

Iván Arturo López Jiménez

The Science Disseminators Academy

A teacher training program for implementing phenomenon-based learning using astronomy.

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Iván Arturo López Jiménez
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ABSTRACT

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Author: Iván Arturo López Jiménez

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The thesis aims to develop a comprehensive pedagogical model and teacher training program prototype for scientific dissemination in K12 education, with a STEAM approach. It integrates the role of emotions in learning, the latest findings on how brains learn, phenomenon-based learning focusing on astronomical phenomena, and active educational techniques like game-based learning and maker-learning. The program prototype follows service design principles for user-centricity and effectiveness, with the goal of enhancing scientific dissemination and creating a more engaging learning experience.

The work of this thesis demonstrates that teachers prefer a hands-on, collaborative learning style that fosters active participation, knowledge sharing, and inspiration from colleagues. Regardless of the training format, diverse teacher groups and a supportive environment for communities of practice are crucial. The training should seamlessly integrate into teachers' schedules without affecting their free time or administrative duties. Voluntary participation with institutional support is essential, and the program's duration aligns with the academic year to facilitate immediate classroom implementation.

A significant concern is teachers' lack of knowledge about how the human brain learns. Despite their passion, they often neglect teaching methods aligned with the brain's natural processes due to technology-driven priorities. Training should focus on teachers becoming facilitators, storytellers, and emotion readers, recognizing the connection between emotions and learning. Understanding emotions and leveraging them for enhanced learning outcomes create an optimal learning environment. Empowering students to take responsibility for their learning requires a paradigm shift from traditional expectations.

The research proposes a framework for implementing teacher training programs on a larger scale, emphasizing benefits for students and teachers, and addressing potential challenges. This framework serves as a roadmap for designing effective programs promoting active learning and scientific dissemination in K12 education.

Keywords: Scientific dissemination, STEAM approach, Phenomenon-based learning, Active educational techniques, Emotions in learning, Practical teacher training, collaborative learning.

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1 INTRODUCTION

In a rapidly evolving world, the significance of education and its transformative power cannot be understated. As we seek to equip future generations with the knowledge, skills, and competencies required to navigate an increasingly complex global landscape, the role of teachers becomes paramount. This thesis endeavors to address the challenges faced in K12 education, focusing on the vital task of scientific dissemination with a STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach.

The objective of this research is to develop a comprehensive pedagogical model and a teacher training program prototype that embraces the essence of STEAM education. By incorporating the role of emotions in learning, understanding the latest findings on how the human brain learns, adopting phenomenon-based learning with a focus on astronomical phenomena, and leveraging active educational techniques such as game-based learning and maker learning, this initiative aims to revolutionize scientific dissemination in K12 education.

The thesis is structured in a way that reflects the systematic exploration and analysis of key elements essential to the development of an effective pedagogical model and teacher training program. The contents cover various aspects that converge towards the goal of enhancing scientific dissemination and creating a more engaging learning experience for both teachers and students.

The contents are organized as follows:

Theoretical Background: This chapter delves into the theoretical foundations that underpin the research. It explores the role of emotions in learning, the cognitive processes of the human brain, phenomenon-based learning, and the educational techniques of game-based learning and maker learning.

Methodology: The research methodology employed in this thesis is outlined here, providing insights into the approach used to gather data and analyze the effectiveness of the teacher training program. It follows the service designs logic steps,

Findings: This section presents the empirical findings derived from investigating the context, teachers, and students involved in the research. The results contribute to the formulation of the training program prototype.

Conclusions: Drawing from the gathered data and analysis, this chapter offers insightful conclusions, recognizing the significance of enhancing scientific dissemination, promoting active learning, and fostering a more robust educational environment.

The culmination of this research leads to the undeniable realization of the profound impact that teachers have on the learning experience of students. Teachers play a pivotal role in bridging the gap between scientific knowledge and the practical application of essential concepts in students' lives. As the world embraces the possibilities of STEAM education, this thesis advocates for a paradigm shift in how we perceive and elevate the role of teachers in society.

The integration of emotions, cognitive insights, active learning methodologies, and phenomenon-based learning lays the groundwork for an innovative pedagogical model and an effective teacher training program. By empowering teachers to become facilitators, storytellers, and emotion readers, we create an optimal learning environment where students take responsibility for their own learning journeys.

This research highlights the urgent need to dispel the prevalent notion of a binary division between science and art, which has long limited students' potential to excel in both fields. With STEAM education, students are presented with the opportunity to discover unexpected connections between scientific and artistic realms, fostering a holistic approach to learning.

Ultimately, this thesis seeks to embolden society to recognize and celebrate the pivotal role of teachers in shaping the future generation. A concerted effort to uplift and support teachers will ultimately pave the way for a brighter and more innovative future, where scientific dissemination, creativity, and active learning form the bedrock of K12 education.

2 THEORETICAL BACKGROUND

Scientific dissemination plays a crucial role in sharing scientific research and knowledge with the general public. This process involves presenting complex scientific information in a simplified manner, making it accessible to individuals who may not have a background in scientific concepts. The effectiveness of this dissemination is essential for achieving the educational benefits of informing and engaging a wider audience.

Similarly, science, math, and technology teachers share some similarities with scientific disseminators. Their role involves presenting educational content in a comprehensive yet approachable manner, encouraging students to not only grasp the concepts but also actively engage with them. However, teachers face an additional responsibility beyond simple dissemination – they must ensure that students internalize these scientific ideas and can readily apply them in real-life situations beyond the confines of the classroom. This requires fostering a deeper understanding and practical application of the knowledge they impart.

At the time of this writing, the educational landscape has seen numerous initiatives focused on STEM (Science, Technology, Engineering, and Mathematics) implementation in K12 classrooms. However, there is a noticeable scarcity of initiatives that explicitly embrace STEAM, encompassing STEM with the arts – including humanities, language arts, dance, drama, music, visual arts, design, and new media. “The debate on adding an “A” for the arts in STEM education centers on whether it dilutes the original purpose or enhances interdisciplinary learning. Some argue that artistic expression confuses the scientific focus, while others see it as an organic expansion. STEAM fosters connections between science and art, dispelling binary thinking and allowing students to discover unexpected links, such as how chemistry affects paint or physics influences music.” -Acer for Education 2020- In the context of this thesis, the author firmly supports the adoption of the STEAM approach, recognizing its potential to foster holistic and integrated learning experiences that nurture students' creativity, critical thinking, and appreciation for the interconnectedness of different disciplines. By embracing STEAM, educators can cultivate well-rounded individuals who not only excel in science and technology but also find inspiration and understanding in the realms of art and creativity.

The main objective of this thesis is to develop a comprehensive pedagogical model and teacher training program for scientific dissemination with a STEAM approach in K12 education. The broader concepts, pedagogical approaches and educational techniques that are the base of this thesis and the subsequent training program, are categorized in figure 1.

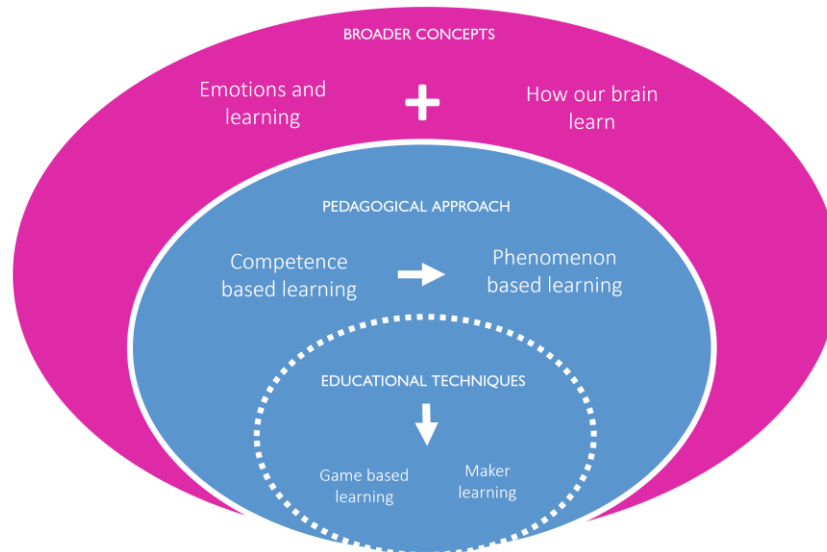


Figure 1 – Pedagogical model for teacher training. Authors summary

The first two broader topics (Emotions and learning and how our brains learn) are deeply connected. In the following paragraphs the main definitions of some of their components will be found and it will help define how these components can be included in the training program of this thesis, but it can also be used as a generalization for other educators' training programs.

2.1 Emotions and learning

The following is a brief description of the four most repeated items when it comes to the relation of emotions and learning and those the author considered are more relevant and easier to implement in the teacher training program. These are the concept of constructivism, the relation between emotions and attention, the importance of interest, novelty and meaning, and building on strengths.

Constructivism in the context of learning involves an ongoing and progressive journey where an individual constructs a personal comprehension of their surroundings by engaging in distinct experiences

and interactions with the environment as suggested by (Ertmer and Newby, 1993). These experiences and interactions can be individual or in a group, but it will always depend on the context where it happens, therefore the learning environment, understood as all the surroundings of the student, including the peers and the teacher, will deeply shape the construction of the knowledge.

Another implication with constructivism is that all the content that comes to our brains is interpreted according to the previous mental models that each individual had. “That is why it takes a very long time to be a subject expert. Our minds need that time to create all the mental models to make sense of the knowledge we are acquiring. These poses a challenge to topic experts because they need to translate the content topic to pedagogical content” (Lonka, 2018) and help learners create their own mental models. Possessing large amounts of information does not mean having high quality mental models.

“Emotion and attention are the principal processes that our body/brain uses in its efforts to survive” (Sylwester, 1995). Emotions play a role in cognitive processing through various avenues. Information that elicits a sense of significance and enthusiasm tends to be retained more effectively. This is discussed by (Tyng CM, Amin HU, Saad MNM and Malik AS, 2017), but merely possessing this knowledge is insufficient; the ability to effectively trigger distinct emotions holds significance for the enhancement of learning processes. We pay attention to things that we consider important for us. For classifying these emotions, we can also link them with intrinsic and extrinsic motivation (see Table 1).

Table 1. Type of emotions and its relations with types of motivation. Author’s summary from: Lonka, K. (2018). Phenomenal Learning from Finland

Type of emotions	Related type of motivation
Achievement emotions (related to test, examinations, grading, etc)	Extrinsic motivation
Topic emotions (related to the content itself)	Intrinsic motivation
Social emotions (interactions with people)	Extrinsic and intrinsic motivation
Epistemic emotions (related to knowledge and learning)	Intrinsic motivation

Achievement-related emotions emerge in scenarios of student competition. These emotions encompass both positive aspects like hope and pride, as well as negative facets such as anxiety and shame. Subject-related emotions exhibit significant diversity. For instance, students may experience empathy or anger while engaging with topics related to injustice. Art and music subjects have the potential to evoke a broad spectrum of emotional responses, similarly observed in experiential learning. Interactions between individuals give rise to social emotions, which encompass a wide array including sentiments like pride, admiration, or jealousy. These emotions can evolve into achievement-related emotions, particularly in competitive contexts. Epistemic emotions play a vital role in the learning process by maintaining our engagement with subjects or tasks. They manifest when we grapple with intricate problems. When encountering novel challenges, students might experience surprise, confusion, or frustration – a phase not inherently detrimental, yet necessitating assistance for comprehension and transitioning into phases of enthusiasm, curiosity, and inspiration.

Interest, novelty, emotion and meaning are crucial for grabbing people's attention and subsequent learning (Caine, R., Caine, G., McClintic, C., & Klimek, K. 2016): One good way to trigger these emotions in students is using multisensory stimulation, using a wide variety of instructional tools where the student can choose, encourage active participation, and connect the learning with a deeper purpose. When a learner feels good, there is a greater chance of that they will actually learn.

According to (Hodges & Clifton, 2012). Utilizing one's strengths offers numerous advantages to the learner, such as heightened energy and drive, an enhanced sense of purpose, and an increased likelihood of achieving goals. Additionally, it boosts self-assurance and effectiveness. Within traditional educational systems, where students are required to learn the same topics and pass standardized examinations, educators are compelled to concentrate on addressing identified weaknesses related to these standard subjects. Consequently, half of the students will always be below an average, leading to demotivation among them. However, by shifting the focus towards nurturing the strengths of individual learners, educators can potentially cultivate a more positive learning environment, resulting in happier, more motivated, and higher-achieving students.

2.2 How our brain learns

Brain-based learning refers to the utilization of main neurological findings about the human brain as the basis for educational practices and approaches. (Degen 2011)

The following is a brief description of the five most repeated items found in the Brain Based Learning research that was consulted and those the author considered are more relevant and easier to implement in the teacher training program. The five items are: Active vs Passive learning, the power of storytelling, the principle of contiguity, the role of context in knowledge creation, and the flow of the learning experience.

Both the process of learning and the outcomes derived from it are notably more effective when conducted within an active learning setting compared to the conventional learning environment. Traditional learning environments typically involve a unidirectional flow of data and information from the teacher to the students, often within closed classroom settings where the teacher is regarded as the sole source of knowledge. However, numerous studies suggest that incorporating active learning methodologies leads to improved learning outcomes, and the majority of research findings indicate that students exhibit higher levels of engagement and motivation when actively participating in such methodologies.

A common misconception regarding active learning is that it suggests learning through physical movement or self-exploration is superior to passive activities like attentively listening to lectures. However, this notion is inaccurate, as there are instances where physical activities can impede the essential cognitive processing necessary for optimal learning (Clark & Mayer, 2008; Kirschner, Sweller, & Clark, 2006). In fact, if properly stimulated, lectures with good design can encourage active learning.

According to Mayer (2011), active learning involves three main cognitive processes: choosing relevant material to focus on, cognitively organizing that material into useful representations, and fusing those representations with prior knowledge.

Students, just like any other human being, crave for human connection. The craving for human connection is deeply ingrained in our nature, as it provides numerous physical, mental, and emotional well-being benefits. Amidst the various ways to connect with one another, storytelling emerges as a remarkable art form that has withstood the test of time.

Dating back to the third millennium B.C., storytelling is one of the oldest known art forms, encompassing both artistry and scientific elements. Whether captivating an individual or engaging millions, storytelling holds the power to forge profound connections with its audience.

“However, becoming a skilled storyteller requires effort and dedication, as it may not come naturally to everyone. At its core, being a proficient storyteller signifies being a skilled connector. It involves finding common threads in the shared human experience that resonate with others, making them feel heard, acknowledged, and understood. A skilled storyteller possesses the ability to alleviate feelings of isolation, assuring their audience that they are not alone in their experiences” (Miles, 2022, *Better up*, {<https://www.betterup.com/blog/how-to-be-a-good-storyteller>})

The 4Cs Map (The 4Cs model ©2014-2023 Bowperson Publishing and Training) is a model for instructional design and delivery consisting of four sequential steps. This model is grounded on the fundamental principles of how human beings naturally and typically learn, rather than outdated assumptions about human learning. The human brain has inherent learning mechanisms that operate similarly across individuals, regardless of their age, gender, nationality, or culture. The following is a concise overview of these innate learning mechanisms as explained by Sharon Bowman:

- Connections: Learners make connections with what they already know or think they know about the training topic, with what they will learn, with what they want to learn and with each other.
- Concepts: Learners take new information in multisensory ways: hearing, seeing, discussing, writing, reflecting, imagining, participating, and teaching each other.
- Concrete practice: Learners actively practice the new skills, or they participate in an active review of the new knowledge they have learned.
- Conclusions: Learners summarize what they have learned, evaluate it, celebrate it, and create action plans for how they plan to use this new knowledge and skills.

The Law of Contiguity is a keystone of most scientific theories of learning, memory, and knowledge. Broadly speaking, the Law of Contiguity asserts that when events happen closely in time and space, the recurrence of a single event triggers the recollection of the other event. (Lachnit, H. 2003). This principle can be used for shaping learning environments and experiences, making sure that students

recognize evidently when they have constructed new knowledge. The moment a student solves a problem or creates something new is the ideal moment for connecting with the theoretical knowledge he just used.

“The theory of situated cognitions suggests that our understanding is always situated in the context where something has been learned”. Lonka, K. (2018). This discovery presents a significant challenge within traditional classroom and training room setups. When learners are taken out of their familiar contexts and immersed in theoretical and generic situations, the knowledge acquired may not readily translate to practical application in real-life scenarios. This highlights a major advantage of the Phenomenon-based learning approach, which enables students to engage with relevant, everyday issues and situations, fostering a more meaningful and applicable learning experience.

A proficient educator faces the challenge of comprehending the diverse learning experiences that each learner undergoes. As individuals progress through their educational journey, they may not be at the same stage simultaneously. While the design of the learning experience can strive to guide them in a unified direction, the educator must remain vigilant in identifying those who may be encountering anxiety or boredom and skilfully guide them back into the flow of learning. By carefully observing and understanding the students' varying needs and progress, the educator can ensure a more inclusive and engaging learning environment that nurtures each student's development effectively.

An excellent instructional model for this purpose was created by Mihaly Csikszentmihalyi and it is shown in figure 2.

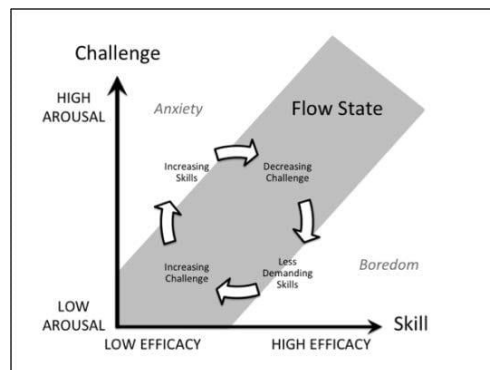


Figure 2. Summary of Flow: The Psychology of Optimal Experience by Mihaly Csikszentmihalyi

2.3 Phenomenon based Learning. An application of Competence Based Learning

A definition of Competence-Based Learning can be concluded from (Symeonidis, Vasileios & Schwarz, Johanna. 2016) as an educational method that assesses students' proficiency by observing their exhibited knowledge, skills, attitudes, and behaviors. Phenomenon-Based Learning can be seen as a cross-disciplinary approach, centered on inquiry, and resolving real-world problems. It incorporates real-life occurrences into a structured educational setting, fostering collaborative problem-solving and the exploration of students' interests and curiosities. Phenomenon-Based Learning is a multidisciplinary approach that focuses on questioning and problem-solving real-life issues. It is paramount that it integrates these real-life phenomena into a structured pedagogical environment, encouraging group-based problem-solving and exploration of students' interests and curiosities.

The manifestation of knowledge, attitudes, values, skills, and behaviors within the context of Phenomenon-based Learning (PhBL) holds greater significance and relevance due to its direct association with real-life issues. By tackling authentic and practical problems, PhBL engages learners in a more meaningful and impactful way, allowing them to apply their learning to actual situations. The appeal of PhBL is further heightened by its capacity to address trending and controversial topics, enabling the creation of dynamic and captivating learning experiences that resonate with students. Moreover, PhBL offers opportunities to integrate various subjects and themes, drawing from techniques utilized in problem-based learning and project-based learning, which enhances the interdisciplinary nature of the approach and fosters a more comprehensive and interconnected understanding of diverse concepts and issues. Wolff (2022) argues that "Phenomenon-based learning (PhBL) is an indistinct concept with many roots. Its unclear principles are interpreted and implemented in many ways. It is neither a theory nor a method, but it is called an approach".

Symeonidis, Vasileios & Schwarz, Johanna (2016) also provide us with what they consider the five dimensions that PhBL must consider: holistic, authentic, contextual, problem-based, and learning process. The following is a way to use these five dimensions for building engaging and meaningful learning experiences.

- Holistic: The phenomena can be studied from different points of view, utilizing practices and knowledge from diverse themes. The involvement of teachers with different subject focuses and expertise is paramount, and engaging the community is preferred.
- Authentic: It employs methods, tools, and materials that are or can be used in real-world situations. The approach is developed as closely as possible to a real environment, rather than within a traditional classroom.
- Contextual: The phenomenon is relevant to students' lives and holds significance within the community. Both students and teachers must perceive it as worthwhile to study and address.
- Problem-based: Students formulate their own questions, engage in team interactions with their peers and teachers, and collaborate with other members of their communities to define and follow action plans for problem-solving (usually guided by the teacher).
- Constructive Learning Process: As they collaboratively work and progress in their efforts to solve the problems, students construct knowledge. The teacher must be observant and attentive to recognize this progression and make it evident to the students.

Considering these definitions, the phenomena to be studied can rarely be predefined in the long term. They stay vague and ambiguous, and they will have a different set of interpretations by different groups of students and in different times.

2.4 Game based learning as an educational technique.

It has been almost 12 years since the hype of gamification started. In the Gartner hype cycle -a graphic representation of the maturity and adoption of technologies and applications according to Gartner consulting, it is expected to start wide adoption after it has gone down the curve of disillusionment.

(Simoes) 2015 started analysing its behaviour. The author has complemented his graph in figure 3 with data from 2016 from Gartner and data from 2018 according to Webworks.

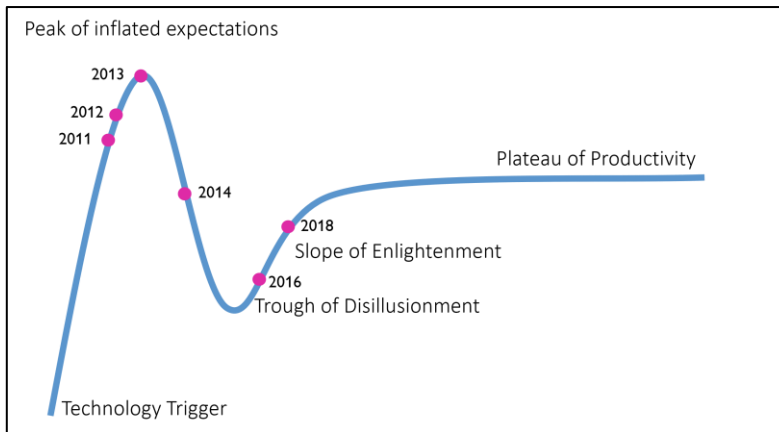


Figure 3. Gartner hype cycle for gamification. Gartner, (Simoes) 2015 and the author

Apparently, this innovation is in the plateau of productivity and the broad estimate of over two thousand gamified learning apps and services in the google play store demonstrates this.

An analysis on the topic's keywords will help us understand the differences or relations between gamification and game-based learning.

According to (Deterding et al. (2011), gamification is the use of game design elements in non-game contexts. Considering this definition, and summarizing from (Dicheva, Agre, & Angelova, 2015): The "gamification" approach proposes the utilization of game thinking and design elements to enhance learners' engagement and motivation. It emphasizes providing immediate or shortened feedback, opposite to the current traditional educational practices of set examination periods and necessitates careful pedagogical integration to be effective.

(Dicheva, Agre, & Angelova, 2015) Created a comprehensive list of educational gamification design principles with some mechanics associated to them. This list includes broadly known elements in games like goals, challenges and quests, customization, quick onboarding, time restriction, visible progress and status, immediate feedback, competition, and cooperation, accessing and unlocking new content, freedom of choice and freedom to fail, adopting new identities and submerging in stories.

The possible pitfall when employing these design principles is the risk of lacking pedagogical validity and justification for incorporating gamification techniques. This is where the concept of Game-based learning becomes relevant. To avoid the mere inclusion of game elements solely for their amusement or popularity, educators must recognize that gamification, within an educational context, falls under the broader umbrella of game-based learning. Gamification constitutes a valuable and potent technique,

but its effectiveness is contingent on being integrated with learning objectives and broader educational dynamics.

It is crucial to note that despite more than a decade of implementing these techniques, empirical data to demonstrate their effectiveness in enhancing learning outcomes in educational settings is still insufficient. While gamification has been shown to improve attention and motivation, conclusive evidence regarding its impact on learning achievement is yet to be established. Nevertheless, if approached as a technique within the broader scope of social-emotional learning and integrated with the principles of brain-based learning, the advantages of gamification in learning contexts can be effectively harnessed.

2.5 Maker learning as an educational technique.

Maker learning builds on the work of educational theorists like Jean Piaget (constructivism) and Seymour Papert (constructionism). Maker-centered learning develops that awareness through interactive, open-ended, student-driven, multi-disciplinary experiences that allow for the time and space needed to develop diverse skills, knowledge, and ways of thinking. In maker-centered learning environments, students imagine, design, and create projects that align the content of learning with hands-on application. Maker education isn't about the stuff we can make, it's about the connections, community and the meaning we can make. {<https://makered.org/>}

Although the maker learning and maker communities concepts are relatively new, in their essay, Erica Rosenfold and Kimberly (Sheridan Halverson, Erica & Sheridan, Kimberly. 2014) recall that specific tools and programs have been used in both formal and informal learning spaces from the Logo programming language to using LEGO Mindstorms kits, the Scratch programming language, and the Computer Clubhouse programs. Additionally, educational approaches such as project-based science and problem-based learning emphasize learning through making.

There is a strong relationship between the maker learning, game-based learning and two specific items of social-emotional learning and brain-based learning: the flow of the experience and role of emotions. (Dougherty, 2013) argues that students actively pursue enriching and engaging educational encounters, discerning between authentic learning and conventional schooling. Constricted by inflexible academic structures, they explore avenues of self-expression beyond formal education. This divide curtails

inventive thinking and imaginative capacity, with genuine learning unfolding during informal activities, rather than within the confines of high-pressure grading traditional academic systems. The emphasis on theoretical thinking leaves students unsatisfied and the traditional system falls short in nurturing the innovative thinkers and proactive contributors essential for societal progress.

There are three fundamental elements that maker learning promotes in students and can be evidenced: agency, social scaffolding, and design process. (Grace, Lin, Nigam and Nori, 2021)

Agency pertains to the ability of the involved in the maker environment to make choices that influence and mold their experience, while simultaneously recognizing their possession of such capability.

Social scaffolding encompasses the capability to provide assistance to and receive assistance from others.

The design process is comprehended as learners' strategy for addressing difficulties, encompassing several iterative stages such as ideation, creating prototypes, and testing.

2.6 Service Design Principles.

The actual research performed for this thesis follows the service design principles. From This is service design doing. Stickdorn, Hormess, Lawrence, Schneider O'Reilly Media, Inc (2018.) "Service design is a problem-solving discipline that begins by investigating user needs through qualitative research. It emphasizes rapid experimentation and prototyping to test solutions, leading to iterative development. This approach ensures projects are grounded in reality, based on research, and testing rather than outdated authority or opinion."

3 METHODOLOGY

This research utilized mixed methods, with a primary emphasis on qualitative approaches. The research methodology was integrated into the service design process, as depicted in the following graph.

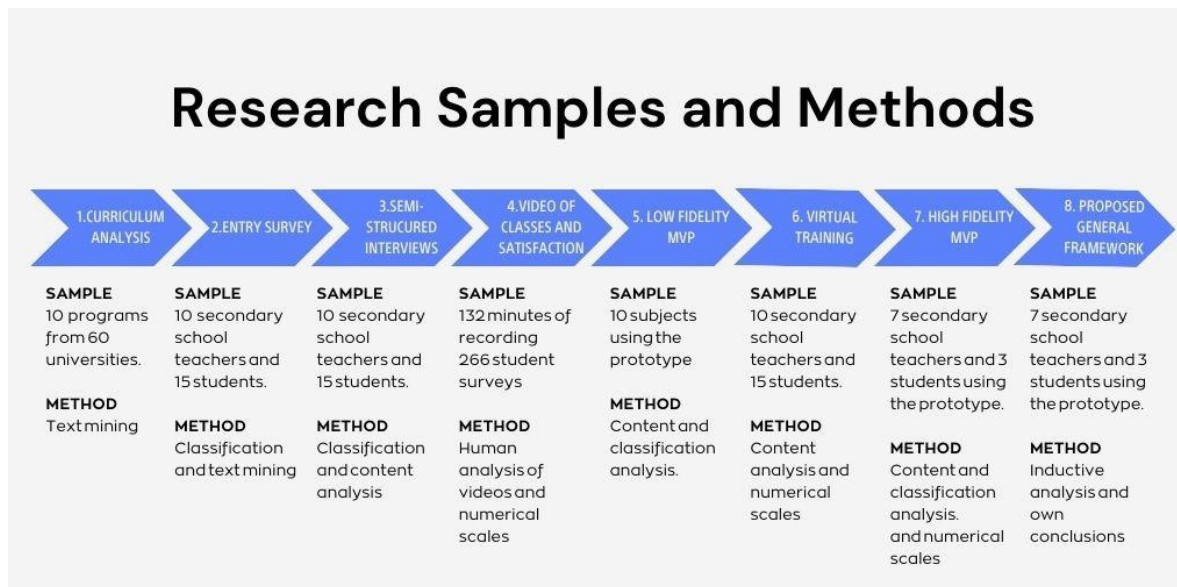


Figure 4. Summary of research Samples and Methods by the author

The selection of these methods and the test subject group size were guided by the aim of working with a highly dedicated and experienced group. This facilitated the rapid implementation of prototypes, easy access to pertinent data, prompt feedback, and iterative refinement.

Part 1. Curriculum analysis. Ten teaching bachelor's degree programs were selected from sixty Colombian universities that were certified by the Ministry of Education for their high-quality bachelor's degree programs. The content of the curricula was analysed to identify any potential gaps in the implementation of the learning trends and techniques investigated in this thesis. Simple text mining techniques, such as information extraction and summarization, were used for this purpose.

Part 2. Entry survey. A written entry survey conducted with two test groups. The first group, referred to as the TTG (teachers test group), comprised ten secondary school teachers (nine specializing in science and one in social sciences), while the second group, referred to as the STG (students test group), comprised fifteen students (six freshmen and nine in their sixth semester) studying for a bachelor's degree in natural sciences teaching at Universidad de La Sabana. The TTG group consisted of teachers who volunteered to participate in a training program aimed at improving their skills in the classroom and incorporating astronomy into their teaching. The STG group participated as part of the practical implementation of the learning theories.

The entry survey for the TTG group consisted of ten questions: three closed general profile questions, three closed questions to identify where they teach, their age, and their subject of specialty, and three open questions to inquire about their most memorable learning experiences from their time as bachelor's degree students and recent learning experiences. The entry survey for the STG group consisted of seven questions: three closed general profile questions, and four open questions to inquire about their most memorable learning experiences from high school and their motivation for becoming teachers. The entry survey was performed to have an initial understanding about the test subjects and start connecting them with the topic and the researcher. Simple classification techniques were used to process the closed questions, while information retrieval and categorization text mining techniques were used to process the open-ended questions.

Part 3. In-depth semi-structured group interviews. During these interviews the familiarity of the teachers with the trends and techniques of the research was discussed. As a result of these interviews, a scale of knowledge and experience of the teachers with the topics explored in the theoretical background was created, and a first round of expectations for the training program was gathered. Content analysis and classification techniques were used for this part of the study.

Part four. Video of classes and satisfaction survey. The TTG group was asked to record a fragment of their class and conduct a satisfaction with learning survey among the students after the class. The aim of this phase of the research was to observe the implementation of a sample of teaching methods employed by the TTG and assess their impact on the students. The processing of this video, combined with the satisfaction survey answers, aimed to identify active learning and social-emotional outcomes

studied in this thesis. Human analysis of the video was conducted to assess the degree of active learning present in the classroom fragment. The analysis involved categorizing the level of activity into four distinct categories: null, indicating unidirectional teaching; low activity, representing conversations between the teacher and students; medium activity, signifying extensive conversations among students and with the teacher; and high activity, denoting instances of physical movement during the learning process. At the end a simple numerical satisfaction scale was used to analyse the content of the survey.

Part five. The low fidelity MVP (minimum viable product) of the training program. It consisted of a guide for running an active learning activity, following the principles of PhenoBL and in collaboration with a teacher of a complementary subject. For example, science teachers had to find a social sciences, art, or physical education colleague to coordinate and execute the activity, and vice versa for the social science teacher. The guide provided the description of the phenomenon to be studied (Flat earth theory), the necessary interdisciplinarity to address this phenomenon, the definitions of phenomenon-based learning, and the pedagogic methodology to be used (the 4C® model). The guide then described the broad concept to be applied (the scientific method) and suggested three experiments (the Coriolis effect, Magallanes, and Elcano's first voyage around the world, and the simulation of night skies from different parts of the earth). Finally, the guide included suggestions on how to wrap up and evaluate the activity.

The TTG conducted their activities with their students and fellow teachers at various times and durations based on their class arrangements and agreements with their colleagues during a three-week period from April 10th to April 26th, 2023. After completing their activities, the TTG received a questionnaire of nine open-ended questions. The first three questions were aimed at exploring the overall experience, the next two inquired about the guide, the following two were about the topic, and the last two were about the experience of the students. The participants provided their responses in writing and voice messages, and the data collected was analysed using simple text and audio mining techniques. This phase of the research yielded essential data, culminating in the finalization of the initial low-resolution Minimum Viable Product (MVP) for the training program. Subsequently, the findings served as the foundation for the development of the high-resolution MVP design.

Part 6. Virtual training for the test groups. It was delivered in three sessions of one and a half hours each, which took place on May 23rd, 25th and 30th 2023, This training program used the pedagogic methodology of the 4C ® model and covered the five topics from the theoretical framework of this thesis. At the end of the training, each participant was required to prepare a science dissemination activity of their choice that they would present to the rest of the group during the practical in-person session. The formal measurement performed at the end of the training consisted of a mixed quantitative and qualitative measurement. The first measurement was a numeric satisfaction survey with two scales: new learning acquired and delivery method. The second was an open-ended question about the overall experience of the training. After this, more content and format were incorporated to the high-resolution MVP.

Part 7. The high-definition MVP (minimum viable product). Both test groups embarked on a trip to Orión Campamento Interstellar, an astronomical observation and scientific dissemination camp situated in the Tatacoa desert of Huila, Colombia. They stayed at the camp on June 3rd and 4th, immersing themselves in a scientific learning environment. Each test subject was assigned a random thirty-minute time slot during which they conducted their scientific dissemination activity to their peers and getting immediate feedback. Each teacher used simple materials for their activity that can be found in standard classroom setups. On the night of June 3rd, all test subjects participated in two additional scientific dissemination activities and engaged in night sky observation. These activities were organized and facilitated by the lead scientific disseminator of the camp and the author of this thesis.

Upon the conclusion of the weekend, the participants engaged in discussions revolving around four main topics: the methodology employed in the training program, the relevance of the selected topics, the challenges and opportunities associated with integrating these activities into the classroom as a fundamental part of the academic year, and the ideal approach for receiving both the necessary training and guidance tools for seamless integration. These discussions were conducted in a learning café format, providing an interactive and collaborative space for exchanging ideas and insights. To gain a more comprehensive understanding of the participants' perspectives, the author facilitated an in-depth group interview as the culminating activity. The aim was to gather valuable feedback and reflections on the training program and its potential implementation in educational settings.

Part 8. Proposed general framework. The final inductive analysis of the seven parts of this research has resulted in a proposed general framework for implementing this type of teacher training program on a larger scale. The analysis also identified the expected benefits for both students and teachers, as well as the potential challenges and suggested solutions for overcoming them. This framework provides a roadmap for designing and implementing effective teacher training programs that promote active learning and scientific dissemination in the classroom.

4 FINDINGS

The findings to be presented follow the process of service design. The following figure consolidates the research methodology within this process.

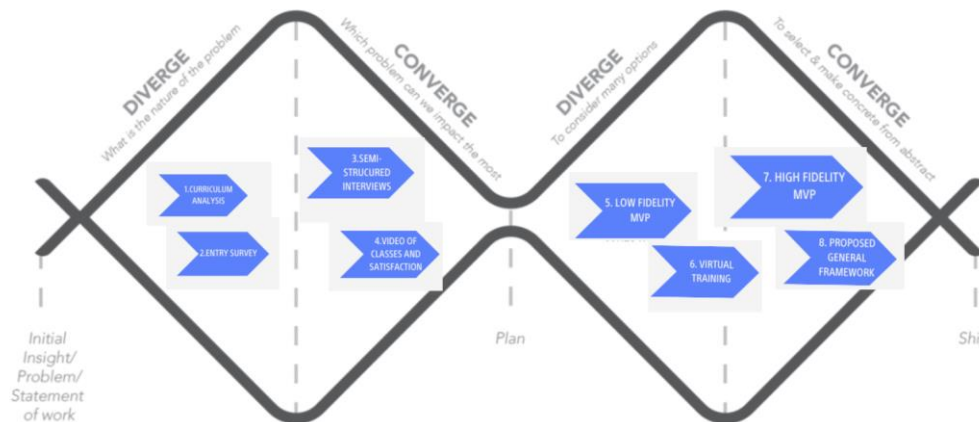


Figure 5 Consolidation of research methods in the service design process made by author using the Double Diamond Model (British design council 2004)

4.1 Understanding the context – What do they teach our teachers?

In Colombia, there is a wide range of options for individuals pursuing a bachelor's degree in education, with more than 90 universities offering over 450 programs in this field. Out of these universities, 60 have been certified by the Ministry of Education for their high-quality bachelor's degree programs. These programs cover various specialization subjects, encompassing different learning stages from preschool to secondary education, as well as education focused on minority groups. The duration of these programs typically ranges from four to five years.

Between the years 2015 and 2020, a significant number of students, totalling over 820,000, enrolled in these education programs. However, upon examining a small sample of ten programs that primarily focus on science teaching, it was found that only an average of 11% of the curriculum explicitly includes hands-on practical experience. Furthermore, the portion of the program dedicated to pedagogy and

didactics, without explicit practical application, does not exceed 30%. Consequently, approximately 60% of the program is dedicated to theoretical passive learning, equivalent to approximately 2.7 years of study. This implies that between 2015 and 2020, aspiring teachers collectively spent a substantial amount of time, totalling at least 2,214,000 years, passively consuming information in traditional classroom setups. To provide some context, 2,2 million years ago, our ancestors were still in the Stone Age.

These findings shed light on the need to critically assess and reconsider the educational approach within these programs. A significant emphasis on passive theoretical learning without corresponding practical application raises questions about the effectiveness and relevance of the education received by aspiring teachers. It highlights the importance of incorporating more hands-on practice and active pedagogical methodologies to better prepare future educators for the dynamic and interactive nature of the teaching profession.

4.2 Understanding the person – Who are our teachers?

Two test groups participated in this research. The first group, referred to as the TTG (teachers test group), comprised ten secondary school teachers (nine specializing in science and one in social sciences), while the second group, referred to as the STG (students test group), comprised fifteen students (six freshmen and nine in their sixth semester) studying for a bachelor's degree in natural sciences teaching at Universidad de La Sabana.

4.2.1 TTG entry survey

Descriptive traits of TTG:

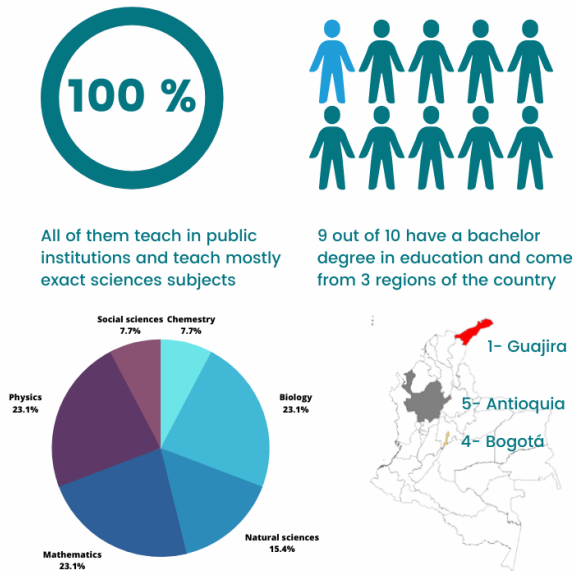


Figure 6. Infographic describing the descriptive traits of the TTG.

Their learning experiences.

Original question 1: What percentage of your career was theoretical/passive (traditional classroom format with one-way information from the teacher to the students) and what percentage was practical/active (where you put into practice what you learned in any way)

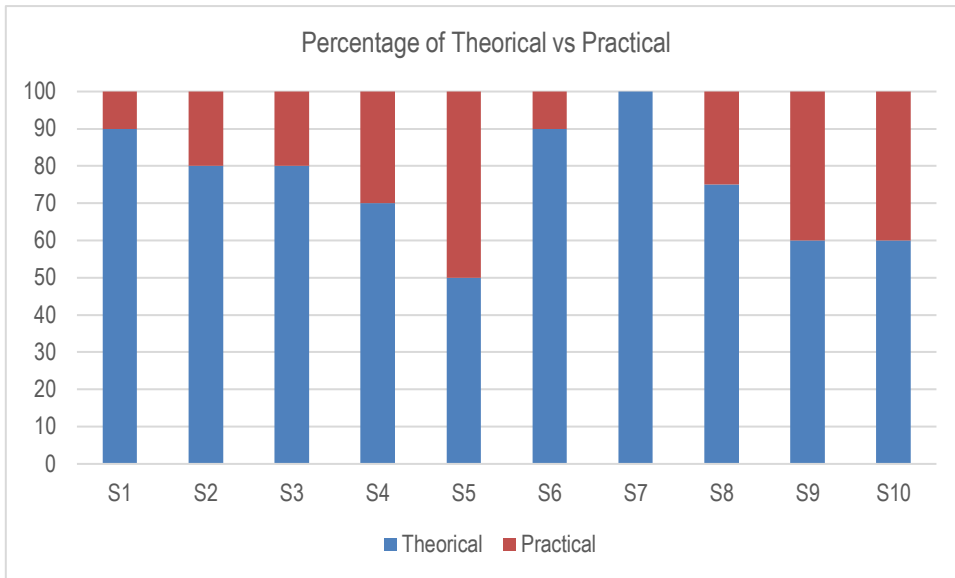


Figure 7. Theoretical vs practical component during TTG bachelor's degree

An average of 75% of the bachelor's degrees were delivered in a passive/theoretical format, with only one teacher experiencing a 50-50 approach. Two teachers mentioned special cases with laboratory practice, but this did not apply to the majority of their studies.

Original question 2: What was your undergraduate subject or project that you liked the most and why? Apart from the subjects as such, here is an analysis of the underlying components of those learning experiences.

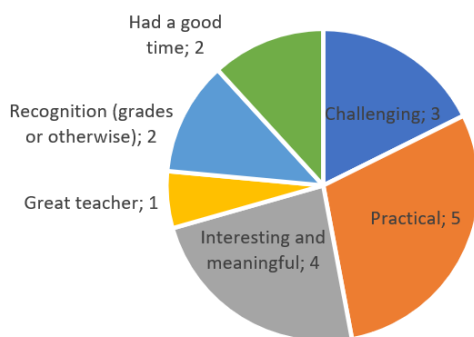


Figure 8. TTG reasons of the best learning experience during bachelor's degree

The interesting and meaningful experiences reported by the TTG are closely related to the role of emotions in attention and interest, which are studied under the subtitle of Emotions and Learning in the

theoretical background of this thesis. The practical component mentioned by the TTG directly relates to Phenomenon-Based Learning (PhenoBL), and the challenging characteristic is linked to the flow of the learning experience, as discussed under the How are Brains Learn subtitle.

Original question 3: What has been your most significant learning experience in recent years and why? (where you have felt that you learned a lot and were inspired by that learning) It can be during formal, informal education or any other opportunity.

In addition to the topics themselves, this analysis examines the underlying components of those learning experiences and compares them to the components present in the teachers' bachelor's and later learning experiences.

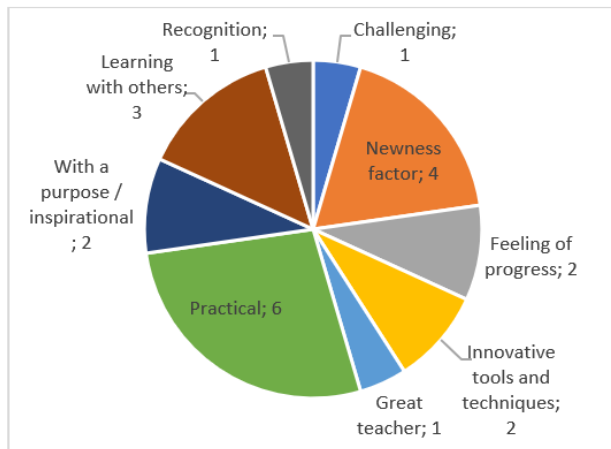


Figure 9. TGT reasons of the best learning experience in recent years.

Apart from the traits discussed under Emotions and Learning, PhenoBL learning, and How are Brains Learn, the innovative tools and techniques of Game-Based Learning were also mentioned as components of the recent learning experiences.

The practical nature of the learning experiences was the most frequently reported aspect in both bachelors and the most memorable recent learning experiences.

The interesting and meaningful aspects mentioned in response to the question about their favourite undergraduate subject had similar descriptions to the novelty factor mentioned in response to the question about their latest, most meaningful learning experience.

Collaborative learning, having a sense of purpose, and feeling inspired were reported in the recent learning experiences of the teachers, but not in their bachelor's studies.

Recognition and grading were generally less significant compared to the other factors that made the learning experiences memorable.

4.2.2 STG entry survey

Descriptive traits of STG:

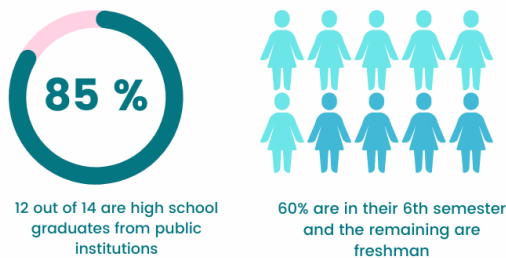


Figure 10. Infographic describing the descriptive traits of the STG.

Their learning experiences.

Original question 1: What percentage of your study was theoretical/passive (traditional classroom format with unidirectional information from the teacher to the students) and what percentage was practical/active (where you put into practice what you learned in any way)

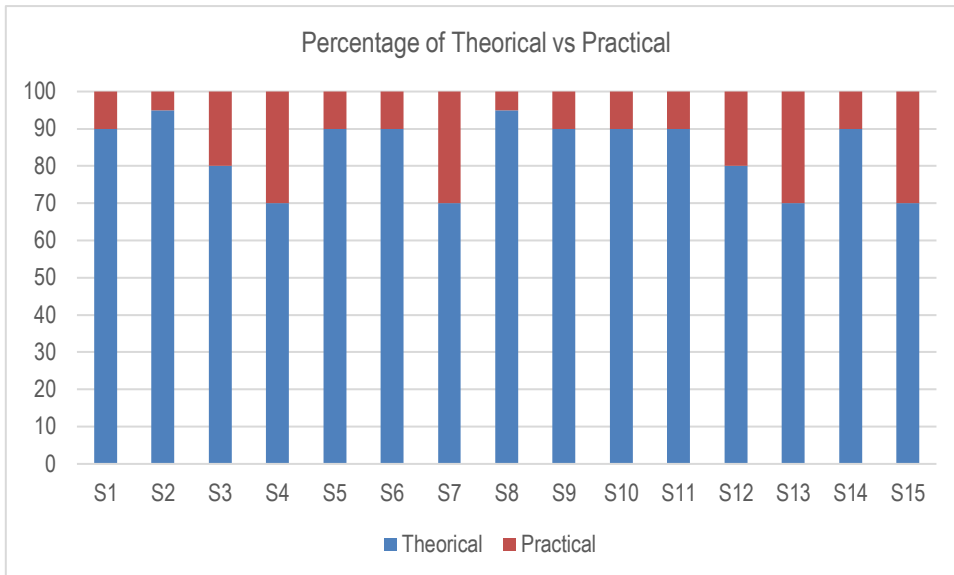


Figure 11. Theoretical vs practical component during STG high school studies.

An average of 84% of the high school learning experience was delivered in a passive/theoretical format, with the highest proportion of practical experience reported by only four students being 30%. Most students mentioned remembering sitting in a traditional lecture-style classroom with little to no opportunity to discuss or actively participate in class.

Original question 2: What was the subject or high school project that you liked the most and why? Feel free to answer as broadly as you see fit.

Apart from the topics as such, here is an analysis of the underlying components of those learning experiences.

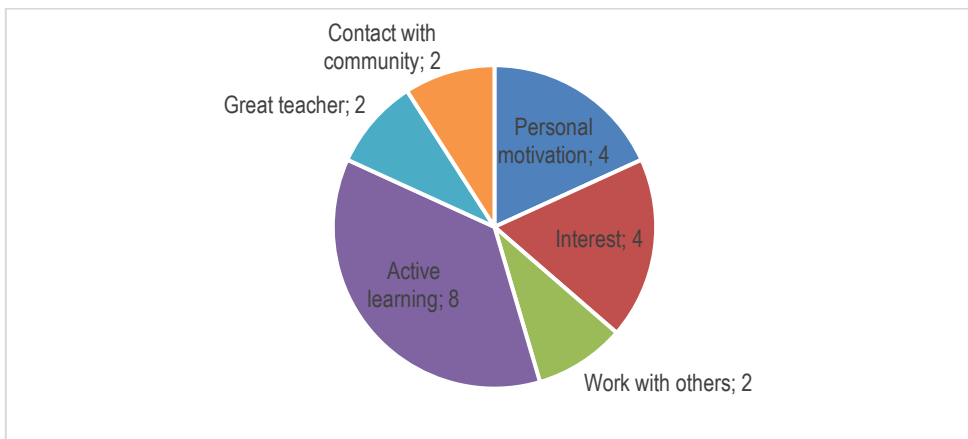


Figure 12. STG reasons of the best learning experience during high school

Although only 16% (on average) of the high school learning experience was delivered with active learning methodologies, this aspect was the most memorable for the students.

The interest and personal motivation of the students are related to the topic of epistemic emotions, which trigger intrinsic motivation, as discussed under subtitle 2.1.

Original question 3: What has been your most significant learning experience in recent years? (where you have felt that you learned a lot and were inspired by that learning) It can be at your school or any other opportunity. Feel free to answer as broadly as you see fit.

This analysis examines the underlying components of those learning experiences and compares them to the components present in the students' high school experiences.



Figure 13. STG reasons of the best learning experience in recent years.

The same three components (active learning, interest, and personal motivation) are present in their most impactful recent learning experiences and almost with the same weight.

The practical attribute mentioned in their recent learning experiences is closely related to active learning, with the addition of being applied to a specific project or community and heavily involving working with others and in close contact with a community.

4.3 Understanding the need – Interviewing our teachers

Most of the interview session centred around an in-depth exploration of the theoretical background pertaining to the topics that the teachers were already familiar with. The objective was to gauge the extent to which these theoretical concepts were implemented in their respective classrooms. Based on the analysis of the interview data, the findings can be categorized into three distinct groups: concepts that were well-known to the teachers but not actively practiced, concepts that were somewhat practiced but not well-known or fully understood, and concepts that were neither known nor practiced by the teachers. This categorization serves to provide a comprehensive overview of the teachers' level of familiarity and implementation of the discussed theoretical concepts of this thesis in their instructional practices.

4.3.1 Well-known but not practiced topics.

Active vs passive learning

The teachers are aware of the differences between active and passive learning and the potential benefits of active learning, yet they do not consistently apply it in their teaching. The following table aims to explore the reasons behind this inconsistency.

Table 2. Categorization of causes for not applying active learning methodologies.

The teachers	Teachers are accustomed to delivering classes in a certain way and may become entrenched in their routines. They fear trying new methods and perceive a loss of control, while lacking knowledge of how to strike a good balance between passive and active learning.
The learning environments	Some schools view active learning as disruptive, messy, and noisy, and perceive it as a hindrance to other classes and teachers. Physical spaces are not designed to facilitate active learning activities.
The students	Students are accustomed to traditional passive setups and following instructions from the teacher, therefore they feel lost and uncomfortable when they

	are given the responsibility of their own learning. This also inhibits the teachers.
The system	Teachers are often pressured to cover a large amount of content in a short amount of time, which is often more efficiently achieved through traditional lecture-style teaching. Due to time constraints, teachers may not have the opportunity to experiment and put new concepts into practice.

Emotions and Learning

The majority of the participants in this study reported having recent experience with social-emotional learning; however, they noted that this aspect is not explicitly addressed in their bachelor's or master's programs in education. The focus of their teacher education programs primarily revolves around vertical subject knowledge, particularly in the exact sciences. Nonetheless, the participants acknowledged the growing significance of social-emotional learning, particularly in the aftermath of the pandemic, as they observed an increase in student aggression and challenges in fostering healthy relationships.

The participants also recognized the need for better management of their own emotions, as they believed that incorporating social-emotional learning into their instructional practices requires personal emotional regulation. They observed that the current education system prioritizes content delivery, perceiving social-emotional learning as complementary rather than central to student formation. Consequently, there is limited time allocated and minimal emphasis placed on incorporating social-emotional learning experiences within teaching, with teachers directed to focus solely on their subject areas.

Upon reflection, the participants concluded that the role of emotions and learning can be effectively integrated into everyday teaching if educators are consciously aware of its importance and equipped with concrete tools to do so. They highlighted the necessity for explicit training and support in implementing social-emotional learning strategies in the classroom to facilitate the holistic development of students.

4.3.2 Somewhat practiced but not well-known topics.

Game based learning

Only a limited number of teachers, specifically two, reported actively incorporating game-based learning techniques in their classroom practices. One teacher, who worked with high school students belonging to a research seedbed, encouraged them to design board games aimed at teaching younger students various science concepts. The other teacher utilized modified board games, including the recent introduction of Sea Battle, to reinforce understanding of the periodic table among their students.

4.3.3 Not known and not practiced topics.

How are Brains Learn.

Among the teachers in the TTG, it was found that only a single teacher possessed knowledge regarding the latest advancements in neuro-learning. This particular teacher was a member of an independent research seedbed consisting of educators actively seeking innovative educational practices. In contrast, the remaining teachers indicated a lack of engagement in researching or implementing new techniques or methodologies based on the understanding of how the brain learns during their instructional delivery.

These examples of game-based learning experiences provided by the two teachers sparked inspiration among their colleagues, generating interest in implementing similar activities within their own classrooms. Additionally, the group recognized the positive impact of game-based learning on student engagement and creativity. Consequently, these experiences served as valuable insights, reinforcing the potential benefits and effectiveness of integrating game-based learning techniques into their teaching practices.

Phenomenon based learning.

Two teachers within the group acknowledged the relationship between Phenomenon-Based Learning (PhenoBL) and other instructional approaches such as problem-based learning and project-based learning. However, it was noted that only one teacher had implemented a school farm project in collaboration with other teachers. Despite this, the teacher acknowledged that the project did not encompass the analysis of a specific phenomenon as emphasized in PhenoBL.

Maker learning

Maker learning emerged as a relatively unfamiliar concept among the group of teachers, as none of them reported having applied it in their instructional practice or being aware of any colleagues who had. The teachers expressed limited knowledge or experience with maker learning, indicating a need for further exploration and professional development in this area.

4.4 Making the need evident – Seeing our teachers at work

The teachers were requested to capture a segment of their regular teaching practice during a class session, resulting in a total of eight class recordings with a combined duration of 131 minutes and 53 seconds. These recordings were subsequently categorized into four distinct types based on the level of student engagement and activity observed: passive (indicating minimal or no student involvement), semi-passive (involving teacher-student conversation in a traditional classroom style), semi-active (involving student and teacher interaction in a traditional classroom style), and active (involving physical activity and active student participation).

Table 3. Time in seconds spent by the participants of TTG by category.

	Teacher 1	Teacher 2	Teacher 3	Teacher 4	Teacher 5	Teacher 6	Teacher 7	Teacher 8	TOTAL	Percentage
Passive	758	633	147	43	0	724	221	94	2.620	33%
Semi-passive	139	139	376	196	0	181	679	465	2.175	27%
Semi-active	0	107	0	0	0	15	0	0	122	2%
Active	0	21	134	839	1301	0	0	698	2.993	38%

Table 4. Percentage of time spent by the participants of TTG by category.

	Teacher 1	Teacher 2	Teacher 3	Teacher 4	Teacher 5	Teacher 6	Teacher 7	Teacher 8	TOTAL	Percentage
Passive	85%	70%	22%	4%	0%	79%	25%	7%	2.620	33%
Semi-passive	15%	15%	57%	18%	0%	20%	75%	37%	2.175	27%
Semi-active	0%	12%	0%	0%	0%	2%	0%	0%	122	2%
Active	0%	2%	20%	78%	100%	0%	0%	56%	2.993	38%

Test subject five data is an outlier. This is the data without its participation.

Table 5. Time in seconds spent by the subjects of TTG by category without test subject five.

	Teacher 1	Teacher 2	Teacher 3	Teacher 4	Teacher 5	Teacher 6	Teacher 7	Teacher 8	TOTAL	Percentage
Passive	758	633	147	43	0	724	221	94	2.620	40%
Semi-passive	139	139	376	196	0	181	679	465	2.175	33%
Semi-active	0	107	0	0	0	15	0	0	122	2%
Active	0	21	134	839	0	0	0	698	1.692	26%

Significant variations were observed in the time allocation of different teaching approaches among the participating teachers. While the overall average of approximately 73% for passive or semi-passive teaching configurations does not indicate a pronounced general pattern, it is noteworthy that three teachers displayed a strong inclination towards semi-active or active learning techniques, and four teachers utilized at least three different setups. It is important to consider that the analyzed video fragments were relatively short, lasting only 15 minutes each. However, adhering to Sharon Bowman's 4Cs model (©2014-2023 Bowperson Publishing and Training), which suggests that our attention span diminishes after ten minutes of passive learning, teachers 3, 4, and 8 demonstrated a commendable balance between active and passive learning strategies.

At the conclusion of the class, the teachers were asked to conduct a sentiment evaluation of the students. They anonymously rated their feelings during the class using an emoji scale.

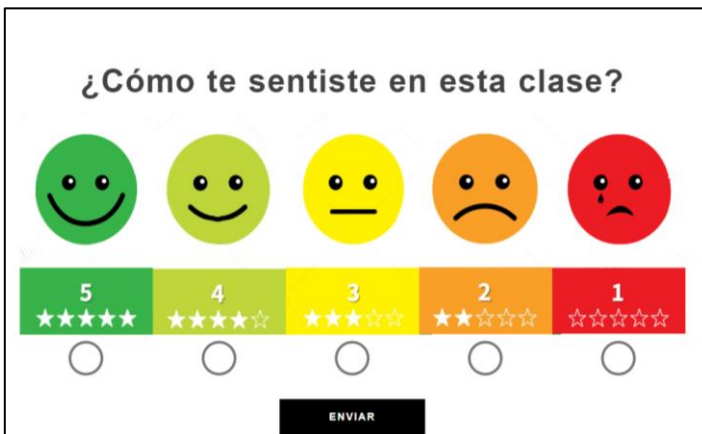


Figure 14. Emoji scale used by the students after the class which had a fragment recorded.

A total of 266 students graded their sentiment after the class. The following is the summary of the data gathered.

Table 6. Emoji scale sentiment results after the class

	Teacher 1	Teacher 2	Teacher 3	Teacher 4	Teacher 5	Teacher 6	Teacher 7	Teacher 8	TOTAL	Percentage
5 😄	40	23	8	21	55	42	13	33	235	74%
4 😊	7	5	11	5	11	3	5	14	61	19%
3 😐	0	0	1	3	7	1	1	3	16	5%
2 😞	0	1	1	1	1	0	0	0	4	1%
1 😡	0	0	0	0	0	0	0	0	0	0%

Table 7. Individual percentage of sentiment grading for each teacher

	Teacher 1	Teacher 2	Teacher 3	Teacher 4	Teacher 5	Teacher 6	Teacher 7	Teacher 8	TOTAL	Percentage
5 😄	85%	79%	38%	70%	74%	91%	68%	66%	235	74%
4 😊	15%	17%	52%	17%	15%	7%	26%	28%	61	19%
3 😐	0%	0%	5%	10%	9%	2%	5%	6%	16	5%
2 😞	0%	3%	5%	3%	1%	0%	0%	0%	4	1%
1 😡	0%	0%	0%	0%	0%	0%	0%	0%	0	0%

94% of students rated their positive feelings after the class as very high or high.

Subject three had the highest proportion of students rating their feelings as number four, while subject six had the highest proportion of students rating their feelings as number five.

No clear correlation can be identified between the positive feelings after the class and the active-passive configuration used in the classroom.

4.5 Defining the problem and a possible solution – The first low resolution MVP

Teachers demonstrate a strong desire to incorporate engaging, innovative, and pedagogically proven approaches into their teaching practices. However, they face challenges in terms of time constraints, lack of concrete implementation strategies for non-traditional approaches, and uncertainty regarding how to measure the success of these methods while aligning them with curriculum and evaluation standards mandated by schools and the education system.

To address this issue, the test teacher group (TTG) was provided with a comprehensive guide that facilitates the implementation of theoretical concepts outlined in this thesis. An activity guideline was specifically developed and made available to both test groups. The guide offers practical recommendations for integrating these innovative approaches into classroom instruction. The guide can be consulted in [this link](#). Furthermore, a video was created to accompany the guide, providing a detailed explanation of its content, and suggesting effective ways to utilize it. The video, available in Spanish, can be accessed through [this link](#).

By offering this guide and supporting video, the aim is to empower teachers with the necessary tools and resources to successfully incorporate innovative teaching approaches into their classrooms. This comprehensive support package serves as a practical roadmap for teachers, helping them overcome implementation challenges and ensuring alignment with curriculum requirements and evaluation standards.

The guide begins by addressing the concept of flat Earth belief, highlighting the need to create experiments and conversations so the students increase their critical thinking and communication skills while practicing science concepts. The general premises of the project emphasize the interdisciplinary nature of astronomy education and the importance of phenomenon-based learning. This approach aims to bring real-world phenomena into the structured learning environment, making the content more relevant and engaging for students.

The guide then delves into the pedagogical methodology, introducing the 4C model (Connections, Concepts, Concrete Practice, and Conclusions) developed by Sharon Bowman. The model aligns with how humans naturally learn, encouraging meaningful connections with the environment and personal experiences. It emphasizes the importance of connecting prior knowledge with new information, practicing, and applying concepts, and drawing conclusions. The model promotes active learning and encourages students to engage in multisensory experiences to enhance their understanding.

Furthermore, the guide provides guidance on making connections in the classroom and offers suggestions for concept exploration and experiments related to astronomy. It suggests three potential experiments: the Coriolis effect, the journeys of Magellan and Elcano, and simulating night skies from different locations on Earth. These activities aim to foster students' scientific thinking, encourage hands-on experimentation, and enhance their understanding of astronomical concepts. The guide concludes with a section on evaluation, highlighting the assessment of transversal skills such as communication, creativity, intercultural understanding, research, problem-solving, data interpretation, and scientific relationships.

4.6 Starting to solve the problem – Using the prototype.

After completing the activities and documenting them through videos and photos, the teachers were invited to provide feedback by answering a questionnaire comprising nine questions. The following are the significant findings from their experiences, which can be instrumental in enhancing these types of activities and enabling the author to identify the essential components of the teacher training program.

General Experience

a) Planning of the Activity:

Eight out of the nine teachers in the TTG collaborated with at least one and up to four colleagues during the planning phase. They reached a consensus on the flow, pedagogy, subject-specific content, and duration of the activity.

Seven teachers made adaptations to the guide, with one of them transforming it into a complete presentation for the students.

Initially, one teacher expressed doubts about the relevance of the phenomenon to be studied. However, by the end of the activity, this teacher became highly involved and recognized a wide range of scientific topics that she could incorporate into the experimentation.

b) Execution of the Activity:

All teachers successfully followed the proposed flow for implementing the scientific method.

Six participants incorporated the suggested connection activities into their lessons.

Each participant conducted at least one experiment, with two of them allowing students to design their own experiments based on initial hypotheses and the phenomenon being studied.

All students actively engaged in physical experimentation based on their prior preparations. A selection of these diverse experiments, including the creation of prototypes, exhibition materials, and games was shared with the author.

One teacher, along with her colleague, decided to assess this activity for grading purposes.

More than half of the teachers exceeded their initial time estimates due to comprehensive coverage of planned activities.

Two teachers recognized the potential for confusion and misinterpretation of concepts and data, emphasizing the critical role of the teacher in identifying and addressing such situations. They acknowledged the importance of assuming leadership during these moments to guide students effectively.

Two teachers recognized the importance of collaborating with colleagues to make learning experiences more transversal and engaging for students.

Two participants noted that the traditional approach of solely delivering content by the teacher posed challenges for executing these types of activities. Students were accustomed to following specific instructions and expecting clear leadership from the teacher, which limited their involvement in projects requiring initiative. These teachers also reflected on how the prioritization of content delivery in classes had diminished students' capacity and willingness to explore, be curious, and take charge of their own learning.

It appears that older students demonstrate greater proficiency in designing experiments.

c) Closure and Evaluation:

Two teachers found it useful to conclude the activity by asking students to reflect on the experiments they proposed and be aware of their own learning.

One teacher expressed that a part of her group of students was more interested in the grade of this activity than the activity itself, reflecting a pitfall of the current system.

One teacher could evaluate communication competencies as well as the implementation of mathematical concepts and creative thinking.

Regarding the Guide:

d) Ease of Understanding and Following the Guide:

Eight teachers acknowledged that the guide was excellent in terms of clarity, and they found its graphical design pleasant.

None of them encountered difficulties in understanding or following it.

They emphasized the significance of the planning phase in ensuring the proper implementation of the activity.

Almost all participants utilized the guide as a framework rather than a strict script, finding the overall structure and building blocks to be helpful.

One teacher faced challenges in implementing the guide. While she agreed that phenomenon-based learning is effective in engaging students and colleagues, she felt that there was a lack of complete alignment between the scientific method, the phenomenon of flat-earth theory, and the proposed experiments.

Regarding the Topic:

e) Relevance:

Two teachers expressed that the topic was relevant because it is current, and students are constantly exposed to content about flat-earth theory, which makes it controversial and allows the teacher to emphasize the importance of critical thinking.

More than half of the teachers agreed that the topic is very different from what is typically taught in classrooms, and this uniqueness makes it engaging for students.

They all recognized that the development of a well-founded opinion and critical thinking were the key competencies targeted by this activity. They observed that many students were surprised when they struggled to provide an easy and scientific demonstration that the earth is round.

Most participants realized that the topic enabled students to connect with how science is practiced and how scientific knowledge can be applied.

f) Easiness to align with the planned learning objectives for the course.

Four teachers expressed some difficulty in aligning the activity with the subject-specific themes currently being covered. They mentioned that due to the strict academic year planning and structured nature of the themes, this activity stood out as an independent project.

On the other hand, five participants stated that they were able to seamlessly align the activity with the flow of the planned learning objectives for the course.

Four other teachers highlighted that the scientific method is an abstract concept that can be challenging for students to grasp within a short timeframe. One of them suggested implementing different levels of depth depending on the academic year.

Another teacher mentioned that the concepts applied in the experiment had not been studied yet, so she had to invest extra effort in understanding them herself and preparing for the class.

Regarding the students:

g) Level of interest and satisfaction.

All teachers unanimously expressed that their students were highly engaged and interested throughout the activity.

The students displayed motivation to actively participate in designing and developing their experiments. Five teachers reported that even after the activity, the students continued to investigate and discuss the topic in subsequent classes.

One teacher mentioned that although her students didn't delve deeply into the concepts, they were actively involved in conducting investigations, and their capacity for argumentation increased.

Another teacher reflected that the activity encouraged the active participation of students who are typically withdrawn and distant in the classroom.

Almost all teachers concluded that the students thoroughly enjoyed the activity and had fun throughout the process.

One particular group of students took the topic and their experimentation further, planning to refine their experiments and showcase them at the school science fair scheduled for September this year.

4.7 Improving the solution – The high-definition MVP of the teacher training program

A 4.5-hour virtual training, along with an in-person weekend training boot camp at the Orion Science Camp (<https://orioncamp.com/>), was conducted for the teachers and students. The virtual training session involved revisiting the key concepts that form the theoretical framework of this thesis. To incorporate a practical learning approach, all participants were tasked with creating a scientific dissemination activity that applied the studied concepts.

Seven teachers and three students finished their virtual training and participated in the in-person training. Each participant was then expected to deliver a 30-minute scientific dissemination activity during the in-person boot camp. The topics chosen by the participants and a picture sample of their science dissemination activity can be seen in the following table.

Table 8. Science dissemination topics and sample pictures

<p>Gravitational lenses:</p> 	<p>Planets, asteroids, and meteors for the hearing impeded:</p> 
<p>Measuring distances and identifying the skies using the astrolabe:</p> 	<p>Global warming and taking care of the planet:</p> 
<p>The expansion of the universe:</p> 	<p>The planets and its characteristics for the visually impeded:</p> 
<p>The frogs of the country and the desert:</p>	<p>Dimensions and time in the universe:</p>



Experimenting free falls:



The subatomic particles:



During the camp, the entire group also had the opportunity to engage in two scientific dissemination activities organized by the camp staff. Additionally, they enjoyed a night of stargazing using professional equipment and had the chance to practice astrophotography.

To conclude the camp and the overall learning experience, a learning café was held and aimed to delve deeper into the topics studied and identify areas of interest for further learning, as well as preferred learning formats.

Here are the main conclusions for their interest in learning more about the topics that were studied:

Emotions and Learning

The topics that stood out were how to manage emotions related to the grading process, the role of emotions in science teaching, emotional intelligence for teachers and students, interpreting emotional verbal and non-verbal cues, managing emotions in the classroom, and utilizing triggers to enhance learning outcomes based on emotions and motivation.

All participants unanimously expressed a desire for a practical "how-to" approach to acquiring this knowledge and ensuring its applicability in the classroom. Workshops were the preferred format, with two participants suggesting a boot camp. One participant suggested a conference or talk.

How our Brains Learn

The topics discussed included implementing the 4Cs model in practice, applying the principle of continuity, creating optimal learning environments with existing resources, and exploring the latest trends in neuro-learning, particularly in relation to students with special needs.

Regarding the format, all participants once again agreed on the preference for practical approaches such as workshops or the sharing of professional practices.

Phenomenon based learning.

In terms of learning interests, the teachers expressed a desire to gain insights from successful experiences in implementing phenomenon-based learning, identifying relevant local and global phenomena for classroom study and community involvement, integrating PhenoBL within the current curriculum, and receiving a detailed how-to guide for implementation.

For this topic, the participants reached a consensus that a blended format combining knowledge-sharing of best practices for inspiration and ideas, as well as workshops and collaborative experiments, would be the ideal approach.

Game based learning

Participants expressed a strong interest in deepening their knowledge of game-based learning. Specific tools such as Phet Colorado, simulators, interactive video games, and popular video games were identified as areas they wished to explore. Four participants were specifically interested in learning how to design games that align with learning objectives. Additionally, there was a shared desire to gain a

deeper understanding of using game techniques to enhance learning, adapt them to pedagogical approaches, and align them with learning objectives.

In terms of format, participants expressed a preference for hands-on experiences with platforms and tools, combined with workshops and collaborative work with experts.

Maker learning

Participants acknowledged that there were significant understanding gaps and a lack of clarity regarding the implementation of maker learning. They expressed a desire to study best practices and identify ways to apply it in the classroom. They believed that the best way to acquire this knowledge was by becoming makers themselves and experiencing the methodology firsthand. They emphasized the importance of reflection and preparation for their own practice as essential components of the learning process.

A final learning café session was conducted with all participants to address the question of how the teacher training program could be implemented on a larger scale and to identify the advantages and potential challenges based on their experiences. The responses were categorized into four areas: Teachers, Current Physical Environment and School Conditions, Students, and the System. The following is a summary of the key findings and the items listed here become the identified pains and gains to be addressed with a potential more robust prototype of the teacher training program:

Teachers

ADVANTAGES	POTENTIAL CHALLENGES
<p>Diverse group: allowed them to foster communities of knowledge and dissemination. This diversity of perspectives and experiences enriched their learning as they had the opportunity to learn from one another and gain insights into different teaching methodologies.</p> <p>Meaningful experiences: Through inspiring and creative activities, they were able to cultivate their creativity and apply innovative pedagogical</p>	<p>Time and duration: the need for a well-distributed allocation of time throughout the program's duration, to prevent exhaustion and facilitate effective engagement. Given the program's span across multiple months, ensuring a balanced schedule that avoids overwhelming demands on teachers' time emerged as a crucial factor to be mindful of.</p>

strategies in the classroom. This reflective practice enabled them to improve their pedagogical skills and enhance their teaching effectiveness and foster meaningful learning experiences in the classroom.

Community of learning: The learning environment created by the program proved to be motivational, fostering both personal and professional growth among the teachers. By engaging with their academic peers, they were able to expand their horizons, gain interdisciplinary perspectives, and develop a deeper understanding of their own teaching practice.

Scientific dissemination: the teachers acknowledged the significance of scientific outreach and the implementation of strategies to empower educators. The program equipped them with tools to enhance their pedagogical practices in response to contextual needs, promoting inclusivity in the classroom and aligning workshop activities with the Fundamental Learning Rights (FLR).

Additional time and effort: Teachers emphasized the significance of maintaining a consistent focus and purpose throughout the various meetings and workshops. The allocation of additional time and effort to secure their attendance was deemed necessary.

In person meeting location: the availability of time and resources required for attending in-person meetings was identified as a potential obstacle. Some teachers expressed difficulties in accessing the designated meeting location, emphasizing the importance of convenient and easily accessible venues to facilitate broad participation and engagement.

Motivation and commitment of all: The teachers also expressed concerns regarding the reception of feedback and observations during the program. It was recognized that some individuals might display apathy or a lack of enthusiasm in response to feedback. Thus, the provision of constructive and supportive feedback emerged as a crucial element to foster a positive and motivating environment conducive to growth and development.

Effective implementation in the classroom: the acquired knowledge and insights from the program might not be fully integrated into their teaching practice. The personal struggle of balancing curriculum requirements with the application of the learned strategies was acknowledged. Therefore, the alignment between the program's

	objectives and the demands of the curriculum was identified as an area requiring attention and support.
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Current physical environment and school conditions

ADVANTAGES	POTENTIAL CHALLENGES
<p>Adapting to the context: the schools in rural environment provide favourable conditions for stargazing. The unique situational context of schools can be incorporated for effective planning and execution of activities.</p> <p>Awareness of available resources: the utilization of available spaces and optimization of resources were identified as important considerations. Recognizing and leveraging the physical environment within schools was seen as a means to exert greater control over the proposed activities and enhance their impact. Furthermore, the notion of resource sharing and collaboration among teachers from different disciplines was seen as a valuable opportunity to promote integrated work and maximize resource utilization.</p>	<p>Resources for studying astronomical phenomena: light pollution in urban environments, which poses difficulties for observational processes. The lack of adequate instruments and prioritization of sky observation was also identified as a significant constraint, indicating a scarcity of resources to support such activities.</p> <p>Regular classroom setup: The regular classroom setting was deemed less conducive to fostering engaging learning experiences, potentially hindering student motivation</p>

Students

ADVANTAGES	POTENTIAL CHALLENGES
<p>Soft skills: the program provides a conducive space for the teaching-learning process to unfold. It enables students to increase knowledge appropriation and develop their creativity and</p>	<p>Adapting to school timetables: One significant concern is the constraint of time, as the dynamics of the school schedule and class timetables may pose limitations on the implementation of</p>

<p>fosters the cultivation of scientific and critical thinking skills.</p> <p>Interdisciplinary: This interdisciplinary nature allows for the integration of various subject areas, promoting a holistic understanding of concepts. The utilization of sensory amplification techniques and the application of teaching methodologies such as Enseñanza para la Comprensión (Teaching for Understanding) further enhance the learning experience.</p> <p>Real and visible phenomena: to connect their learning to tangible experiences. This approach generates motivation among students, as they receive education in a meaningful and engaging manner. Collaborative work is also emphasized, fostering the formation of focus groups and research seminars, facilitating knowledge sharing and collaborative problem-solving.</p>	<p>the activities. Finding suitable time slots that align with the curriculum can be a potential challenge.</p> <p>Capture interest of all: It is crucial to go beyond mere compulsory participation and cultivate intrinsic motivation among the students. This requires designing activities that resonate with their interests and passions, ensuring their active engagement throughout the learning process. Today's generation of students may have different interests and are often immersed in media-related activities. As educators, it is important to acknowledge and adapt to these evolving trends, finding ways to compete with and incorporate these interests into the learning experience.</p> <p>Connecting and improving learning of basic concepts Teachers also expressed concerns about the lack of in-depth conceptual understanding among students, which can hinder their ability to recognize and apply the learned concepts effectively. It is essential to address this issue by providing sufficient support and guidance to help students develop a solid foundation of knowledge.</p> <p>Furthermore, there is a risk of deviating from the intended objectives of the class due to various factors. Teachers need to ensure that the activities and discussions remain focused on the core learning objectives, avoiding any potential distractions or tangential discussions.</p>
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The system

<p>Fostering inclusion: Currently, the system promotes the involvement of all roles within the educational setting. This inclusive approach ensures that students, teachers, and other stakeholders are actively engaged and contribute to the learning process.</p> <p>Available resources: The system also provides essential resources necessary for the development of activities. These resources enable teachers to access a wide range of materials, tools, and technologies that enhance the learning experience. The system offers various platforms and tools that facilitate student engagement and support teacher professional development. The system offers teacher training programs and encourages student participation in science outreach activities and dissemination efforts.</p> <p>Freedom in curriculum design process: allowing teachers to tailor activities and instructional approaches to address specific topics. This flexibility empowers teachers to explore innovative teaching methods and adapt their strategies to meet the unique needs and interests of their students.</p> <p>Socialization of best practices: the system promotes the socialization of experiences through events such as conferences and local forums. These gatherings provide opportunities for educators to share their experiences, insights,</p>	<p>Student-teacher ratio: overpopulation in classrooms, which limits the amount of information that can be effectively conveyed to students. The large student-to-teacher ratio poses a challenge in providing individualized attention and personalized learning experiences.</p> <p>Focus on content coverage and scores: The system also faces challenges stemming from the dense curriculum guidelines and structures, which often prioritize content coverage over exploratory activities. The educational focus on achieving high scores in standardized tests and university entrance examinations further reinforces the emphasis on content memorization rather than holistic learning experiences. The current academic schedule often limits the opportunities for extended project-based work, forcing teachers and students to allocate their personal time for such endeavors. Many stakeholders remain focused on content delivery rather than prioritizing the development of skills and competencies. Overcoming this resistance and promoting a shift towards skill-based education is crucial for fostering meaningful and relevant learning experiences.</p> <p>Lack of support for non-traditional formats: There are also concerns among teachers regarding the legal responsibilities associated with educational outings. Fear of potential legal repercussions hinders the organization of pedagogical</p>
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<p>and best practices, fostering a sense of community and collaboration within the education sector.</p> <p>Encourage partnerships: it is essential to establish partnerships and collaborations with inspiring institutions and organizations in each city. By forging alliances with such entities, the system can broaden its reach and provide students with access to diverse learning environments and resources.</p>	<p>field trips and experiential learning opportunities outside the school premises. There is a need for emotional and financial support for teachers who adopt non-traditional approaches to education. Providing adequate support to these teachers is crucial in recognizing and valuing their efforts to implement innovative pedagogical practices. There is a limited number of spaces available within schools for hosting dissemination activities and socialization events. This scarcity of spaces restricts the opportunities for students and teachers to engage in collaborative learning and knowledge sharing beyond the confines of the traditional classroom.</p> <p>Outdated guidelines of curricula: The outdated and disconnected nature of curricula is another concern. The curricula need to be updated and contextualized to align with current societal needs, advancements, and real-world applications.</p>
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4.8 The foundations for the program and the system around it

The list of nineteen topics outlined in appendix 1 can be regarded as the curriculum for the teacher training program. It is noteworthy to mention that thirteen of these topics primarily focus on developing practical skills for implementing the theoretical framework presented in this thesis. Only three topics introduce new knowledge, two topics relate to integrating topics within current conditions, and one topic pertains to detailed procedural knowledge.

Teachers express a strong preference for a hands-on, collaborative style of learning that fosters active participation, knowledge sharing, and inspiration derived from their colleagues' work. Regardless of the training format chosen, it is crucial to consider the creation of diverse groups of teachers and create an environment that facilitates the formation of communities of practice, where learning becomes a meaningful and transformative experience.

In an ideal scenario, the training should be seamlessly integrated into teachers' existing schedules, without encroaching upon their free time or administrative duties. Voluntary participation is essential, and teachers should receive full support from their educational institutions. The training program's duration should align with the academic year's timeline, ensuring immediate implementation in the classroom to avoid being perceived as an extracurricular activity and instead serve as a facilitator for their teaching practice. While an in-person component of the training would be advantageous, it should be designed to be as straightforward and accessible as possible. It is also imperative that the training program be adaptable to different classroom setups and accommodate diverse infrastructural resources.

Besides the visible benefits of enhancing social skills, promoting interdisciplinary learning, and offering highly engaging topics for students, the training's impact in classrooms should be adaptable to various school timetables. It should provide teachers with the clarity and flexibility to incorporate the specific concepts relevant to their specialization areas.

5 CONCLUSIONS

The title of this thesis inherently reflects its underlying objective: to advocate for the significance of enhancing scientific dissemination across all levels. In a world where nearly nine million scientists conduct research in their respective fields, the need for a broader, more impactful approach to disseminating their findings is paramount. This is particularly crucial in a landscape saturated with well-marketed misinformation and baseless arguments lacking scientific support.

If we equip our more than nineteen million science teachers in primary, secondary, and upper secondary schools with accessible pedagogical tools and techniques to bridge the gap between scientific knowledge and the fundamental concepts and skills our children need to navigate an ever-changing world, we can enhance the relevance of science education while nurturing students' motivation and evoking positive emotions in their learning journeys.

One effective method to achieve this is through phenomenon-based learning (PhenoBL). Both the research participants and the consulted experts concur on the benefits of integrating subject-specific content within relevant, real-life phenomena that resonate with the local community, ultimately fostering student engagement. However, implementing PhenoBL on a larger scale poses challenges, as teachers are often burdened with a vast amount of content to cover within limited class time. Overcoming this constraint necessitates flexibility in curriculum design, prioritizing learning outcomes that can be addressed and assessed from various perspectives. However, gaining the support and acceptance of parents is crucial, as they may harbor reservations stemming from their own traditional educational experiences, where grades held utmost importance.

Furthermore, when implementing PhenoBL, it is imperative to establish connections with authentic, holistic, and meaningful phenomena that exist within the school environment and students' lives. This requires dismantling the barriers of traditional classrooms, which often detach students from reality. Teachers must possess the capacity to forge partnerships with both the private and public sectors, as well as the broader community within their school districts. To facilitate this collaboration, school administrators and parents must be committed to fostering dialogue and forging alliances with other stakeholders in society. Simultaneously, they must recognize that learning extends beyond the confines of

classrooms, and prioritizing the development of life skills alongside essential subject areas will better prepare students for future success and well-being.

To successfully implement these methodologies, teachers face the challenge of determining when, how, and to what extent active learning methods should be incorporated. Extensive evidence from prior academic research and the findings of this thesis demonstrates that active learning enhances student engagement and motivation. Moreover, if active learning occurs in unconventional and modernized learning environments that facilitate contextualization, it further supports the practical application of acquired knowledge. Nevertheless, determining the ideal balance between active and passive learning remains an unanswered question. The formula varies depending on factors such as learning objectives, classroom dynamics, teacher expertise, and available resources. Thus, there is a clear need within the teaching community for greater understanding, dissemination, and sharing of best practices related to these methods. Teachers must also possess the ability to organize available materials into useful representations and integrate prior knowledge from students, subject areas, and ideally, other disciplines to promote holistic and practical learning experiences.

The concept of game-based learning holds relevance in this context. However, it is crucial that teachers move beyond incorporating game elements purely for entertainment or popularity. Instead, they must recognize that gamification, when integrated within an educational context, falls under the broader umbrella of game-based learning. Gamification can be a valuable and potent technique, but its effectiveness relies on its integration with learning objectives and broader educational dynamics.

One crucial area where teachers currently lack knowledge pertains to the latest findings on how the human brain truly learns. While passionate and knowledgeable teachers can be found within schools, they often lack awareness or do not actively apply formats and methods tailored to how the human brain acquires and utilizes knowledge. Ironically, with the increasing prevalence of technology in the classroom, there is a tendency to prioritize technology over pedagogy. This prioritization must be reversed. It is universally agreed by the participants of this research that teachers must be trained, or retrained, to act as facilitators, storytellers, and emotion readers. Recognizing that learning, like any other human activity, is inseparable from emotions highlights the importance of understanding these emotions, their triggers, and how best to harness them to enhance learning outcomes and create an optimal learning environment.

By excelling in these three competencies, teachers can relinquish control and empower students to take responsibility for their own learning. However, this paradigm shift requires a departure from traditional expectations, as students will no longer be simply told what to do or how to do it. As students emerge from a system that conditions them to comply and convey information, they must now be encouraged to find their own way.

In terms of subject-related content for teaching in secondary schools, as well as the latest discoveries in pedagogy, educational psychology, and neuro-learning, a wealth of information is readily available online and free of charge. However, the challenge lies in the fragmentation of this information across various formats and hundreds of web pages. It would be ideal to establish a comprehensive online library that consolidates these resources, serving as a valuable complement to teacher training programs and benefitting educators. Such a centralized platform would afford teachers convenient access to a plethora of resources.

A broader conclusion regarding the traditional educational system, while beyond the scope of this thesis, is worth mentioning. The relevance, or perhaps irrelevance, of the grading system emerges as a critical point of discussion. Only a mere eight percent of educators and students involved in this research expressed that recognition or grades motivated them during their most profound learning experiences. Extensive research on motivation and emotion in learning demonstrates that while grades may contribute to extrinsic motivation, other types of motivation and emotional triggers prove more powerful and engaging. Furthermore, in an optimal flow of learning experiences, grades and exam-related pressure often lead students toward exhaustion and negative anxiety. Recognizing this, it is expected that new performance assessments that genuinely measure learning outcomes and emulate real-life situations will become the norm.

Finally, it is both concerning and disheartening that the role of teachers in society is often marginalized and undervalued, not only in Latin America but also in many countries worldwide. Considering this, I firmly believe that a concerted effort to uplift and promote the role of teachers in society is essential. Teaching should be regarded as an esteemed and attractive profession, offering desirable working conditions and adequate compensation. Teachers serve as vital nodes within our learning networks, acting as conduits for driving genuine societal change. They are the individuals who spend the most time with our children and adolescents, and any efforts to enhance their practice and job satisfaction

will ultimately shape the education and well-being of future generations - a responsibility that directly impacts our collective future.

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LIST OF TOPICS AND FORMATS TEACHERS DESIRE FOR THEIR TEACHER TRAINING PROGRAM
APPENDIX 1

Highlighted in yellow (3): New concepts	Highlighted in blue (2): Integration with current practice and conditions	Highlighted in grey (1): Detailed procedures	Not highlighted (13): Practical skills for implementation
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Emotions and Learning

1. Managing emotions while grading
2. The role of emotions in science teaching
3. Emotional intelligence for teachers and students
4. Interpreting emotional verbal and non-verbal cues
5. Managing emotions in the classroom
6. Emotional and motivational triggers to enhance learning outcomes.

Format: Practical "how-to" approach ensuring its applicability in the classroom. Workshops were the preferred format.

How are Brains Learn.

7. Implementing the 4Cs model in practice
8. Applying the principle of contiguity
9. Creating optimal learning environments with existing resources
10. Exploring the latest trends in neurolearning, particularly in relation to students with special needs.

Format: Practical approaches such as workshops or the sharing of professional practices.

Phenomenon based learning.

11. Successful experiences in implementing phenomenon-based learning.
12. Identifying relevant local and global phenomena for classroom study and community involvement
13. Integrating PhenoBL within the current curriculum

14. Receiving a detailed how-to guide for implementation.

Format: blended format combining knowledge-sharing of best practices for inspiration and ideas, and workshops and collaborative experiments.

Game based learning

15. Specific tools (Phet Colorado, simulators, interactive video games, and popular video games)

16. How to design games that align with learning objectives

17. Using game techniques to enhance learning.

18. Adaptation of game techniques to pedagogical approaches

Format: Hands-on experiences with platforms and tools, combined with workshops and collaborative work with experts.

Maker learning

19. Best practices and identify ways to apply it in the classroom.

Format: Becoming makers themselves and experiencing the methodology firsthand.