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Methodologies Used In The Teaching Of Systems Engineering: Overview Review 2015-2024

Luis Eduardo Muñoz Guerrero

Facultad de Ingenierías, Universidad Tecnológica de Pereira
lemunozg@utp.edu.co , ORCID: https://orcid.org/0000-0002-9414-6187

ABSTRACT
This document reviews of the studies carried out on the methodologies used in the teaching of Systems Engineering, such as: Project Based Learning, Gamification and the Integration of Online Learning Platforms. The information is collected through reading different study articles on the constant evolution in educational methods and approaches carried out in research, theses and repositories that have been made in Systems Engineering programs, between the years 2015-2024. The challenges that educators face when adopting emerging technologies are mentioned and the impact of Project Based Learning is highlighted. Based on the analysis of different articles related to the topic, these indicate that the adaptation of digital tools and personalized approaches should be incorporated into the teaching of future systems engineers. Finally, future implications for the teaching of this discipline are presented.

Keywords: Systems Engineering, Collaborative Projects, Teaching Methodologies, Project-Based Learning.

Introduction
Technological development and the needs of the labor market have driven a significant change in the teaching of Systems Engineering. The role of systems engineers is no longer limited to programming or implementing technology solutions, but also includes the ability to work in collaborative environments, adapt quickly to new technologies, and apply critical thinking and complex problem-solving skills.
In this context, educational institutions face the challenge of adapting their teaching methods so that future systems engineers can cope with current demands. The purpose of this article is to review some of the methodologies and tools used in the teaching of Systems Engineering and how these align with the competencies required in today's industry.

1. Theoretical Framework: The teaching of Systems Engineering is based on educational theories that prioritize active and collaborative learning. Among the most prominent are:

Constructivism: According to Bertrand, for Piaget, learning is an active process in which students build new knowledge based on previous experiences. (Bertrand, 2015)

Competency-Based Learning (CBA): Sánchez and Leicea (2007) call competency-based learning CBA and explain it as the development of two types of competencies, generic and specific. They speak of generic ones as systematic instruments and describe the specific ones as adjusted to each profession. At the university level, the goal is to strengthen the research process, supported by procedural, conceptual, and attitudinal contents, moving from teaching only repetitive concepts, to an awakening of the student's motivation and intellectual curiosity. This approach focuses education on the development of specific skills and competencies, assessing not only theoretical knowledge but also its application in real contexts.

2. Current Methodologies in Systems Engineering Education.

The implementation of innovative methodologies in Systems Engineering is necessary to improve the teaching-learning process. This document presents, as a summary, a comparative review of the four methodologies mentioned: Project-Based Learning, Gamification, Online Learning Platforms and Massive Open Online Courses (MOOCs). The advantages, disadvantages, and challenges of each methodology are highlighted to provide a comprehensive view of its effectiveness and application in the current educational context.

Table 1

Advantages

Methodology	Advantages
Project-Based Learning	- Promotes practical skills and real problem solving.- Increases student motivation and engagement.- Improves teamwork and communication skills
Gamification	- Increases motivation and interest in learning.- Facilitates the retention of knowledge through playful experiences.- Promotes active learning and continuous participation.
Online Learning Platforms	- It facilitates access to updated content and multimedia resources.- It allows flexibility in learning, accessible anytime and anywhere.- It facilitates self-directed learning and time management.
MOOCs (Massive Open Online Courses)	- They offer access to quality education from world-renowned universities.- Flexibility and variety of courses for different interests and skill levels.- Low cost or free, democratizing access to education.

Table 2 Disadvantages

Methodology	Disadvantages
Project-Based Learning	- It requires extensive and detailed planning by teachers.- Students with less experience may feel overwhelmed.- Complex evaluation of results.
Gamification	- It may require additional technological resources.- Possibility of distraction if it is not implemented correctly.- Adapting educational content to the game format can be difficult.
Online Learning Platforms	- It can generate a feeling of isolation and less social interaction.- It requires self-motivation and discipline skills of

	students.- Possible digital divide due to limited access to the internet.
MOOCs (Massive Open Online Courses)	- High dropout rate due to lack of personalized follow-up.- Limited evaluation and certification compared to formal programs.- May not be adapted to specific local or contextual needs.

Table 3 Challenges

Methodology	Challenges
Project-Based Learning	- Need for adequate resources and institutional support.- Continuous training of teachers for effective implementation.- Additional time required to develop and evaluate projects.
Gamification	- Design and development of gamification elements that are meaningful and non-trivial.- Effective integration with learning objectives and the evaluation of results.- Initial resistance from students or teachers less familiar with the methodology.
Online Learning Platforms	- Guarantee the quality of the educational content offered.- Overcome technical and connectivity problems in different regions.- Promote active and meaningful interaction among students.
MOOCs (Massive Open Online Courses)	- Adaptation of content to different learning styles.- Encourage participation and completion of courses.- Develop more effective and personalized evaluation systems.

2.1. Project-Based Learning (PBL) PBL focuses on the creation and development of concrete projects and is one of the most popular methodologies in the teaching of technical disciplines such as Systems Engineering. This methodology allows students to work on real or simulated projects, applying knowledge gained in various areas of the curriculum. According to Prince & Felder (2006), PBL significantly improves students' ability to solve complex problems and work in teams. PBL promotes key skills such as critical thinking, creativity, collaboration, and communication, as well as facilitating deeper, more contextualized learning. The PBL method is a useful tool to increase analytical capacity, conceptual richness, knowledge and skills through problem solving.

Technological advances and the demand of the labor market have forced the teaching of Systems Engineering to constantly evolve to keep up with the demands of the world of work; these advances have modified people's lifestyles, and although they have caused the loss of jobs, it is also true that they have created new ones; That is why educational strategies should focus on the development of technical competencies, soft skills, and an innovative mindset that allows students to face the complex challenges of modern engineering. This context has prompted a reflection in the academic world about the competencies and skills that must be deployed by future engineers and the pedagogical strategies that can be used so that their learning experiences are the result of practices, techniques and ways of working that the current work context demands. In the study carried out by the National University of San Marcos called, "Project-Based

Learning and Systems Design", it determines that there is statistical evidence to affirm that, "The application of PBL will significantly improve learning in the Procedural dimension of the Information Systems Design course among students of the Faculty of Systems Engineering, Universidad Nacional Mayor de San Marcos" (see Table 5, Espinoza. A)

Tabla 5

Estadísticas de grupo, dimensión procedimental, Post Test alumnos del estudio

Curso Diseño de Sistemas		N	Media	Desviación estándar	Media de error estándar
Calificación	Grupo Control	25	6,72	1,429	,286
	Grupo Experimental	27	8,56	1,188	,229

2.2. Gamification in Education

Gamification is the use of elements, mechanics and dynamics belonging to the game, which, applied to other types of scenarios, practices or contexts, allows the most stimulating and fun aspects of the game to be recovered, and incorporated into scenarios that need additional motivation. In recent years, Gamification has been of special interest to academics and professionals in many fields, particularly in the area of Information Technologies where it has been used for the development of systems and applications in different domains, with positive results (Kazhamiakin et al., 2015). Thus, both the studies reported in the literature and practical experiences in the labor market, confirm that gamification can be useful in educational, collaboration, and software engineering activities to work in technology, research and development companies in various sectors.

2.3 Online Learning Platforms and MOOCs

The growth of Massive Online Open Courses (MOOCs) has transformed access to learning, allowing students around the world to access high-quality content without geographical limitations. Platforms such as Coursera, edX, and Udemy have enabled the teaching of complex topics such as software engineering, networking, and databases. Using open-source tools such as Python, TensorFlow, and GitHub not only allows students to experiment with innovative technologies, but also prepares them for a collaborative work environment. One of the most prominent challenges of MOOCs is the low completion rate. Despite the high enrollment, which can reach thousands of students per course, completion rates typically range from 5% to 15%. For courses focused on Systems Engineering, these figures tend to improve slightly when active methodologies such as peer evaluation and the use of practical projects are implemented (Jordan, 2014). The duration and type of assessment are also influential factors: shorter courses and those that combine automated assessment with peer assessment have higher completion rates, around 20% (Veletsianos & Shepherdson, 2016)

2.4 New Technologies

Companies need a profile trained in design and creative technologies. In recent years, the demand for specialists in graphic design, illustration, 2D and 3D animation, infographics, website design or application development for mobile devices has grown. Many companies have emerged from the creativity of these new professional entrepreneurs. In the study Gamification as a tool for recovering attention in long-term classes carried out at the Polytechnic University of Valencia, the use of Gamification has been implemented in the subject: Sciences of the Autonomous University of Madrid, since being a theoretical-practical subject it causes loss of attention by being exposed to classes for a long time. (Bedia, J., Peña-Garzón M.) (2023)
Virtual learning environments (VLEs) are widely used in higher education institutions. These environments have been changing from a first generation based on the distribution of content and student assessment, to

a generation much more oriented towards promoting the processes of interaction and communication between participants (Onrubia, Colomina & Engel, 2005).

Stanford University: Personalized Learning for Advanced Skills: Stanford University has pioneered the adoption of personalized learning within its Systems Engineering program. One of its most notable projects is the use of artificial intelligence to automatically adapt educational content and activities to the individual needs of students. Personalization allows each student to progress at their own pace, receiving the right resources and support at the right times. Through the **Stanford Online** platform, the system adjusts learning paths based on each student's specific progress and challenges, starting and ending the course at any time. New careers will continue to increase the number of offers already offered by Stanford Online, making Systems Engineering indispensable in different universities worldwide. Among the prominent programs offered by Stanford University are, to name a few, the Artificial Intelligence Professional Program, and the Generative AI Technology Society and Companies Program, making personalized learning an important tool of Systems Engineering.

University of Helsinki: Master of Science in Computer Science
Student-centred learning provides a solid foundation for lifelong learning. The leading research unit in computer science at the University of Helsinki in Finland allows the student regular contact with the latest research and insight into development patterns in this field, which will give them permanent professional competencies for specialist, design or management positions in the business world.

Massachusetts Institute of Technology (MIT: Combining Gamification and Personalized Learning
The Massachusetts Institute of Technology (MIT) has adopted a blended strategy that combines elements of gamification with personalized learning in its computer science and systems engineering programs. Through its MITx platform, students complete modules in which the content is adapted to their learning pace, while gamification is used to keep motivation high.

The Polytechnic University of Valencia: the Implementation of Gamification
The implementation of this methodology requires not only technological tools, but also a comprehensive pedagogical approach, which includes adequate teacher training and the careful design of activities aligned with learning objectives. This review cites part of the conclusion of the study carried out by three professors from the University of Valencia, called "Gamification at the University II: we learn to have fun teaching. They have fun learning": "The gamification of the university classroom is a novel alternative in our university and, above all, in the Faculty of Medicine and Dentistry. Although some of the teaching staff are skeptical of this type of method in university education, our results in the degree in Podiatry agree with previous work in Dentistry (Pintor Holguín 2014 and Serna 2015) and Biomedical Engineering (San-Miguel 2016) among others, showing that, for students, playing is a valid way to acquire knowledge". The following graph shows the approval percentages of the students in the aforementioned study (Teresa San-Miguel, Javier Megías, Eva Serna):

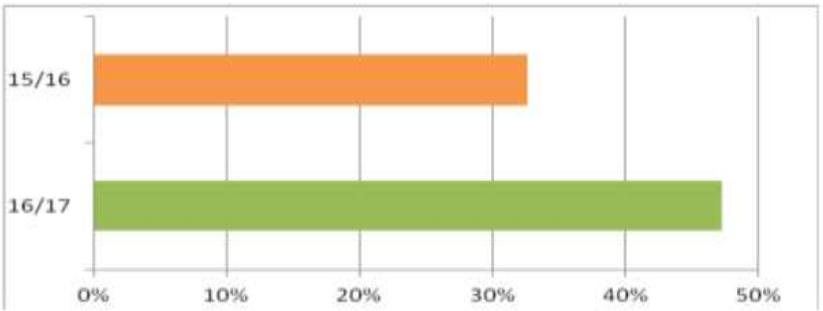

Fig. 1. Proportion of students who pass the theoretical exam in Cell Biology in the first call in the 2015–2016 and 2016–2017 academic years.

Innovative methodologies such as Gamification are being used more and more at various educational levels and Higher Education has not been left out of it, so much so that it is increasingly common to incorporate them into university teaching.

In both gamification and personalized learning, the role of the teacher is fundamental. Training programs should focus on how to integrate these technological tools within long-term learning objectives, to ensure that their implementation is effective and sustainable. In contexts where technological infrastructures are not optimal, it is necessary to ensure the availability of platforms and tools that facilitate the implementation of these methodologies. This may require significant investment in technology, but the long-term benefits in terms of student success justify the investment; When these methodologies are well integrated, they can generate notable improvements in student performance and motivation.

3. Collaborative Projects: University-Industry Alliances

In the study, "Linkage Company State University, some Experiences in America and other countries of Europe and Asia" it is expressed that currently, due to the qualitative changes at the global level that are taking place, universities are required to insert the training of the professional in the work environment to guarantee not only the acquisition of theoretical and practical knowledge and the development of professional skills, but also a professional trained in his environment and for his environment. (Rodríguez M, Rojas L.) (2014)

In the study, Development of collaborative projects with industry as an engineering education strategy, an educational strategy applied in the Metallurgical Engineering program of the Industrial University of Santander is described, which consists of developing collaborative projects with industry. The strategy allowed students to acquire competencies required in the world of work by identifying, analyzing, and formulating alternative solutions to real engineering problems. (Viáfara, C.) (2020). In this way, students alternate between studies and work with companies associated with universities.

In Canada, more than 800 university master's programs throughout Canada in different disciplines such as health sciences, engineering and technology, business, arts and others, are the preferred option for international students since they allow them to work at the same time, obtain a prestigious higher degree in a country like Canada, and at the same time. (Post-Graduation Work Permit), a work permit that allows foreign students to work in Canada after finishing their studies.

These alliances or collaborative work also occur in other universities such as the UAEMÉX and the UABC as shown in a study on "The role of institutions and university-business collaboration in development: evidence from the UAEMÉX and the UABC" (García, R. 2018)

Joint Innovation Labs: Collaborations between Universities and Industries or Companies are becoming more and more frequent, because they see this type of cooperation as a way of working together with benefits for both parties and providing an effective response to real problems.

"In collaboration with MIT (Massachusetts Institute of Technology) Media Lab, Brigham & Women's Hospital, Tulane University School of Medicine and Samsung Medical Center, this new research program will explore improvements to the digital health ecosystem and new approaches to wellness. With the research results from these collaborations, Samsung will strive to further develop its technology to support the healthcare sector, expand understanding of people's minds and bodies, and unleash the full wellness potential of personal devices

Joint Certification Development: The collaboration between Coursera and the University of Illinois offers a master's degree in Computer Science with a specialization in data science, endorsed by leading companies such as IBM.

Key Benefits of Internships

Partnerships with technology companies allow universities to update their curricula on an ongoing basis through collaborative projects and internships, These companies are often at the forefront of innovation, which means that educational programs can quickly incorporate the latest trends and emerging technologies making it easier for students to access resources, such as, proprietary software, large volumes of real data for analysis and simulations, and development platforms. This access prepares students to use the same tools and environments they will find in the professional field; On the other hand, working on projects proposed by industry allows students to apply their theoretical knowledge to real problems, developing critical problem-solving and critical thinking skills.

Students who participate in programs developed in conjunction with industry are usually better positioned in the labor market. Companies that collaborate on these programs are more inclined to hire graduates who are already familiar with their technologies and methodologies, reducing costs and training time. In addition, this results in greater employability, since dual programs allow the company to observe the student in a work environment that is its own and measure their competencies, knowledge and skills that are evident in the solution of real problems.

Collaboration with industry also encourages applied research, which focuses on solving specific problems that companies face. Not only is this research valuable to the industry, but it also offers students the opportunity to contribute directly to technological advancement. In this context, as Systems Engineering is a transversal discipline to all sciences, it is essential that it includes new teaching methodologies, such as PBL and Gamification, as is already happening in some universities and that has been demonstrated in the review of the studies cited in this article.

4**. Propose an effective collaboration framework between academic institutions and technology companies**

Considering the rapid technological advancement at a global level, education in all its fields cannot be left behind and it would be good to consider strategies that allow such progress to be achieved.

The following tables present some key strategies to improve learning in this field:

Innovative Strategies to Improve Learning in Systems Engineering

Table 4 Dual Program Promotion

Advantages	Description	Challenges
It combines academic studies with practical experience in business. It improves employability, develops technical and soft skills, and strengthens the link	Students work on real projects while completing their education Example: Programs at European universities with	It requires close collaboration between universities and companies, and curricular adaptation.

between academia and industry	companies such as DHL and BASF	

Table 5 Project-Based Learning (PBL)

Advantages	Description	Challenges
It encourages creativity, critical thinking, and problem-solving.	Students work on projects that simulate real industry problems. It involves working in teams to develop applicable technology solutions.	It requires resources and time for planning; can be challenging for students with no prior experience

Table 6 Use of Open Source Technologies

Advantages	Description	Challenges
It promotes collaboration, allows for experimentation, and improves readiness for the work environment.	Implementation of tools such as Python, TensorFlow, and GitHub in courses, allowing students to experiment and collaborate on real projects.	The learning curve can be steep for those who are not familiar with these

Table 7 Active Assessment Methodologies

Advantages	Description	Challenges
Assesses technical and soft skills such as leadership and teamwork	Assessment that includes teamwork, case studies and peer assessment, rather than traditional exams	It can be subjective and difficult to standardize
Increases learning retention		It requires training for evaluators.

Dual Program Promotion

This approach allows students to apply their knowledge in real-world settings while gaining hands-on experience. In addition, companies have the opportunity to evaluate and train future employees, creating a direct bridge between academia and the labor market. Although it is not a massive practice yet, many universities worldwide are already incorporating this practice both in their last years of career and in their postgraduate courses. To cite one, there is the EU, which promotes within its programs, internships and practical projects, building global networks through teamwork, internships, business links and academic experience with partner companies, such as DHL and BASF among others, which will allow students to gain experience in real business projects and be able to access a variety of leading companies. In this sense,

Systems Engineering should be a support in the development of courses and projects that are based on real problems provided by the industry and that can make higher education more relevant and attractive.

Competency-based assessment methods

The approach of innovative assessment and training strategies to improve the quality of learning in Systems Engineering. not only allows the evaluation of technical skills, but also soft skills such as problem solving, teamwork and decision-making in the different disciplines. that reflect the students' ability to apply knowledge in practical situations. Below is an example of a rubric used in Systems Engineering focused on evaluating student performance in Teamwork:

Working Effectively in Teams

Unsatisfactory 1	In Development 2	Satisfactory 3	Exemplary 4
It does not collect any information related to the topic. It does not perform any of the functions of the assigned team role. Always rely on others to get the job done. He is always talking. He never allows anyone to speak.	It collects very little information—some of which relates to the topic. He rarely does the assigned work: he often needs to be reminded. He is generally the one who talks the most, rarely allowing others to speak.	Gather basic information; Part of it relates to the theme. Performs almost all assigned tasks. Generally does the assigned work. he rarely needs to be reminded. He listens, but sometimes he talks too much,	It collects a lot of information, all related to the topic. Performs all tasks in the assigned team role. He always does the assigned work without needing to be reminded. Listen and encourage others to participate.

Figure 1: Example of a holistic rubric (consulted from Rogers, 2010)

(Chan, CKY (2015).

Competency-Based Assessment: Competency-based assessment focuses on measuring how well a student can apply their knowledge to solve real-world problems. Rather than being limited to written tests or exams, this approach encompasses a variety of methods such as practical projects, simulations, digital portfolios and peer assessment, which will allow the student to face the world of work better prepared,

The Technical University of Denmark (DTU) has been one of the pioneers in the implementation of competency-based assessment methods in its Systems Engineering programmes, because this type of assessment fits very well as it is a technical university. Since the implementation of this approach, a significant increase in the course pass rate has been observed. According to statistical data provided by the DTU, between 2018 and 2023, the pass rate in Systems Engineering courses increased from 78% to 92%, reflecting an improvement in student academic performance (DTU Annual Report, 2023).

DTU is a leading academic institution in the fields of engineering, science, and technology, internationally recognized for its focus on technical and natural sciences. It stands out for its business-oriented training and its contribution to research, Its dual programs in collaboration with industries and companies allows students to develop their competencies and be evaluated in a real work environment. The benefits are a more realistic and practical assessment, a comprehensive development of soft skills, such as collaboration, critical thinking and decision-making. These skills are increasingly valued by employers and are critical to success in a complex and globalized work environment. Students who are assessed under this approach tend to be better

prepared to face the challenges of the world of work. Working on real or simulated projects, they develop hands-on experience that allows them to quickly adapt to professional work environments.

Conclusions

This review of articles of studies related to the Methodologies applied in Systems Engineering has involved an important search, because they have been implemented in the Universities gradually and have been increasing a few years ago, which is why there are not many studies done on the subject. The studies reviewed allow us to conclude that: Systems Engineering is characterized by being holistic and interdisciplinary and allows the study and understanding of reality, and in its broadest sense, studies any existing system. In recent years it has made significant progress and its influence both in higher education, as well as in industry and business is evident. However, being a methodology in itself, the continuous evolution of Systems Engineering comprises the development and identification of new methods and techniques that help in a better understanding of the various systems as they become more complex. In this sense, universities have incorporated new methodologies incorporating new technologies that bring teaching closer to students in a different way than the traditional one, in their different programs and especially in Engineering.

In the review of the study carried out at the University of Valencia cited in this article, it can be observed that the use of gamification as a methodology in the university classroom shows that students consider it valid to acquire knowledge; in the aforementioned study, it is observed that in the first call, the percentage of approval in the academic year 2015 – 2016 reaches 30%. while in the 2016-2917 academic year it increased to almost 50%. Gamification has been of special interest to academics and professionals in many fields, particularly in the area of Information Technology. On the other hand, PBL has been revealed in the review of this article, as one of the methodologies that is increasingly used in universities, because it allows students to learn in real contexts and to solve real problems, acquiring knowledge, soft skills, work practice and developing critical thinking and solving complex problems.

Undoubtedly, it is the beginning of many more changes that will come in teaching methodologies. The use of Emerging Technologies such as AI, Automations, MOOCs, Online Platforms, among others, in collaboration with Universities, have brought many benefits as already pointed out in this article, but this rapid progress in teaching presents challenges and to face them it would be beneficial to involve the industry, as an educational strategy, in the design and evaluation of projects. which can increase the relevance and applicability of the results. The implementation of PBL in Systems Engineering programs can help to bridge the gap between theory and practice, marked between what is taught in the classroom and the reality in the development of Systems Engineering, whose objective is the formalization of different methodologies to identify new methods and research opportunities in a similar way to what is done in other branches of engineering. The continuous evolution of System Engineering includes the development and identification of new techniques and methods that help to better understand different systems, especially engineering systems, as they grow and become more complex. Projects in Systems Engineering involve the integration of technology, processes, and people and aim to create a product from start to finish. By applying, analyzing and adapting systems design processes that manage to generate projects that meet predetermined needs, making use of the technologies and different methodologies mentioned in this article and collaborative strategies also mentioned, Systems Engineering will meet its objective in the different higher education programs.

Using Gamification to Incentivize

Sustainable Urban

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