accompanying templates. Your report should be at least six pages long, including figures and tables. The report should be composed of the following sections:

1. ***Abstract.*** Five or six sentences only! The abstract should be the only section on the first page, and it should clearly explain *what* you are proposing and *why* you are making the proposal. It should also explain the need for additional electrical power generation capacity at each site that you have chosen (including future projections of demand for energy), the resources (or lack thereof) that are available for meeting those needs, and any other reasons that the site is a desirable investment. Provide a few overall system specifications.

2. ***The site.*** Both the country and location in the country of the proposed site.

3. ***Specifications of the proposed system.*** The details of the system.

Do not include a conclusion section in this report! This report is a proposal, and the abstract should include a complete synopsis of the report. In many companies, individuals in management positions typically don’t have the time or patience to look through an entire report for the conclusions. They want to be able to see from a cursory read of the first page what the report is about and what it is recommending.

Include appropriate tables and figures to illustrate the information that you are conveying. Your report should include adequate justification for the suitability of the proposed power system for the site that you have selected. Citations must be included to support claims that you make.

Peer evaluations. Each submission will be made in .docx/Notability format. Peers must make at least ten suggestions for improvement. Suggestions may be for grammar, spelling, wording, etc. Peers must also complete the short rubric. Items must be addressed by the next submission. At the next submission, compliance will be checked by peers and professor.

First deadline

By the first deadline you should have:

1. Documented **the need** for additional electrical generation capacity at the **proposed site.**
2. Described the **economic situation** in the country where you are proposing the new system.
3. Provided projections of the demand for electricity at the proposed site.
4. Described **the resources** that are available to meet the projected need.

Second deadline

By the second deadline you should have:

1. Description of the **economic impact** of the proposed project.
2. Description of **the societal impact** of the proposed project.
3. Description of the **potential political** of the proposed project.

Third deadline

By the third deadline you should have:

1. Description **of technology** you are proposing for the thermal power system.
2. Overall **specifications of** the proposed system including the maximum theoretical efficiency of the system, working fluid for the system, the estimated cost of the system, and the estimated duration of construction for the system.
3. A **component diagram** for your system including items such as pumps, boilers, heat exchangers, turbines, condensers, etc. Label the critical points in the component diagram corresponding to points in the process diagram that you will also provide.
4. Provide descriptions of the functions of each component in the system.
5. Discussion of the environmental impact of the proposed system.

Final deadline

By the final deadline you should have:

1. **Justifications** for your choice of features/components for the system you are proposing. The components in your system are not to be ideal
2. components but should have associated efficiencies that are taken into account in your calculations.

3. Temperature and pressure values at each critical point in the system.
4. Mass flow rate(s) of working fluid(s) to achieve the targeted power output for the system.
5. Process diagrams. This is a scale T-s diagram of the processes that make up the cycle that you are proposing.
6. Calculations to show how you arrived at the specifications for your system. Calculations must be neat and easy to follow.

A. 2-Rubrics table

Dimension/ Weight	Points			Score
	2	1	0	
Organization (sections, order) 10 %	All sections are present and in correct order. Sections include: Abstract, Background, Technical Details.	A section is missing or sections are not in correct order.	Sections are missing or are not clearly marked.	
Formatting (fonts, header, footer, cover page, margins, spacing) 10 %	Header, footer, and cover page are present and contain required info. Fonts are acceptable.	One of these required items is missing, fonts are not acceptable, and/or info in these sections is not correct.	No header, footer, and/or cover page.	
Figures, tables, and equations 10 %	Figures and tables contain clear captions, are centered and of equal size and proportions, have appropriate margins, and do not contain excess border lines. Equations are centered and are numbered.	Figures and tables do not contain compete information. Formatting could be improved. Equations are incorrect.	No figures, tables, or equations.	
Graphics (photos, figures, diagrams) 10 %	Graphics/photos are cropped correctly, the subjects are clear and they support the content in the report.	Photos, figures, and/or diagrams are present, but of poor quality and do not support the report.	No photos, figures, or diagrams.	
Mechanics (spelling, grammar, punctuation) 10 %	No spelling or grammar errors.	Two or three spelling or grammar errors.	Too many errors to count!	

Dimension/ Weight	Points			Score
	2	1	0	
Citations 10 %	All claims are supported by citations. Citations are correctly formatted.	Citations are not correctly formatted and some may be missing.	No citations.	
Calculations 10 %	All calculations are correct.	Small errors in calculations.	Calculations are absent or totally incorrect.	
Abstract 10 %	The problem is clearly presented. Solution is presented along with brief justification. One succinct paragraph.	The problem is obscure. The solution is missing adequate justification. The abstract is too long or two short.	The abstract is opaque and fails to encapsulate the entire proposal.	
Background section 10 %	Clearly explained are: the need for additional electrical power generation capacity, the resources that are available for meeting those needs, and the economic situation.	Background information is missing or poorly explained and supported.	No background section.	
Proposed system 10 %	Clearly explained are the technology you are proposing and justification for your choice. All of the items requested in the project write-up are included.	Some of the required items of the proposal are missing.	The proposed system is not adequately explained.	
Total 100%				

A.3- Students' feedback survey form

	Rating				
	1	2	3	4	5
Overall Project					
Determining what aspects should be considered when managing a project					
Project reasoning and discuss the demands and benefits					
Recourses which are or are not available					
Economic condition and impact of the project					
Societal conditions and impact of the project					
Geographic and project reciprocal impact					
Political and project reciprocal impact					

Determining what aspects should be considered about the technology of choice					
Project tool					
Project tool: a profound understanding of the course material					
The impact of the project to retain the course material for future use					
Project tool: an overview of the energy problem					
Project tool: geographic aspect data					
Project tool: energy aspects data					
Project tool: Economic aspects of data					
Project tool: Rankine cycle function					
Project tool: Rankin cycle processes					
Project tool: components & equations					
Educational methods					
Having access to the top well-done assignments as a paragon					
Having the opportunity to receive feedback from the peers					
Having the opportunity to give feedback to the peers					
Dividing the project into several segments rather than a single final project as a whole.					
Hearing the feedback from the researcher					