Problem-Based Learning Methodologies and Tools

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1. Introduction

Problem-Based Learning is an emerging pedagogical design through which individuals build knowledge by focusing on a particular problem. This document aims to summarize Problem-Based Learning methodologies and related educational approaches, such as Active Learning and Experiential learning and to discuss the benefits of these approaches towards building knowledge, skills, and competences for addressing the complex challenges of the 21st century.

The document further discusses the roots of Problem-Based, Active, and Experiential Learning in constructivist educational theories that advocate that knowledge is synthesized rather than transferred. It further discusses how Problem-Based, Active, and Experiential learning contribute to the development of fundamental knowledge in the field of engineering as well as highly demanded soft skills, such as critical thinking, analytical thinking, and collaborative capacity in diverse groups.

The document further analyses how technology may be deployed to support emerging pedagogical design by increasing interaction and collaboration in learning contexts and by allowing knowledge development to take place both in and outside of the classroom, anywhere and anytime. The document focuses on the deployment of specific digital trends in learning contexts including serious games, simulations, MOOCs, and mobile technology and discusses their benefits in enriching Problem-Based Learning educational experiences.

The document constitutes the summary of the work conducted by the “Problem-Based Learning Methodologies and Tools” special interest group of project ALIEN: Active Learning in Engineering Education.

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2. Problem and Project-Based Learning

Problem-Based Learning is an educational method where complex real-world problems are being used in order to promote student learning of concepts and principles. The method is in contrast to traditional instruction, which is based on direct presentation of facts and concepts. PBL aims to equip students with effective problem-solving abilities and critical thinking skills as well as communication skills. It furthermore fosters the development of collaboration skills, evaluation of research materials, and ability to engage in life-long learning [1].

Some of the principles on which PBL is based on are summarized below:

- It is a student-centered method that allows participants to take responsibility for the learning process.
- The problems that are presented to the students are inspired by real-life.
- The teacher has the role of a learning facilitator. She creates a framework to support students' efforts to synthesize a solution to a given problem.
- Problem-Base Learning includes evaluation processes of both in terms of cognitive development, learning processes, collaborative activities, and metacognitive skills.

Problem-Based Learning can be incorporated into any learning process and any subject area. Some characteristics of good problems are:

- Problems should motivate students to strive for a deeper understanding of concepts.
- Problems should be structured around learning objectives that are connected to previous knowledge or educational activities.
- In group settings, group problems encourage students to work as a team and are solved by exploiting the combined available knowledge of all participants in the group.

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In order to integrate PBL methods is his course a teacher should start by choosing a central idea, concept, or principle. The teacher may then select a typical problem, project, or assignment through which student may build understanding of the concept in focus. Subsequently, the teacher should list the learning objectives that are expected to be achieved by completing the activity. As a next step, the teacher may link the activity to a real-world context. Engaging with real-world practices that they are familiar with provides students with motivation to adapt existing experiences towards synthesizing a solution to a new challenge. Finally, the teacher may introduce a given problem in stages, encouraging students to engage in targeted sub tasks before synthesizing a solution to a broader challenge.

2.1 Essential PBL design elements

Before designing a PBL activity a teacher should consider the following:

- What will the first stage of the activity look like? What questions may be asked? What learning concepts will students engage with?
- How will the problem be structured?
- How long will the activity? How much time will the students invest into solving the given challenge?
- Will students be given information in stages as they work through the problem?
- What resources will the students need in order to solve the problem they are given?
- What will the end product the students have to produce upon completing the activity?
- What resources will the teacher make available to students for solving the problem? While part of the benefit for students in engaging in PBL is researching of resources, it may helpful if the instructor indicates a few good sources to get them started.

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2.2 How does Project-Based Learning differ from "doing a project"?

A variation of the Problem-Based Learning method is Project-Based Learning. The acronym PBL is often used interchangeably to refer to both methods. For this reason, the two methods are often considered as identical. The boundaries between the two methods are usually indistinguishable in practice. The main differences between Problem and Project-Based learning are the following:

- In Problem-Based Learning everything starts with the problem. Students work in groups towards introducing a potential solution to a given scenario. Knowledge and skills are developed through the solution synthesis process. Problem-based Learning is not based on known material or on a pre-specified solution method. On the contrary, learning objectives are achieved through the problem-solving process selected by students.
- In Problem-Based Learning group collaboration is fundamental and not an optional method of implementation.

There are some key differences between "doing a project" and engaging in Project-Based Learning. In Project-Based Learning, the project is the means for building knowledge and skills. The project is structured: it has a curriculum and is introduced through instructions. Project-Based Learning also requires critical thinking and problem-solving skills, collaboration, and various forms of communication. Students go beyond memorizing information; they use higher-order thinking skills and learn to collaborate as a team.

2.3 Essential project design elements

Project learning strategies for students include skills such as decision making, problem solving, communication, self-management, project management and teamwork.

The project that is chosen for the PBL process, is either a problem that needs to be solved or a question to be answered. Students engage in a process of asking questions, finding resources, and applying information they find. It is more likely for students to engage in a

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project that is about a real-life problem, or speaks to personal concerns, interests, and issues in the students' lives. After that, students should make some decisions about the project, including how they will work and what they should create. The process continues with students and teachers that reflect on the learning, the effectiveness of their inquiry and project activities, the quality of student work, and obstacles that arise and strategies for overcoming them. Upon completion of the process, students give, receive, and apply feedback to improve their process and products. Finally, students make their project work public by explaining, displaying and/or presenting it to audiences beyond the classroom.

2.4 Project-based teaching practices

In Project-Based Learning process the teacher should be able to give up some degree of control over the classroom and trust her students.

As a first step, a teacher designs or adapts a project to his course content and plans its implementation. Then, the teacher ensures that the project addresses key knowledge and understanding in the subject area being studied. It is important for the teacher to promote student independence and team spirit. The teacher works with students to organize tasks, research, and use recourses. Furthermore, the teacher may employ a variety of lessons, tools, and instructional strategies to support all students in reaching project goals.

2.5 Why use Problem and Project-Based Learning?

Problem and Project-Based Learning help students to engage in the learning process. First of all, Problem and Project-Based Learning have positive impact. They connect real-life problems with students' interests and personal connection to create powerful learning experiences in terms of both academic achievement and students' personal growth.

There are many ways in which Problem and Project-Based Learning help to transform students' educational experiences:

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- Students actively engage with projects that are relevant to real-world problems. Students are more likely to solve problems that are relevant and important to them and their communities.
- Students develop a better understanding of content knowledge and are better equipped to apply the new knowledge in real-life.
- By observing the positive impact of their solutions, students develop a sense of purpose.
- Students gain skills valuable in today's workplace and in life, such as how to take initiative, work responsibly, solve problems, collaborate in teams, and communicate ideas.
- Teachers work closely with students.
- Students enjoy using helpful technology tools for research and collaboration.

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3. Active Learning

Over the past decades there has been a significant evolution of learning design. However, in practice the learning process is still most often implemented in the traditional way. Students enter the classroom, sit at their desks, follow (or not) their teacher's lecture, return back to their home, study the material that they have been taught at school, and do their homework. Students are evaluated on a regular basis through oral or written exams or through school assignments through which they receive their grades.

This educational method is influenced by behavioral theories according to which knowledge gets presented to students by the teacher and is evaluated by the students' responses. For example, students' correct answers will have as a result an encouraging and positive behavior from teacher's side and incorrect answers will have a discouraging and negative one. In this model, knowledge gets evaluated through feedback in the form of grades or possible clarifications from the teacher. Traditional educational models are based on the principle that repetition allows students to retain knowledge. For this reason, traditional instruction is heavily based on exercises and drills.

The traditional educational approach is not without merit, as it has educational benefits. However, it seems to ignore some basic concepts and principles of learning. These include the need of students to influence educational processes and content, to become responsible for their educational evolution, and to build skills in a manner that allows students to use it in the real world. As a result, traditional approaches to learning do not bring the best possible results. That is why it is important for teachers to implement the principles of Active Learning in their teaching process. According to Active Learning, real learning takes place when students actively engage in the learning process, that is, when they pay attention and actively evaluate and select the important elements of the course content, understand them, and connect them with their previous knowledge. Active Learning is the opposite of traditional learning in which students are passive recipients of knowledge from the instructor.

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If a student does not pay attention and does not try to understand what the teacher explains, he is not going to learn. The main reasons why a student may not pay attention are either because he does not like the object, he finds it difficult or useless, or because he is bored or focused on something else. It does not make much sense to try to bring the student back to the subject because, sooner or later, he will stop paying attention again. The key is for the student to understand the usefulness of what the teacher is trying to teach, to be interested in it, to be motivated to focus on the lesson, and to actively strive to get involved during the learning process and beyond that, at home.

Active Learning refers to a broad range of teaching strategies where students are actively participating in the learning process in the context of formal or informal learning activities. These strategies involve a number of students that work together during class, but may also involve individual work. The teaching approaches can be either short, simple activities, such as journal writing, problem solving, and paired discussions, or longer activities, such as case studies, role plays, and team-based learning. Active Learning can take many other forms. It is quite common that students engage in activities centered on writing, talking, problem solving, or brainstorming.

In a traditional classroom, it is common for only some students to engage during the course, to ask questions, or to respond. In contrast, a class with well designed Active Learning activities provides an opportunity for all students to think and engage with course material and practice skills for learning, applying, synthesizing, or summarizing new content.

Active Learning is a student-centered approach. In student-centered learning, education focuses on students' needs, interests, abilities, and learning styles. Student-centered learning has introduced big changes in the way that teachers teach. Teachers are challenged to be more open-minded, flexible, and ready to redefine their role in the educational process. Learners benefit from student-centered design, but so do teachers. Student-centered design benefits society at large by building individuals that possess value-adding knowledge and skills.

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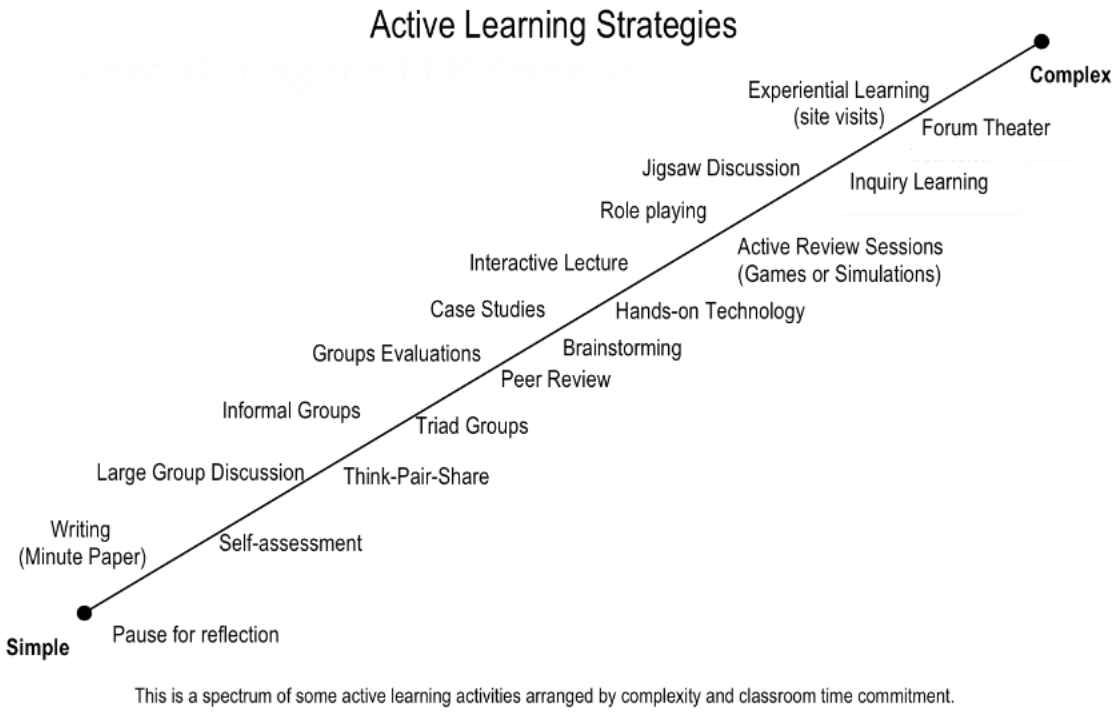

Figure 1. Active Learning strategies

Using Active Learning strategies does not imply abandoning the lecture format. Rather, it may be implemented by adding small Active Learning strategies that can make lecturing more effective towards knowledge building.

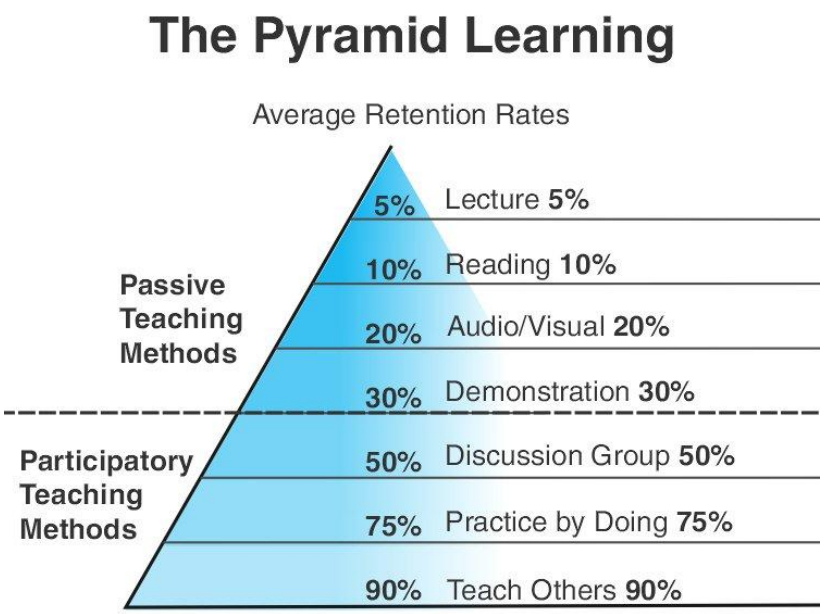

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Figure 2. The Learning Pyramid – Adapted from National Training Laboratories, Bethel, Maine

Active Learning gives students the opportunity to check their understanding of newly introduced content in the context of a course, practice a skill, or highlight gaps in their knowledge before providing an explanation.

3.1 Why use Active Learning?

The benefits to using active learning are many. They include improved critical thinking skills, increased motivation, and improved interpersonal skills [2]. Active Learning encourages the true understanding of new knowledge, rather than simply memorizing information. It further encourages the development of problem-solving skills, which students can then apply in different contexts. Universities gradually adopt Active Learning as a result of the benefits that the approach offers in terms of knowledge retention and knowledge transferability from the academic environment to the world of work. Active Learning prepares students to act as responsible citizens and professionals to address industry and societal challenges.

Active Learning supports the development of soft competencies such as teamwork, critical thinking, and analysis. In addition, students' performance and effectiveness are improved. It allows learners to build and use knowledge in a manner that simulates real world practices that prepare them to transition to the world of work as effective professionals. It also equips them with skills to promote lifelong learning in the future. Hands-on, interactive, and collaborative Active Learning tasks promote students' personal development [3]. Active Learning encourages students to constantly review the knowledge gained and "re-examine" concepts already familiar to them.

Excessive focus on test results reduces the scope of student-centered Active Learning. The development of a school culture that focuses on actual learning rather than exam success is essential in order to enable students to feel joy from gaining knowledge in their own learning style. Freeman et al. [4] in a meta-analysis on 225 science, engineering, and mathematics education studies demonstrated that Active Learning can significantly

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increases course grades over other didactic methods. The review further demonstrated that Active Learning is particularly effective in small classes of 50 students or fewer. The analysis in this work showed that students in courses that do not use Active Learning techniques were 1.5 times more likely to fail the course than students in courses with implementation of Active Learning. Finally, the research showed that Active Learning can positively affect student motivation [5] as well as help students gain key learning characteristics such as attention and memory consolidation [6].

It is important for students to realize that understanding is more important than memorization. Students have a greater chance at success through learning processes that build long-term understanding rather than focus on memorization of information. It is beneficial for students to approach learning with an attitude to "make sense" of the concepts in an active way and not just to remember data. Success depends on their willingness to make mistakes, to participate in discussions, to realize and accept that sometimes their views are wrong, and to learn from each other.

3.2 Implementing Active Learning strategies

In order to successfully implement Active Learning strategies into their instructional processes, teachers should first adjust their practices so that content and activities are linked to the real world. Teachers should discover the cognitive starting points of learners before planning an educational offering. They should then identify the goals of their course, focus on what they want their students to learn, and examine the way in which they currently address this goal. Teachers should design activities and assignments that help students achieve the desired learning outcomes. Once the instructional design is complete, teachers should present to their students the activities that they will be engaged in, what is expected of them, and why it is important. For more complex learning tasks, teachers may have to develop an information sheet or instructions. Finally, teachers should decide how students will receive feedback, which can include using a technology-based response system, such as clickers or a web poll, or more involved feedback from peers. Teachers

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should also identify, adapt, and utilize additional learning assessment strategies, including effective questioning, sharing of evaluation criteria, peer-assessment, or self-assessment. Teachers may also use assessment information to adapting their teaching towards better addressing educational goals.

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4. Experiential Learning

The term Experiential Learning refers to an alternative way of learning for students that aims at the direct contact of the student with the object/knowledge she needs to know and the processing of this learning experience. Experiential Learning does not limit itself to the traditional, established school practices and routines, such as the use of books, predefined teaching material, or memorization, but extends beyond and above them, supporting the reflective processing of the student's immediate experience.

The implementation of Experiential Learning in school with the participation of teachers is known as experiential education. Its main feature is the active participation in innovative activities and the constant reflection, which offers expansion of knowledge, development of skills, and formation of moral values.

The differences between traditional and experiential education are the philosophical background and the educational techniques it applies. In particular, experiential education becomes a tool for solving social problems and political change, which places the student at the center of a process of discovery and self-realization with the ultimate goal of personal development and change in society. There are many who think that experiential learning sounds good in theory but it is difficult to apply in practice. As long as teachers are ready to accept something new and are willing to apply it in practice, students will be open and effective in applying the methodology of experiential learning and will undoubtedly love it.

The differences between traditional and experiential education concern two main areas: the role of the teacher-student and the learning process.

In traditional, formal educational models the teacher is the only source of knowledge that has full authority over how she will educate students. She has responsibility, power, and the control over the entire educational process. Students passively accept the knowledge that the teacher transmits, while they need constant supervision both in terms of behavior and in terms of school performance; this approach implies that students are not worthy of the trust of the teacher and for this reason they are in need of constant monitoring.

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On the other hand, in experiential education the teacher has the role of counselor, mentor, and facilitator and learns with her students. She aims to facilitate the learning process in a climate of mutual interest, care, and understanding. Students are considered to be co-responsible for their learning in which they actively participate and which they direct through questions they ask themselves, their teacher, and their classmates.

In traditional education the teacher seeks to assimilate and apply the curriculum material and is interested in academic knowledge and mental skills. Knowledge is specific and follows the curriculum. Learning focuses on a topic whose theories come from an external source. What is particularly important and evaluated, in addition to discipline and correct behavior, is the performance and cognitive results of students.

On the contrary, experiential education follows a holistic approach to knowledge with an equal distribution of interest in emotion, observation, thought, and action. Experiencing, processing, and assimilating new knowledge into life emerges as a priority. The source of learning is the experience, the inner world, the thoughts, feelings, and actions of the learner. Experiential education pursues personal development, creativity, emotional and social awareness, critical examination-processing, and personal and social change.

4.1 Kolb's model of Experiential Learning

In 1984, psychologist David Kolb presented his own theory of Experiential Learning and proposed a model called the "learning cycle". He supported that *"learning is a process in which knowledge is created through the transformation of experience".* Kolb's experiential theory of learning operates on two levels: a four-stage learning cycle and four separate learning styles.

Experiential learning is a method of knowledge building through four ways of learning, according to David Kolb's experiential learning model:

- Concrete experience
- Abstract conceptualization

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- Reflexive observation
- Active experimentation

Kolb (1984)'s cycle of experiential learning emphasizes the active way of understanding experience and considers the goal of learning to be the development of awareness and skills through the process of reflection. Kolb empirical learning has six characteristics:

- Learning is perceived as a process and is not determined by the result
- Learning is an ongoing, experiential process,
- Learning requires resolving conflicts between opposing ways of adapting to the world
- Learning is a holistic process
- Learning presupposes an interaction between the individual and the environment
- Learning is knowledge generating method

The Experiential Learning Cycle by Kolb is demonstrated in the following image.

Learners with a preference for concrete experience learn better from examples than from theories. They choose to participate in groups and have highly developed feeling. They like to participate in activities and apply the skills they have acquired. They are activists, they like practice and experience. They know things by contact and not by descriptions.

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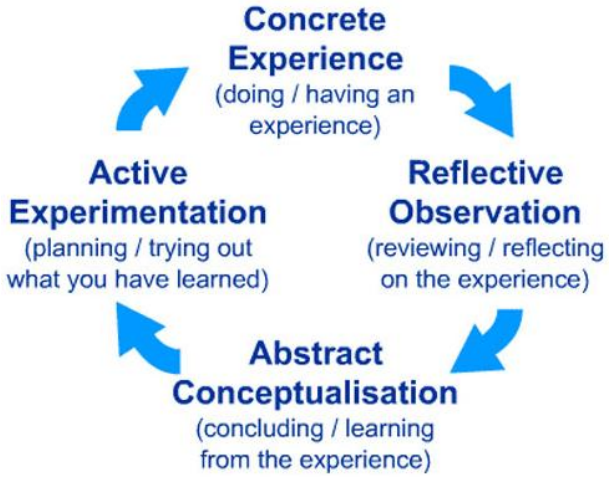

Figure 3. The Experiential Learning Cycle (McLeod, 2013)

Learners that learn through reflexive observation judge what they observe carefully and prefer to learn by formulating judgments. They choose traditional ways of teaching, accurate and clear presentation of concepts, and see their teacher more as an authority than as a guide. They are reflective and observant. They learn by thinking and by implications.

Abstract conceptualization, or the formation of ideas, is addressed to learners with highly developed analytical and abstract ability, logical thinking, and an internal motivation to search for causes. Students have a higher understanding of the symbolic representation of concepts and things and prefer to approach them theoretically rather than participate in experiments and simulations. They have a highly developed function of thought. They are theorists and they like to discover underlying concepts, causes, and relationships. They learn mainly from descriptions and from understanding concepts.

Learners that prefer active experimentation enjoy active participation in experiments and learn best when they act with others and take on tasks. They do not like theories and the traditional way of teaching with lectures and monologues and are more extroverted. They are pragmatists and they like to confirm with a test the way things work. They learn by using content or processes and they build intuition from clues.

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In Kolb's learning cycle an individual may begin learning based on his knowledge and previous experience. In order to address new challenges, he should be prepared to make decisions, act fast, and apply in practice what he has learned. In a second stage the person acts, deals with real situations, and acquires new experiences. During the third stage of the learning cycle, the person processes experience by carefully examining (observing) it through a variety of perspectives. The individual processes and evaluates the results, understands them, and draws conclusions. The final stage is the stage of generalization and theorizing. During this stage the learner mentally processes observations and conclusions, classifies acquired experiences, and links experiences to scientific data, theoretical approaches, and existing knowledge. The learner draws general principles and rules of action. The person at this stage feels able to act more effectively and devises new programming.

Kolb also supported that a learner may enter the learning cycle at any stage and repeat the processes continuously in a spiral motion, where the conclusions of each phase feed into the next. Once entering the cycle the learner follows the 4 stages in order to acquire new knowledge. In order for effective learning to happen the learner should complete all 4 stages of the model. There cannot be a single stage that can stand alone as a learning procedure. In this sense new information and knowledge that the student gets is based on the previous.

4.2 Kolb's Learning Styles

Kolb's four-stage learning cycle is the basis of the model of learning styles. Kolb further explains that different people naturally prefer a particular different learning style. Social environment and educational experiences can affect a person's preferred style. Despite external influences an individual's preference on a specific learning style is the combination of two variables or two separate "choices" that someone makes, which Kolb presented as lines of an axis, each with "contradictory" forms in each end. Based on Kolb's theory, the two variables that determine the learning style preference of the individual are:

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- The processing continuum, which reflects the ways a person approaches a task
- The perception continuum which reflects a person's emotional engagement, meaning how they think and feel about the task they are given

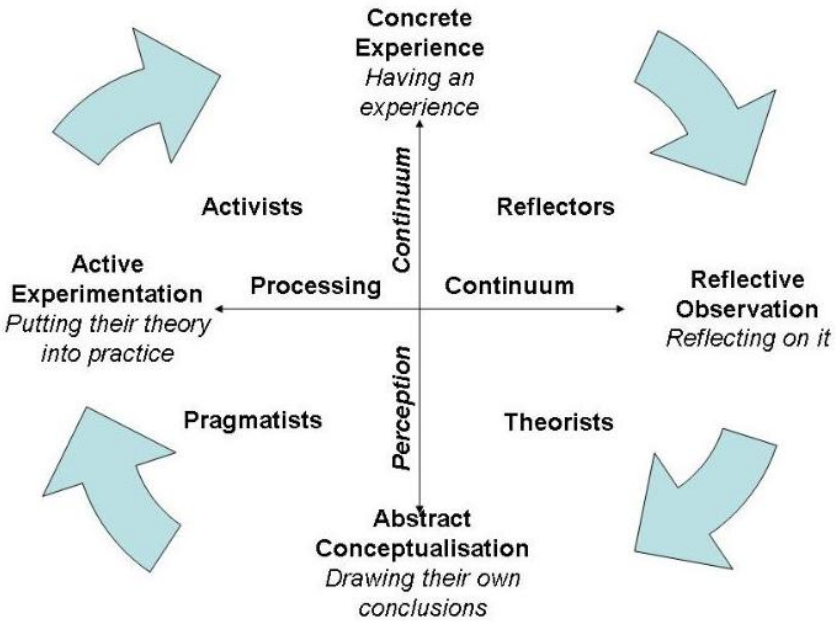

Figure 4. Kolb's continuums - retrieved from https://www.simplypsychology.org/

Kolb also believed that an individual cannot execute both variables on an axis at the same time. It is often easier to understand the structure of Kolb's learning styles by using on a 2 by 2 matrix. Each learning style is the product of a combination of two preferred styles.

	Doing (Active Experimentation – AE)	Watching (Reflecting Observation – RO)
Feeling (Concrete Experience – CE)	Accommodating (CE/AE)	Diverging (CE/RO)
Thinking (Abstract Conceptualization – AC)	Converging (AC/AE)	Assimilating (AC/RO)

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Table 1. Kolb's learning styles matrix

Knowing someone's learning style enables learning to be adapted to each student's preferred method. While everyone responds and needs the stimulus of all types of learning styles to some point but it is important to give emphasis on what best suits a person's given situation and preferences of a learning style.

Accommodating (doing and feeling - CE/AE)

This is a hands-on learning style which is more practical and relies more on instinct than logic. Individuals that prefer this learning style use other people's analysis and prefer practical and experiential approaches. They are attracted by new challenges and experiences as well as by the implementation of projects. They usually act by instinct and not by logical analysis. People with an accommodating learning style tend to rely on others for information rather than doing their own analysis. This learning style is widespread in the general population.

Diverging (feeling and watching - CE/RO)

People with a diverging learning style tend to see things from different perspectives. They are sensitive people and prefer to watch rather than do. They like gathering information and using their imagination to solve problems they are facing. They are better at seeing specific situations from many different perspectives. These people perform best in situations that require the production of ideas, such as brainstorming session. Individuals with divergent learning styles tend to be interested in culture and love to gather information. They are interested in people; they tend to be imaginative and emotional and they tend to be good at the arts. They mostly prefer to work in groups, are open-minded and like to receive personal feedback.

Converging (doing and thinking - AC/AE)

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People with converging learning style are good at solving problems and tend to use their knowledge in order to find solutions to practical problems. They prefer practical tasks and think less about people and interpersonal aspects. Individuals that prefer the converging learning style tend to be excellent at discovering useful ideas and theories. They are more drawn to technical tasks and problems than to social or interpersonal issues. People with converging learning styles tend to be better specialized and have lot of technological skills. They mostly prefer to experiment with new ideas, simulate and work with practical applications.

Assimilating (watching and thinking - AC/RO)

The preference for learning assimilation involves a concise and logical approach. Individuals that prefer the assimilating learning style need a clear explanation rather than a practical opportunity. They are distinguished for understanding broad information and organizing it in a clear, logical form. They tend to be less focused on people and more interested in ideas and abstract concepts. They are attracted more by logically complete theories than by approaches based on practical value. They mostly prefer reading, lecturing, exploring detailed models and having time to think things through. This learning style is important for effectiveness in the information and science professions.

4.3 Educational implications

Teachers can benefit by the use of the learning stages and cycle of Kolb for developing learning opportunities that are more appropriate for their students. It is also important for teachers to ensure that the activities in their courses are planned and performed in ways that offer each student the opportunity to engage in the way that best suits her. If individuals are able to identify the learning styles they prefer and apply they experiential learning cycle they can be helped to learn more effectively.

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Ideally, learning activities and material should be developed in ways that utilize the skills from each stage of the experiential learning cycle and guide students throughout the process sequentially [7].

The participation of learners in an experiential learning process may be best implemented through a supportive framework, for example acceptance and trust, which encourages learners to engage and express their opinions with no fear of rejection from their team members.

Learners should also take initiatives that enhance their self-esteem and recognition within the team. It is also important to pay attention to the observation of and reflection on experiences. Designers of experiential activities should ensure that there is a balance between the creative part, for example the expression of the new, and the cognitive part, for example the understanding of the environment. Experiential learning is not only a pleasant process but should also focus to the cognitive part.

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5. Constructivism

After focusing on the concept of Active Learning, it is also important to get acquainted with one of the main theories of learning, which give the student the active role she needs to develop knowledge and skills. This is the theory of constructivism. According to constructivism learning is not a process of memorizing information but it is an individual knowledge building process in which a student's prior knowledge is modified. According to constructivism knowledge development is the result of the interaction of the student with her physical and social environment.

Constructivism is a learning theory that is rooted in psychology. It focuses on how people acquire knowledge and learn. The psychologist Jean Piaget stated that *"learning comes from trying to balance between what the student already knows and what she does not know"*. Constructivist learning has had wide ranging influence on learning design. It is a core concept of many educational reform movements.

Constructivism is based on the principle that knowledge is not transferred but, rather, synthesized. In constructivism, the teacher plays the role of the facilitator. Students are exposed to a problem and are given tools for solving it, without being exposed to the solution.

Basic constructivist concepts that help understand the process of building new knowledge are shape, adaptation, assimilation, and compliance.

- **Shape** refers to the fact that individuals already posses knowledge that is divided into pieces
- **Adaptation** refers to the fact that when being in a new situation, seeing a new object, or reading new information an individual tries to establish connections with what she already knows
- **Assimilation** refers to the fact that if a new situation fits into an existing shape, it gets categorized accordingly by an individual

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- If new information does not fit to an existing schema, then an individual employs **modification**, namely she modifies a relevant schema or creates a new one to fit the new information

5.1 Constructivist approaches to teaching

Constructivist learning theory incorporates a range of student-centered teaching approaches and strategies that contrast with conventional education, where information is simply passively transmitted by educators to learners. It is very important for the teacher to facilitate the connection of his students' new knowledge with previous knowledge. Before introducing a new concept the teacher may mention to his students' previous concepts or experiences that they have encountered and are associated with the new knowledge in order to arouse their interest and furthermore to facilitate the selection of the piece of knowledge in which the new information will be included.

According to Piaget-based approaches the student benefits from activities that put him in the position of researcher, designer, creator, or builder as he enters the process of examining and organizing his knowledge in order to perform the task assigned.

The teacher's most important responsibility is to create a collaborative problem-solving environment where students can actively participate. In a constructivist classroom the teacher acts as a facilitator of learning rather than an instructor. The teacher ensures that he understands the students' conceptions and guides the learning process to address them and then build on them [8].

Scaffolding refers to the step-wise building of new knowledge on old. Scaffolding is a key feature of effective teaching, where the learner has the ability to continually adjust the level of help in response to the learner's level of performance [9].

Lev Vygotsky enriched the theory of constructivism emphasizing the importance of the tools that the student uses. The student builds knowledge on the tools and then uses them in his own unique way. This process is called appropriation. Lev Vygotsky also emphasized the

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benefits of group learning. He introduced the concept of the imminent development zone according to which learning is supported by the interaction among less and more experienced students. Finally, he supported the importance of the learning context stressing the fact that it must be authentic, namely inspired by the real world. It is important that students be exposed to real tasks that they will be called to perform later, for example in their professional careers. In authentic contexts, learning may also take place outside the classroom in environments in which new knowledge or skills are actually used.

5.2 Features of a constructivist classroom

Tam (2000) [10] supports that when implementing constructivist teaching strategies knowledge should be shared between educators and students. Moreover, he mentions that teachers and students are equal and the teacher should have the role of a facilitator or a guide in the learning process. Tam also mentions that learning groups ideally should consist of small numbers of heterogeneous students.

According to Tam, there are a lot of differences between the traditional classroom and the constructivist one. First of all, contrasts can be found in basic assumptions on knowledge, students, and learning. In a traditional classroom learning is based on a fixed curriculum and based on repetition. The learning process is teacher-centered and the students are passive recipient of knowledge. In a traditional classroom, students primarily work individually. On the contrary, in a constructivist classroom, learning is interactive and based on students' previous knowledge, the teacher's role is interactive, and students work mostly in groups.

It is really important to remember that learning cannot be achieved solely through transmission of information. Constructivism advocates that learning is built through time. Students cannot be passive receivers of information; rather they must be able to be researchers, creators, and members of a community in which they learn from their peers. It is good for the students to use tools and work together to solve problems, perform tasks, and answer questions that are similar to what they will be challenged to do later. In

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Constructivism, true learning is not memorizing information, but it consists of developing a set of knowledge and skills, communication, critical thinking, and decision making that arise from the need to solve real-world problems through interaction with the environment.

5.3 Microworlds

Microworlds are a key concept of constructivism theory. They were first introduced by Papert (1993) [17]. Microworlds are abstract representations of the real world. Well designed microworlds include adequate information for allowing a student to experiment but are abstract enough so that details do not detract a student's focus from the problem at hand. Microworlds consist of objects and actions that modify the relationships among them. The first well known microworld was that of the turtle. The objective of this microworld was to teach Euclidian geometry. The microworld included one object, a turtle, and the actions pen up pen down that controlled the capacity of the turtle to write and to design and the actions left, right, up, down that controlled the direction of the turtle. Through the microworld, students developed short programs that used the available actions to guide the turtle to draw specific shapes.

Microworlds are in many ways the predecessors of games, which deploy many of the microworld design principles. Games are also abstract representations of the real world, include objects, and have well specified rules and objectives that a learner strives to achieve. While games may be advanced worlds that provide rich experiences, their design follows the basic microworld concepts.

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6. Digital tools for Problem-Based Learning

6.1 Massive Open Online Courses (MOOC)

A Massive Open Online Course (MOOC) is an interactive course in which an unlimited number of learners can participate worldwide, aiming to create a community of lifelong learners.

MOOCs are asynchronous, open-access and web-based courses that support the enrollment of hundreds or thousands of students at a time. Their content usually gets delivered via video lectures, online readings, and online assessments as well as various degrees of student-student and student-instructor interaction.

Since the beginning of the last decade universities have provided access to lecture notes, assessment materials, and recorded lectures. A pioneer in these activities was the MIT Open Course Ware in the USA in 2002. It was followed by the Open Yale Courses in 2007 and then several other university initiatives. This need led to the creation of a platform that could accommodate all these educational resources. As a result, in 2007 a free online service, iTunes U, was created. However, the element of teaching was missing from all of the above. Specifically, what was missing was the interaction between students and the teacher in an organized process of knowledge development. This shortcoming was addressed by the first MOOC.

The first MOOC on "Connectivism & Connective Knowledge" by Professors G. Siemens and St. Downes, also known as CCK08, was held in September 2008 by the University of Manitoba, Canada and was attended by 2.000 individuals from around the world. In 2011 MOOCs became widely known outside of North America, while 2012 was the year that 3 of the most well-known platforms, namely edX, Coursera, and Udacity, were created. In 2012, twelve universities in the United Kingdom announced the launch of the Future Learn platform. This is the first MOOC cooperative outside the USA. Finally, the first MOOC in Australia was announced by New South Wales University in October 2012 [11].

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Since MOOCs are supported by several platforms anyone with a computer and an Internet connection can register and attend any course he chooses. Unlike other online training models MOOCs are provided free of charge and on a large scale. MOOCs operate similarly to a real classroom; they have a start date, lectures, assignments, discussions, and evaluation. They enable the student to adjust learning to his schedule as well as to stop or pause studies without any further consequences.

The teaching process through a MOOC is implemented through video lectures, questionnaires, tests and regular assignments. Students have the opportunity to interact with their fellow students through online discussion groups, for example forums. They further participate in local study groups.

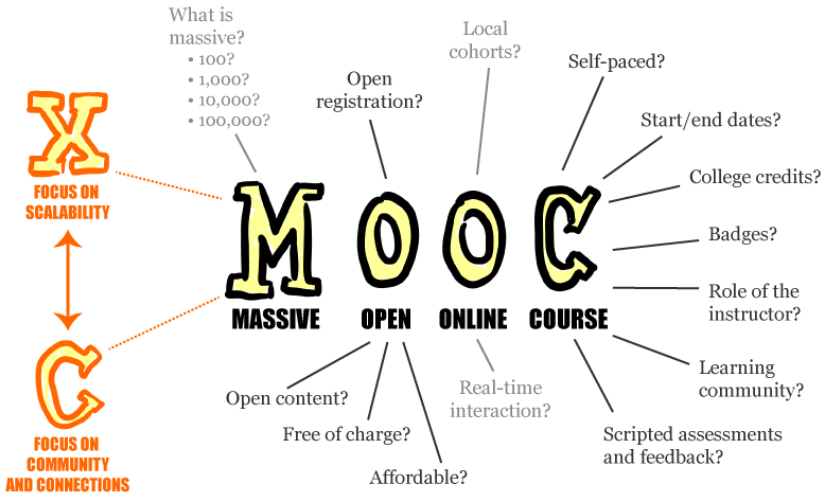

Figure 5. MOOC (Mathieu Plourde)

There is also interaction between students and the teacher through forums, videoconferencing or other similar mediums, or private meetings. Evaluation of developed knowledge is usually executed in two ways:

- Either by automatic grading of closed-ended questions or
- By evaluation of student work by fellow students

Upon successful completion of a course some institutions provide certificates of attendance.

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The characteristics of MOOCs are of great interest. However, in addition to the obvious advantages they also have weaknesses that are the subject of criticism. The positive points start with the provision of free, high-level, and large-scale higher education courses. MOOCs derive a sense of democracy and equality through free access to knowledge as it is no longer a privilege of the "few". As a result, learners from almost anywhere in the world can take advantage of these learning opportunities together overcoming different educational backgrounds and social and cultural cultures as well as the inequalities that exist in the global population. On the other hand, the audience that the teachers address is of a different size compared to a typical university amphitheater.

MOOCs provide significant benefits not only to students but also to the educational institutions themselves. An educational institution may advertise its decision to provide high quality educational programs for free developing the social profile required by modern marketing. The offering of MOOCs by an educational organization broadens perspectives of cooperation with other institutions that provide similar offerings. MOOCs allow the exchange of good practices and the joint creation of online courses. Initiatives in this direction also make universities attractive to sponsorships from large companies thus providing incentives to other institutions to turn to MOOCs and maximizing related offerings [12].

MOOCs are useful in diverse learning scenarios. They are useful for building skills that are not developed by formal educational offerings. Formal educational curricula are rigid and do not easily adapt to emerging educational needs. Take for example the need to build skills on developing applications in emerging portal devices. While traditional educational programs may focus more on fundamental programming skills in languages such as C++ learners may be in need of developing skills demanded by employers such as application development for Android devices. Formal educational curricula evolve at a slower pace than industry demands introducing a need for attending focused and targeted courses for building specific skill sets.

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In the teaching industry MOOCs may offer significant benefits and can improve the way the educational process is conducted. Teachers may be evaluated by the participants in a MOOC, often with an anonymous evaluation through the platform, and to self-evaluate by watching their video lecture. New jobs are created through the MOOCs as postgraduate or doctoral students may work with the instructor having an auxiliary role in the formation and setting up of a MOOC, the correction of assignments, and more. Finally, MOOCs allow the conduction of research by allowing students to quickly respond to questionnaires prepared by teachers.

Another advantage of MOOCs is that they may be deployed for reaching large numbers of students. Through a MOOC students may take courses that are offered by an organization located far away, even in a different country, completing their formal educational studies. However, the fact that MOOCs may be deployed for addressing large numbers of students in a single course has also been criticized as there may be challenges in addressing individualized needs of such large groups of students.

MOOCs have received additional criticism in relation to their educational benefits. The high dropout rate of participants is a major concern. Even for courses offered by major American universities such as MIT, Stanford, and Berkeley, participants' completion rates do not exceed 10%. Dropouts are the result of a number of factors. Since enrollment is often free, some participants may enroll in a MOOC simply out of curiosity and not because they actually want to get involved in the training process. Participants may realize in the middle of the course that their learning objectives deviate from the objectives of the course. On the other hand, the possibility of super-specialization offered by MOOCs allows relative autonomy to participants but may deprive them of the development of critical thinking and further soft skills beyond the explicitly stated learning objectives.

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Figure 6. Popular MOOC Platforms – Retrieved from https://www.mooclearningworld.com/

When it comes to teachers, sometimes the space and time required to create a video lecture is disproportionate to the money they receive from teaching a course. With the hundreds or even thousands of participants in each lesson the individualization of the teaching and the involvement of all students is a challenge and may be prohibitive making even more difficult the work of the teachers who must "predict" the most likely topics of interest for students. The rapid growth of MOOCs from the world's largest universities and colleges may lead in the future to the destruction of smaller universities that unfortunately cannot compete with their infrastructure and reputation. Finally, the certificates provided by MOOCs are not internationally recognized. Employers are reluctant to replace traditional university degrees with these certificates. One solution may be the cooperation of universities offering MOOCs with recognized examination centers for conducting examinations where certificates for academic or professional use will be provided.

However, it should be noted the perceptions and attitudes towards MOOCs are shifting with large corporations often offering their own MOOCs as training to staff and recognizing certificates of MOOC completion by well established providers. This demonstrates the evolution of learning that may go beyond traditional, formal educational models towards flexible educational offerings that can be adapted easily and in a fast way to the development of emerging needs for dynamic skill sets.

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6.2 Serious games

Serious games are online applications designed for educational purposes and training. These games are called "serious" because they come with a serious message that has educational value. Serious games are usually simulations of events that actually take place in real life or processes designed to solve a problem. Although serious games can be fun their main purpose is to educate the participants.

The use of serious games is widespread and particularly useful in the field of education. They may be a valuable addition to the more traditional methods of teaching new skills.

Serious games are the intersection of learning, games, and simulation:

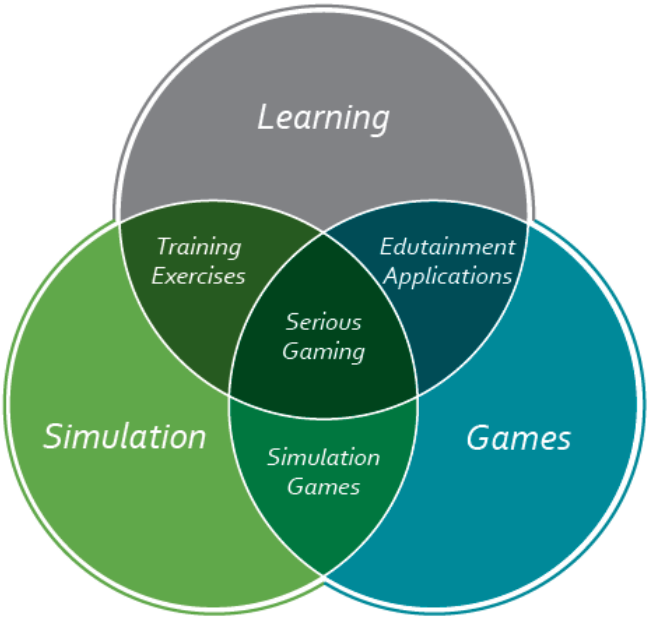

Figure 7. Definition of Serious Games – Retrieved from https://flowleadership.org/serious-games/

Serious games often involve a simulation of a real-world problem, which is designed specifically to challenge students to introduce a solution. They are considered to be an original and fun way to convey a message to the target audience. The fun side of games enhances the learning experience and therefore the transfer of information and the development of knowledge and skills. Finally, games allow the generation of feedback either from the software tool itself or from interaction with other players.

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Serious games can be used as powerful teaching tools. They support the development of a variety of skills such as strategic thinking, planning, communication, collaboration, team decision-making, and negotiation. They also contribute to the enhancement of acquired knowledge allowing the adaptation of learning experiences according to the interests of each student, the learning style, the facilitation of learning to take place in a context that makes sense to the student, and the support of group formation.

Serious games are not only used for building knowledge and skills. Given the fact that they are often based on behavioral sciences, serious games may be deployed for promoting the adoption of positive perceptions and attitudes. These games are called “persuasive games” and are of great interest. One example of persuasive games is applications that promote positive attitudes towards healthy lifestyles. Another example is using games to promote positive attitudes and behavior towards the environment. On the other hand, serious games may be used to promote positive attitudes and social inclusion, for example for fighting xenophobia. They may also be used for training individuals to react positive in diverse situations, such as training educators to identify potential signs of suicide inclinations among students and take action.

Serious games are used in all parts of life. Some sectors in which they are particularly popular are described below:

In business education games are used for developing the skills required by professionals working in a particular corporation or for promoting company values.

Games are also deployed in the health sector. Two large categories of games may be identified. One category of games is applications that target medical personnel, including doctors and nurses, aiming to train them in specific procedures. Another category is games that address the general public. Several types of games may be identified here. For example, some games may promote healthy lifestyles by encouraging individuals to exercise and maintain a balanced diet. Other games may target individuals that are chronically ill and need to maintain a specific regimen; in this scenario, games may be used as positive

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reinforcement. Other games maybe be exercise companions; for example, games on mobile applications may encourage individuals to exercise outdoors while linking their activities to themes of interest, such as following routes of cultural, industrial, or other interest that motivate individuals to follow a healthy walk while at the same time addressing additional interests or curiosity.

6.3 Simulations

Serious games and simulations are considered as important revolutions in education since they can be used as effective pedagogical tools for Active, Experiential, and Problem-Based Learning [12, 13, 14]. As Experiential Learning became increasingly popular for academic and professional training important questions have been raised about how best to understand the learner's experience and how to conceptualize the relationships between learning and the learner's perceptions of their experiences.

Computer simulations have greatly evolved over the past few decades. Simulation tools have given many advantages in education, since they are being used for teaching, training and testing applications. As computer technology continues to improve, serious game and simulations will be used more and more in education.

Simulations are tools that are often deployed in Problem-Based Learning. The user adopts the role of a problem solver responding to realistic workplace scenarios. The activities are built around a series of real-life and complex situations. A scenario-based game is somewhat similar to teaching using case studies. Scenario-based learning allows the players to acquire experience through trial-and-error processes that are as effective as real life experimentation while at the same time they protect students from the consequences of wrong decisions.

Scenario-based learning combines stories with hands-on training. These virtual scenarios allow learners to gather professional expertise and experience in a shorter time than what they would have obtained working in real jobs.

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Although there are differences between games and simulations they are compatible tools. If properly integrated in a learning process they can successfully complement each other in order to enhance learning effectiveness [13]. Simulation games are simplified representations of reality that are structured as interactive games in order to enhance the experiential learning process. The combination of the attributes of games and simulations [14] may result into a simplified but realistic system that allows students to face real-life inspired challenging and engaging scenarios with well-defined goals and rules of interaction [15]. Good simulation games are motivating [12, 13, 15] and can increase student motivation to participate in the learning process.

There are many reasons for using simulations as training tools. Motivation for using simulations may include safety and training cost containment. In other words, simulations may be deployed to build skills through hands-on experimentation in a safe environment before exposing learners to real world conditions. Examples of this scenario include the training of pilots in flight simulators or the training of doctors in specific medical procedures. Simulations may further be deployed when training in real world conditions is not possible to the lack of necessary infrastructure. An example of that is using digital applications as training tools when physical laboratories are not available. Another example is training personnel that works in a production line. Closing down the production for training purposes is very expensive. For this reason, initial training may take place in a simulated environment before continuing skill development in physical settings.

6.4 Mobile learning

Mobile Learning or M-Learning is a method that uses mobile and wireless technologies for learning and educational processes. M-Learning gives learners the opportunity to combine their learning experiences in a shared collaborative environment [16]. The internet and WWW have allowed improvements in learning activity design by introducing an elevated level of interaction between teachers and learners that are geographically separated. The internet is not just a means that facilitates the delivery and distribution of knowledge and

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learning contents. It also helps create learning environments that fit the needs of learner by engaging them in diverse activities such as interaction, collaboration, conversation, and problem solving. The evolution of network speeds has allowed e-learning to become the state-of-the-art for distance learning. M-learning is the next generation of distance learning. Mobile devices can be carried and used everywhere offering learners access to knowledge anytime and anywhere.

The use of mobile phones and tablets nowadays is becoming more and more popular. Students become easily acquainted with and can use the relevant applications while many enjoy the flexibility that mobile devices introduce into learning, whenever and wherever they seek it, away from their desks and desktops. The widespread use of mobile applications has led to an evolution of traditional teaching methods since students are willing to learn through digital tools that they can understand and use.

M-Learning is facilitated by the ability of computing and communication devices, such as smart phones and laptops, to connect to wireless networks. M-Learning gives the opportunity to educators and students to reach past the conventional classrooms. Portable computing and communication devices give instructors and learners increased flexibility and offer new interaction opportunities. Some of the benefits of M-Learning can be seen below:

- It offers access to content anytime and anywhere
- It supports distance learning
- It improves student-centered learning
- It is great for training or review of content
- It supports the differentiation of student learning needs
- It further supports personalized learning
- It facilitates the enhancement of interaction and communication between and among students, learners, educators, and instructors

Moreover, M-Learning allows learning to be implemented in a smart and systematic way. This is facilitated from the on-line storage of content in an organized manner that makes it

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easily accessible by learners. Everything that students need is available on one device and does not have to be based on lectures and courses. Unlike traditional learning methods that focus purely on audio learning mobile and tablet applications incorporate visual, auditory, and kinesthetic learning methods. Using these three types of teaching learners build knowledge and are entertained at the same time, which leads to higher engagement and to more efficient retention information. Mobile applications provide users with an improved learning experience in relation to classical lessons and homework. When combined with difficult subjects, such as mathematics, physics and chemistry, these applications encourage students to find interest in scientific fields that are perceived as “difficult” to master.

Mobile and tablet applications are not only beneficial to students. Educators and parents may also benefit from them. Teachers in particular can take advantage of these applications to organize their lessons and design interactive classes. Applications are also easy to modify and update pushing virtually all users to spend more time designing and participating in learning processes.

Overall, it is certain that M-learning applications enhance self-education as they are convenient, easy to download from the internet, and provide a range of different forms of learning, in and out of the classroom.

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7. Conclusions

This document provided an overview of Problem-Based, Active, and Experiential learning approaches and of digital tools and applications that may be used to support emerging, related educational design. The benefits of these educational methodologies are many. They facilitate the development of foundational knowledge in engineering fields. They further contribute to the development of soft skills such as critical and analytical thinking, entrepreneurial mindsets, collaborative ability, communication capacity that are in demand by industry and society. The evolution of digital technology fosters increased interaction in the context of Problem-Based, Active, and Experiential learning. It further allows the personalization of learning offerings for addressing individualized needs and learning objectives. It supports access to the learning process anywhere, anytime. It allows learners to experiment in learning scenarios that are inspired by real-life challenges in a safe environment and promotes the transferability of knowledge from the academic environment to the real world through activities that simulate problem-solving practices in professional environments. Problem-Based, Active, and Experiential learning are gaining in popularity as, when well designed, they promote increased co-responsibility of students in knowledge development and allow the building of skills that can help address the complex business and societal challenges of the 21st century.

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