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Research Article

Creative Learning of Computer Science of Computer Science Professionals: Case University of Matanzas

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Research on creativity is a common topic today, with a strong psychological component influencing its definition. This research takes the definition of creative learning from the theory of subjectivity, which is a strand of the cultural-historical approach. However, few studies have defined creativity in the field of computer science, and even fewer have addressed learning in this field. This paper aims to diagnose creative learning in computer science in a computer engineering course at the University of Matanzas. In order to achieve this objective, creative learning is first established as an expression of creativity in learning. Then, it is described as a fundamental form of computer activity, and finally, creative learning in computer science is defined. A questionnaire was used to diagnose creative learning in computing. The questionnaire will be administered to 66 final-year students enrolled in the academic year 2022. The indicators obtained in the theoretical section will be measured on a scale from 0 to 1. The study will first compare the data obtained through qualitative state inference, followed by the application of inferential statistical methods to further analyse the results. From the results, creative learning in computer science will be assessed, and it will be found that it is generally poor. Based on the data, the hypothesis is rejected, and the level of development of creative learning in computing is found to be low.

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Introduction

The topic of creativity has been extensively studied by various scientific disciplines, with many considering it a multidimensional phenomenon. The development of creativity in human beings is closely linked to creative learning, and the latter is often seen as an expression of the former. González Hernández et al. (2022) and Torres Oliveira and Mitjáns Martínez (2020) both support this view. Therefore, in order to foster this personality quality in individuals, it is crucial to promote creative learning. Didactics, as a field that studies educational processes in schools, should focus on promoting this.

Additionally, information and communication technologies play a strategic role in a country's development, making it essential to train professionals who can produce them. Several studies have been conducted on creativity and technology by researchers such as Israel-Fishelson et al. (2023) and Leroy et al. (2023). However, there is a lack of research on the subject during the training of technology professionals. While some research, such as that by González-Hernández (2013) and González Hernández et al. (2022), addresses the development of creativity in IT professionals and suggests ways to achieve this goal, it does not provide a clear definition of what constitutes creative learning of IT technologies.

The objective of this paper is to characterize the creative learning of computer technology during the training of professionals, in order to achieve creative learning in a professional training process and to develop creativity in IT. To achieve the proposed characterisation, this text discusses the relationship between creativity and creative learning in the first section, followed by a discussion of the development of computer science in the second section. The final section characterises this type of computer-based learning. The variable is then operationalised, and its status in IT is diagnosed by means of a self-assessment questionnaire applied to the entire degree programme.

Theoretical Frameworks

Creativity and Creative Learning

The study of creativity has been undertaken by various scientific disciplines, which have identified five main themes: process, product, environment, person, and their integration. Research on creative individuals is particularly relevant to the development of creative professions. Currently, there is an ongoing controversy among major psychological schools of thought regarding the explanation of human creativity. In cognitivist psychology, creativity is examined as a cognitive process. However, in the cultural-historical approach, creativity is viewed as an expression of the individual through the activities they perform (Said-Metwaly et al., 2021). Similarly, Vygotsky's cultural-historical approach also considers creativity as a way for individuals to express themselves (Allagui, 2022; Anggraini Saputri & Yuwono, 2022). However, Brosch (2021) acknowledges the significance of emotions in human development. Therefore, this paper employs a cultural-historical approach to elucidate creativity.

Vygotsky's cultural-historical approach rests on three pillars: activity theory, personality theory, and, in the last decade, subjectivity theory (González Rey, 2019; Subero & Esteban-Guitart, 2023). The three directions of Vygotsky's theory are characterised by their differing approaches to the role of subjectivity. The first direction, which aligns with Marxism-Leninism, critiques the excessive objectification of mental processes. The second direction builds on Vygotsky's earlier work but does not extend beyond it. The third direction, however, introduces new theoretical concepts such as subjective meaning and composition (González-Rey, 2019). These categories enable an explanation of human development, with a focus on the relationship between individuality and society, while also considering its historical context. The theory of subjectivity as a construct is used to analyse creativity.

According to de-Almeida and Mitjáns Martínez (2020), creativity arises from singular subjective processes and productions of the individual, which are related to their current context and life trajectory. Each individual achieves this configuration according to their social and historical context, giving creativity a highly individualized character. However, not all social and historical contexts are conducive to creativity. Educational spaces are created by individuals as physical or virtual spaces for learning in which they participate as producers of subjectivity in dialogue with other members. Extensive networks are created in such spaces to seek information and contrast ideas, and dialogue is the primary means of communication. The information obtained in the space is personalised and juxtaposed to each student's specific situation in their socio-historical context. From this contrast of ideas, new ideas are born, which recursively enter the learning space as a space of social subjective production. Thus, learning can be considered creative if it is an expression of the student's creativity within the learning environment (González Hernández, 2021b).

Torres Oliveira and Mitjáns Martínez (2020, p. 129) argue that creative learning "…. includes the subjective meaning of an individual's life story and the subjective meaning that the individual produces in the context in which the action is performed, through the way they relate the action." This context is characterized in particular by social subjectivity". One of the authors of the previous article, Mitjáns Martínez (2013a, p. 250), defines it as follows.

> … a form of learning that differs from the forms of learning common in the school environment, and is characterised by the type of production that the learner makes and by the subjective processes involved in it (…). This learning has different forms of expression and involves a set of subjective resources and is expressed in the configuration of at least three processes: the personalisation of information, the confrontation with what is given, and the production of new ideas of one's own.

Referring to this definition, de Almeida Kosac (2011, p. 65) highlights that

> ...the descriptive characteristics that seek to typify creative learning (the personalisation of information, the confrontation with the given, and the generation of ideas) are, in themselves, subjective processes. This means that the division of the terms "characteristics" and "subjective" does not hold in relation to the nature of the aspects involved, but only in relation to the different functions of each of these aspects (translated by the authors).

According to Soares Muniz and Mitjáns Martínez (2015), these characteristics suggest that the relationship between the learner and information or knowledge is not passive. Creative learning is a mode of learning that is based on subjective functions. It has generative characteristics and involves the realization of the subject's conditions in the learning process of rupture and destruction/transcendence in relation to givenness. This mode of learning generates subjective meanings that support the creation of novelty, which in turn reinforces the learning process. The subject's life history also plays a role in this process. According to Mitjáns Martínez (2013a), learning renewal involves the diverse subjective configurations created during the learning process.

Personalization of information occurs when it becomes meaningful to the learner and serves as a subjective resource. Learners identify meaningful information, develop new information, establish different ways of processing it, and record it. Thus, expressing doubts, asking questions, and not accepting given information as the only option are ways of demonstrating the transcendent nature of creative learning. This allows learners to identify contradictions, failures, and gaps. It involves acquiring new knowledge to generate original ideas that express the novelty inherent in creativity. This is achieved by challenging existing assumptions, proposing new ideas, hypotheses, and alternatives, which are then tested to go beyond the given. This process is essential for creativity.

Creative learning is a complex process that focuses on the stability of acquired knowledge and the achievement of lasting learning outcomes. The content of the improved text is as close as possible to the source text, and no new aspects have been added. Learning is considered creative when it enables the creation of new knowledge that can be applied in various contexts, situations, and moments, contributing to learners' emotional well-being and personal achievement.

In order to foster creativity in learning, it is essential to personalize the educational process to facilitate the development of the learner's subjective resources (Mitjáns Martínez, 2013a). This means supporting educational practices that empower students to take ownership of their learning, which is constructed subjectively and generates new meanings throughout the learning process. Teachers should be aware of the complexities of their students to develop effective strategies and modify existing ones without hindering their development. Moreno García (2019) integrates a set of principles to enhance student development through educational practices and promote creativity in learning within the framework of the Integral Didactic System. Presented is an 'Integral Didactic System' aimed at promoting creativity in learning. Designing such a system requires attention to communication with students and their position in the social composition of the learning space. Dialogue, reflection, and contradiction are necessary elements for the subject's involvement in the learning climate (Rey, 1999, p. 120). Furthermore, to alleviate the tensions that arise between teaching levels, subject characteristics, student characteristics, and teacher creativity, changes in teaching and learning behaviours are required. To characterize creative learning in computer science, it is essential to provide a description of the subject and its current developments.

Developments in Creativity in Information Technology

Computer science has had a significant impact on all aspects of human life in recent years through technology. The production of models, algorithms, processes, systems, and concepts in computer science requires creativity and is closely related to computerization (González-Hernández, 2013). The computerization of processes in organizations is closely related to the production of models, algorithms, processes, systems, and concepts as expressions of creativity in computers. Every organization has processes established by corporate objectives to meet customer expectations. Therefore, information from previous computerized processes is useful. However, information related to new processes depends on the specific situation. For each computerization process, a new project must be initiated to establish the fundamental concepts, framework, and available human resources that require computerization.

A project is an organizational form of informatics technology production, and solutions often require the integration of several organizations involved in technology development (Haq et al., 2019). This integration provides an end-to-end solution to the client organization. A Science Technology Park serves as an example. The interactions among the organizations involved in a project are diverse and depend on the role each plays in the computerization process. The collaborating organizations form a unique framework that integrates their best knowledge, components, and processes to arrive at an efficient and effective solution. The framework formation involves a process of tension between organizations with differing objectives and processes, which is resolved through dialogue. However, the incorporation of the latest IT achievements in the computerization process does not guarantee the efficiency and effectiveness of the developed solution. The proposed solution's suitability may cause tension between the two organizations and must be resolved by balancing the novelty of the technology developed with the efficiency of its implementation in the customer's infrastructure. The solution development process can be executed using an ecosystem or software factory model and depends on the dialogue established by the participating organizations.

Computing has had a significant impact on all aspects of human life in recent years through technology. The production of models, algorithms, processes, systems, and concepts in computing requires creativity and is closely related to computerization (González-Hernández, 2013). The computerization of processes in organizations is closely related to the production of new and innovative ideas focused on models, algorithms, processes, systems, and concepts as expressions of creativity in computing. Every organization has processes established by corporate objectives to satisfy the expectations of customers, who evaluate the novelty of the solutions. For each computerization process, a new project must be initiated that establishes the fundamental concepts, framework, and available human resources that computerization requires. This continuous initiation generates an arduous process of personalizing information, transgressing what is known until now as novel to generate new products for the market that are evaluated by the client as novel and satisfy their needs.

A project is an organizational form of generating new ideas in the form of computer technology, and solutions to problems raised by clients often require the integration of several organizations involved in technological development (Haq et al., 2019). Each organization provides best practices and a history of efficient and effective solutions to common problems, which increases the creative potential of integration. The interactions between the organizations that participate in a project are diverse, depending on the role that corresponds to them, so the result of the generation of ideas and their novelty will depend on their activity. Collaborating organizations form a unique framework that integrates their best knowledge, components, and processes to arrive at an efficient and effective solution. The formation of the framework involves a process of tension between organizations with different objectives and processes, which generates confrontation in the form of a whirlwind of ideas. Determining spaces for brainstorming, searching for unusual solutions in the form of experimentation, analyzing each new project as a challenge, and other techniques within the project framework contribute to increasing the novelty of the product.

The incorporation of the latest IT achievements in the computerization process does not guarantee the efficiency and effectiveness of the developed solution, resulting in the client not perceiving it as novel. The suitability of the proposed solution can cause tensions between the two organizations and must be resolved by balancing the novelty of the developed technology with the effectiveness of its implementation in the client's infrastructure. This process should be seen as an opportunity to generate solutions in which new technology processes are readjusted towards those owned by the client, a process in which novel algorithms and models emerge for those who use them.

To meet the client's needs, it is often necessary to involve experts from fields related to the organization's processes that need to be computerized. Therefore, technical projects have an interdisciplinary and transdisciplinary nature, integrating multiple technical and humanities disciplines. Interdisciplinary relationships in a project must be established through a communication system based on dialogue and understanding among the disciplines. Mutual respect and acceptance of the limitations of each discipline in the computerization process are key to technological development. In general, the development of each computerized project involves configuring nonlinear systems that meet the needs of another system in the client organization. The flow of information between these systems allows each to form an IT development structure and find efficient solutions to the problems detected. The project represents the solution to the organization's computerization process. Hence, computerizing an organization is highly dependent on its specific situation. This presents a fundamental contradiction in computer science: while seeking a general methodology or framework, each computerization project is unique.

In current literature, project-based learning is recognized as a fundamental means of developing creativity in computer science education **(García, 2016; Härkki et al., 2021)**. Zhou (2012) has identified projects as complex initiatives. The author recognizes this and focuses their analysis on project management and resolution, taking those involved in the project out of the background. Mullin (2010) describes the relationship between the project and creativity but does not specify the characteristics of the project. **Zhou (2012)** refers to the project as a 'project-based learning experience' but does not identify its characteristics. These two studies utilize cognitivism as the psychological foundation and disregard emotional relationships between project members. However, according to Anisimova et al. (2021), affective processes play a crucial role in learning within engineering careers.

To satisfy customer needs, it is often necessary to involve experts from fields related to the organization's processes that need to be computerized. Therefore, technical projects have an interdisciplinary and transdisciplinary character, integrating multiple technical and human disciplines in which these specialists generate ideas regarding the solutions that are proposed. These experts logically validate the ideas provided during the work sessions. Interdisciplinary relationships in a project enhance the adoption or transformation of ideas from one discipline to another, which leads to contributing new ideas to the discipline that receives them. This process can lead to a restructuring of the disciplines that receive them during the computerization process; they are key to technological development. In general, the development of each computerized project involves the configuration of non-linear systems of ideas that are generated to satisfy the needs of the client organization. The flow of information between these systems allows each of them to form an IT development structure and find efficient solutions to the problems detected. The project represents the solution to the organization's computerization process and, at the same time, is the idea generator space par excellence in computing. Therefore, computerizing an organization depends largely on its specific situation. This presents a fundamental contradiction in computing: although a general methodology or framework is sought, each computerization project is unique, which leads to the search for information to understand its processes and generate new ideas for its computerization.

In current literature, project-based learning is recognized as a fundamental means of developing creativity in computer science education (García, 2016; Härkki et al., 2021). Zhou (2012) has identified projects as complex initiatives. The author recognizes this and focuses his analysis on the management and resolution of the project, taking those involved in it out of the background. Mullin (2010) describes the relationship between the project and creativity but does not specify the characteristics of the project. Zhou (2012) refers to the project as a "project-based learning experience," but does not identify its characteristics. These two studies use cognitivism as a psychological basis and ignore the emotional relationships between project members. However, according to Anisimova et al. (2021), affective processes play a crucial role in learning within engineering careers.

In projects, members establish affective relationships by creating a climate of trust and security through dialogue. This climate enables the exchange of ideas, collegial decision-making, and a sense of belonging. It also encourages the emergence of positive emotions and facilitates learning. Maintaining an objective climate throughout the project enables members to establish a shared history, which fosters a collective approach. These subjective experiences are incorporated into each member's personal perception of the organization's informatization and are influenced by their role in the project. The relationships and co-living narratives established with each client organization create a social perspective on the computerization of the organization. Therefore, the project aims to achieve high-quality computerization for the client organization. The implementation of each project creates a social configuration, which is then integrated into more complex configurations within a social organization that remains involved in multiple projects. This way, life histories are constructed at the organizational level.

Students' participation in computerization projects enables them to learn behavioural patterns specific to computer science and develop a professional advantage. The uniqueness of each project allows students to apply their knowledge in different ways, contributing to the project's requirements. The deviation from the taught content motivates students to seek information and creates new learning opportunities beyond the school environment. This search can occur within a project setting with fellow graduates or, as with the Internet, can extend to other spaces where necessary information is available. Whenever an information node is relocated or interacts with other individuals involved in the computerization process, subjective meanings related to the given situation arise. This search for information across various spaces results in a shift in the problem-solving process as an important creative process. The search for a solution to a problem has the help of other people with similar experiences who meet in the learning space to generate new ideas and validate them. With the rise of computer networks, students can now use a heuristic rule to search for similar projects and analyze proposed solutions that can be brought to bear on their projects. This leads to a recursive process of comparing the proposed solution with the demands of the problem. This adjustment process is not exempt from searching for solutions in which ideas are generated to solve the problems it entails. The language used is clear, concise, and objective, to understand the problem and communicate the solutions to the rest of the team.

During the process described in the previous paragraphs, the student internalizes each piece of information obtained and compares it with their existing knowledge. The information is then integrated into their existing knowledge, with a sense of satisfaction. However, the information obtained may be relevant to other projects and may require adaptation to be applied to the current project. Code fragments, models, and other system descriptions must be adapted to the project's characteristics. This conversion is necessary due to the unique nature of each computerization project.

To avoid frustration when searching for solutions and applying them to the project, students create original ideas. Veraksa et al. (2020) suggest that the level of drama in a given situation and student involvement in a project can positively impact idea generation. Therefore, it is recommended to grade the level of drama in a situation from simplest to most complex, based on the curriculum design of the training process. Lower-grade students learning introductory programming can create algorithms and test codes for higher-grade students. Intermediate-grade students could design business models and test strategies for final-grade students. Graduating from the simplest to the most complex ideas creates a sense of progression that favours the production and validation of ideas. Simultaneously, students progress from basic to advanced concepts, requiring them to integrate the aforementioned processes at a higher level. Throughout this developmental process, students gain autonomy in decision-making regarding the framework used to implement the technical solution.

The project's challenges and the student's engagement in it facilitate a significant leap forward in personal growth. This is related to the level of drama presented by the situation. The development of personalization of information, production of new ideas, and confrontation with the given all require creative learning. Each decision made by the learner or organization during the development process implies a higher level of creative learning. The development of computerized processes involves a process of progressively higher levels of creative learning within organizations.

The interaction between the computerizing organization and the client organization can lead to the emergence of subjective meanings, which may facilitate creative learning in all organizations. These subjective meanings have the potential to reorganize the dominant subjective configurations in the organization when they are the subjects of change in efficient and effective technological practices and production methods tailored to the context of the client organization. In these processes, tensions may arise between the organization's objectives and its constituents, which must be resolved through dialogue.

If the organization's workers are involved in the technical process, the project becomes a place of creative learning. All members, and the organization as a whole, learn by personalizing information, confronting what they are given, and generating new ideas of their own.

To summarize what has been described so far, creative computer learning involves three main processes: personalization of information, confrontation with the given, and production of new ideas arising from the emergence of subjective meanings associated with computer science learning in the context of the project and social, defined as the social and personal constitution of the project. The dimensions and indicators used to characterise this learning are listed in the table below:

Dimensions	Indicators	Aspects that identify the level of the indicator in the learner
Customisation of IT processes is the main focus of this project	1.2. The author develops personalised forms for recording information received on concepts, procedures, models, systems, and computer algorithms determined within the framework of the project.	1.1.1 The symbolic language of computer science is commonly used to describe various situations in everyday life
		1.1.2 The individual extracts the key elements of computer concepts, procedures, models, systems, and/or algorithms that are useful for the project.
		1.1.3 They compare various computer concepts, procedures, models, systems, and/or algorithms to apply them in their respective roles.
		1.1.4 They prepare different types of summaries on various computer concepts, procedures, models, systems, and/or algorithms.
		1.1.5 The author expresses ideas by synthesising computer concepts, procedures, models, systems, and algorithms.
	1.2. The author develops personalised forms for recording information received on concepts, procedures, models, systems, and computer algorithms determined within the framework of the project.	1.2.1 The author determines the most important elements to be summarised from the concepts, procedures, models, systems, and computer algorithms that are needed for the project.
		1.2.2 The text expresses the essential elements identified using the symbolic forms of computer science
		1.2.3 It establishes relationships between the concepts, procedures, models, systems and/or algorithms, whether received or not, and what the reader already knows.
		1.2.4 The text explains how to record information using the symbolic forms of computer science.
		1.2.5 The text describes how concepts, procedures, models, computer systems, and/or algorithms are recorded using other forms that enable asynchronous communication between project participants.
	1.3. The text distinguishes relevant information from the knowledge possessed about the information associated with the project obtained in the different learning spaces where the project is being developed.	1.3.1 The team compares the information provided by other project members with the information they possess.
		1.3.2 They determine the relevant aspects of the information systems they receive
		1.3.3 They establish non-linear relationships during the execution of

Dimensions	Indicators	Aspects that identify the level of the indicator in the learner
		project-related processes
		1.3.4 They compare the processes and information obtained in the project to make decisions.
		1.3.5 The actor acts based on the information it deems relevant, depending on the assigned roles.
	1.4. The project developer individualises new concepts, procedures, models, systems, and computer algorithms obtained from different learning spaces to develop the project.	1.4.1 Specific concepts, procedures, models, systems, and/or computer algorithms that are not related to the project are specified.
		1.4.2 They incorporates concepts, procedures, models, computer systems, algorithms, or other relevant information into other fields.
		1.4.3 Relevant information within the project framework is identified by the students.
		1.4.4 New information gathered is connected to the project's needs by the students.
	The project applies concepts, procedures, models, systems, and computer algorithms obtained from various learning spaces.	1.5.1 They reflect on the feasibility of introducing the concepts, procedures, models, systems and/or computer algorithms obtained in the learning spaces to the project situations.
		1.5.2 They verify the feasibility of introducing the concepts, procedures, models, systems and/or computer algorithms obtained in the learning spaces to the project situations.
		1.5.3 They introduce the concepts, procedures, models, systems and/or computer algorithms obtained in the learning spaces to the situations of the project.
		1.5.4 They determine the validity of the introduction of the concepts, procedures, models, systems and/or computer algorithms obtained in the learning spaces to the project situations.
Confrontation with the already given computer processes that make the emergence of subjective meanings possible.	2.1. Questions the concepts, procedures, models, systems and/or computer algorithms obtained in the different learning spaces where they is involved in order to develop the project.	2.1.1 They ask original questions that demonstrate reflection on the information received.
		2.1.2 They question the information it receives in the framework of the project.
		2.1.3. They identify contradictions and gaps in knowledge.

Dimensions	Indicators	Aspects that identify the level of the indicator in the learner
		2.1.4 They identify analogies of the information received in the framework of the project with the information it already possesses.
		2.1.5 They argue their positions on the basis of information research.
	2.2. Argues the project development processes considered most efficient and effective on the basis of the concepts, procedures, models, systems and/or computer algorithms obtained in the different learning spaces where they are involved.	2.2.1 They interpret the information necessary for the projects it obtain from the learning spaces in which it is involved.
		2.2.2 They search other sources for judgements that corroborate the initial judgement.
		2.2.3 They select the logical rules on which the reasoning is based.
		2.2.4 They draw conclusions about the elements, relationships and reasoning that appear in the object or information to be interpreted.
		2.2.5 They use correctly the computer symbology that allows they to express their results to the rest of the project members.
	2.3. Argues the tensions detected during the execution of the project development processes based on the concepts, procedures, models, systems and/or computer algorithms obtained in the different learning spaces where they are involved.	2.3.1 They interpret the information associated with the tensions that arise during the implementation of the project.
		2.3.2 They look to other sources for options to minimize the stresses that occur during project implementation.
		2.3.3 They select the logical rules that serve as a basis for reasoning to mediate the tensions that occur during project implementation
		2.3.4 They draw conclusions about the tensions that occur during the implementation of the project.
	2.4. Selects the people with the greatest potential to make up the project development teams, considered on the basis of selection criteria obtained in the different learning spaces in which they is involved.	2.4.1 They determine criteria for the selection of personnel to participate in the tasks associated with the project.
		2.4.2 They develop instruments to determine the strengths and weaknesses of the people who will work on the project.
		2.4.3 They applies the selection criteria taking into account the characteristics of the roles to be performed.
		2.4.4 They enhance interpersonal relationships among team members

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Dimensions	Indicators	Aspects that identify the level of the indicator in the learner
	2.5. Modifies their opinions on the basis of valid opposing criteria during the execution of the project development processes on the basis of the concepts, procedures, models, systems and/or computer algorithms obtained in the different learning spaces in which they is involved.	2.5.1 They determine the validity of the criteria issued by the rest of the team members.
		2.5.2 They acknowledge valid criteria issued by project members
		2.5.3 They express the modification of their opinions to the rest of the team members.
		2.5.4 They introduce the necessary changes in the processes
		2.5.5 They modify its action taking into account the valid criteria that have been issued by the project partners.
Production, generation of own and "new" ideas during the execution of an IT project.	3.1. Proposes new hypotheses during the execution of the project development processes based on the concepts, procedures, models, systems and/or computer algorithms obtained in the different learning spaces where they are involved.	3.1.1 They actively participate **in** the search for new ideas, alternatives, conjectures and hypotheses to obtain efficient and effective processes.
		3.1.2 They show self-confidence, autonomy, initiative and perseverance.
		3.1.3 They propose alternatives and hypotheses for the problems to be solved in the framework of the projects in which they interact.
		3.1.4 Produces new ideas related to the concepts, procedures, models, systems and/or computer algorithms or not needed for the project.
		3.1.5 They communicate new ideas, alternatives, conjectures and hypotheses related to relevant information to the project partners.
	3.2. Selects the most efficient and effective route during the execution of the project development processes based on the concepts, procedures, models, systems and/or computer algorithms obtained in the different learning spaces where they are involved.	3.2.1 They identify different ways of solving the problems that arise in the framework of the project.
		3.2.2 They use the learning spaces to inquire, seek more information, respond to concerns and curiosities.
		3.2.3 They compares different ways or paths to determine the most appropriate way to resolve the situation posed in the project.
		3.2.4 They determine the best solution to the problems associated with the project.
		3.2.5 They evaluate the best way to solve the problems associated with the project.

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Dimensions	Indicators	Aspects that identify the level of the indicator in the learner
		3.2.6 They present to the project members the possible ways to respond to the situation raised.
	3.3. Develops new projects that provoke satisfaction for what has been achieved and the generation of new ideas linked to their training as a computer engineer.	3.3.1 They vary conditions of the situations linked to the project in order to generalize the solutions obtained.
		3.3.2 They develop new situations that generalize current situations to new contexts.
		3.3.3 They concretise new situations in which the framework obtained in the project can be applied.
		3.3.4 They looks for new situations or processes to computerize in other organizations.
	3.4 Collaborates with the people involved during the execution of the project development processes on the basis of the concepts, procedures, models, systems and/or computer algorithms obtained in the different learning spaces where they are involved.	3.4.1 They maintain a respectful attitude towards the project partners.
		3.4.2 They participate in the actions to be implemented in the framework of the project
		3.4.3 They enhance the delivery of information necessary for the project to work.
		3.4.4 They make available to the project members the information obtained from the learning spaces in which they are involved.
		3.4.5 They express solidarity with the members of the group
	3.5. Produces computer concepts, procedures, models, systems and/or algorithms needed in the framework of the project.	3.5.1 They develop new computer concepts, procedures, models, systems and/or algorithms needed for the project.
		3.5.2 They logically verify the computer concepts, procedures, models, systems and/or algorithms produced.
		3.5.3 They argue the feasibility of the computer concepts, procedures, models, systems and/or algorithms produced.

Table 1. Dimensions, indicators and aspects that identify the level of the indicator in the learner. Source. Authors' elaboration.

This definition summarizes the characteristics of creative IT learning and places it in the fundamental context of IT creation: the project. It establishes the conditions for creative IT learning to take place and provides researchers with a definition, dimensions, and indicators to assess its development. Assessing the development of IT creativity can be challenging for novice researchers. In such cases, having quantitative measures that depend on the importance of each dimension for the organization would be convenient, especially for personnel selection. The metric for determining creative learning (*CA*) is $AC = 1/h \sum_{i=1}^{3} P_i * D_i$. Where: h is the number of dimensions, D_i is the evaluation of the i-th dimension and P_i is the weight. To calculate a dimension, a metric is $D_i = 1/m_i \sum_{j=1}^{m_i} 1/n_j (\sum_{k=1}^{n_{ij}} I_{ijk})$. Where: m_i: total indicators of dimension I, n_{ij}: total number of aspects to be assessed for indicator j of dimension I, I_{ijk}: assessment given to aspect k of indicator j in dimension i

To determine the weight of each dimension, it is recommended to use the paired comparisons' method. This method, although classified as a subjective weighting method (Martínez et al., 2018), allows for the quantification of the intensity of preference using the rating scale proposed by (Saaty, 1987). The AHP Online System, a computer tool for the hierarchical analytical process (HAP), will be used to determine these weights. Firstly, specialists with experience as computer science teachers and competence in educational research will be identified to make judgments on the relative importance of each dimension.

Table 2 displays the consultation that each expert was requested to complete, following the order presented in the first row of the table and considering the provided scale.

	Customization of IT processes	Confrontation with already existing IT processes that enable the emergence of subjective meanings.	Production, generation of own and "new" ideas during the implementation of an IT project
Customization of IT processes	1		
Confrontation with already existing IT processes that enable the emergence of subjective meanings.		1	
Production, generation of own and "new" ideas during the implementation of an IT project			1

Table 2. Expert consultation. Source: Authors' elaboration.

If the criterion in the row is more important than the one in the column, the more important it is according to the scale. If it is less important, the reciprocal of the value of the scale is used.

After evaluation of each dimension is determinate importance values gives by each expert about a dimension as is showing in table 3.

doi.org/10.32388/9ESFCM.3

Value	Definition	Comments
1	Equal Importance	Criterion A is equally important as criterion B.
3	Moderate Importance	Experience and judgement slightly favour criterion A over B
5	High Importance	Experience and judgement strongly favour criterion A over B
7	Very High Importance	Criterion A is much more important than criterion B
9	Extreme Importance	The greater importance of criterion A over B is beyond doubt
2,4,6,8	Intermediate values between the above when there is a need for nuancing	

Table 3. Saaty Scale. Source: Penades Pla (2017).

These results are aggregated using the geometric mean to arrive at a new consensus priority vector (Table 4).

	Criterion	Comment	Weights
1	Dimension 1	Personalization of information	16.3%
2	Dimension 2	Confrontation with the given	29.7%
3	Dimension 3	Idea generation	54.0%

Table 4. Weighting of dimensions. Source: Authors' elaboration.

In order to determine an evaluation scale for creative learning, it is necessary to evaluate the expression using the maximum value obtained. $VMáximo_{ijh}$ Subsequently, the formula of Medina Chicaiza (2022) is used to determine the equivalence, but it needs to correct the maximum and minimum of the interval because the way the intervals are calculated, the maximum of the previous interval is included as the minimum in the upper interval. This is an error that is easily correctable by adding a value small enough to be greater than the maximum of the previous upper limit and less than the next to this number. The formula to obtain this small number is, $o = \frac{1}{10^{r+1}}$ where r is the number of decimal places that the maximum value of the previous interval has. This leads to transforming the above author's formula 3 into the one presented as 3.1. In such a way that

Be

$$escala_{indi} = (VMínimo - ValMaxInter_1, \\ VMínimoInter\ _2 - \\ ValMaxInter_2, \ldots, VMínimoInter\ _{n-1} - VMáximo) \tag{2.1}$$

The distance between each of the maximum and minimum values of each interval is calculated according to the expression $Dist = \frac{VMáximo - VMínimo}{NumInt - 1}$ where $NumInt$ is the number of intervals in which the variable is measured. Having this distance, we then proceed to calculate the $VMaxInter_1 = VMínimo + Dist$. Once this maximum value is obtained, the minimum value of the second interval is obtained in the following way $VMínimoInter\ _2 = (VMaxInter_1 + o$ and the maximum value of the second interval is obtained as follows. $VMaxInter_2 = VMaxInter_1 + Dist$ In the case of the maximum of the second interval, the distance to the minimum value is not added to avoid the progressive addition and that it is reflected in the last interval. In this way, the value of the interval n $VMínimoInter\ _n = VMaxInter_{n-1} + o$ and the maximum value would be $VMáximo$.

Be $escala_{indi}$ the vector indicating the scales, $ValMaxInter_1, ValMaxInter_2, \ldots, ValMaxInter_n$ the maximum values of each of the scales, is the maximum value of the weighting of the course indicators, $VMáximo$ is the maximum value on the country scale, $TotalEscala$ is the maximum value on the country scale, $valmxinte$ is the maximum value of each interval, and $valmxinte$ is the minimum value.

The variation made to the proposed formula makes it possible to better establish the limits of each of the intervals in the scale. In addition, quantitative evaluation systems in the world do not go beyond two decimal places, so the sum of the proposed value does not make a significant difference and allows the limits of the interval to be clearly established. In this way, it is possible to evaluate any digital didactic ecosystem regardless of the evaluation scale and the criteria used in different countries, homogenizing the scale and making it comprehensible to any evaluator.

Using formula 3, the scale is determined according to the Cuban evaluation system for Higher Education, as shown in the following table:

Qualitative Scale	Quantitative Scale
Excellent	0.3
Well	0.23999
Regular	0.17998
Mal	0.11988

Table 5. Qualitative and quantitative scales. Source: Authors' elaboration.

The quantitative scale defined allows the assessment of creative learning and the determination of the level of development, taking into account the qualitative scale assumed.

Methods

A questionnaire is used to diagnose creative learning in computer science and computer engineering courses. The questionnaire is administered to all 66 students enrolled in the final year of the 2022 academic year. The self-assessment questionnaire for creative learning was developed by Moreno García (2019) for mathematics and adapted for computer science. It is intended for all students in computer engineering courses and takes into account all aspects that determine the level of this indicator. Students are asked to rate themselves on a scale of 1 to 10, where 1 means 'not at all' and 10 means 'completely'. This questionnaire was also used by Canjongo Daniel et al. (2022) and Molina Hernández et al. (2021).

The University of Matanzas offers two different curricula for its Computer Engineering program: a five-year program called Plan D, which includes only one class in the fifth year and ends in 2022, and a four-year program that started in 2018 as a result of improvements in higher education in Cuba. The curriculum for the four-year program has been in place since the same year. According to (Canjongo Daniel et al., 2022; Molina Hernández et al., 2021), students are requested to evaluate themselves on a scale of 1 to 10, where 1 means 'not at all' and 10 means 'completely'.

The hypothesis of this study is that creative computer science learning is fostered when students are exposed to a curriculum that includes computer science content for professional activities in an employing organization.

At the end of the course, students are expected to have a creative approach to learning computer science.

The results of the study are not provided in the given text.

The analysis of the results is divided into two parts. The first part is a qualitative analysis based on the evaluation of the variable and its qualitative scale. The second part uses inferential statistics to draw complementary conclusions.

Quantitative Analysis

	Second Year		Third Year		Fourth Year		Fifth Year	
Students	**Punctuation**	**Category**	**Punctuation**	**Category**	**Punctuation**	**Category**	**Punctuation**	**Category**
Student 1	0.054055556	Bad	0.154508	Regular	0.204595	Well	0.177706349	Regular
Student 2	0.145452381	Regular	0.114595	Bad	0.145452	Regular	0.145452381	Regular
Student 3	0.114595238	Bad	0.190452	Well	0.127341	Regular	0.12734127	Regular
Student 4	0.176309524	Regular	0.17091	Regular	0.027167	Bad	0	Bad
Student 5	0.145452381	Regular	0.100452	Bad	0.199508	Well	0.091396825	Bad
Student 6	0.027166667	Bad	0.236849	Well	0.10554	Bad	0.159595238	Regular
Student 7	0.018111111	Bad	0.17631	Regular	0.077254	Bad	0.181396825	Well
Student 8	0.072166667	Bad	0.055452	Bad	0.159595	Regular	0	Bad
Student 9	0.032253968	Bad	0.142881	Regular	0.231762	Well	0.159595238	Regular
Student 10	0.051484127	Bad	0.051484	Bad	0.027167	Bad	0.305047619	Excellent
Student 11	There isn’t	No	0.101571	Bad	0.263738	Excellent	0.145452381	Regular
Student 12	There isn’t	No	0.268825	Excellent	0.168651	Regular	0	Bad
Student 13	There isn’t	No	0.164683	Regular	0.177706	Regular	0.145452381	Regular
Student 14	There isn’t	No	0.218738	Well	0.232881	Well	0.213650794	Well
Student 15	There isn’t	No	0.21477	Well	0.185365	Well	0.077253968	Bad
Student 16	There isn’t	No	0.21477	Well	0.108111	Bad	0.027166667	Bad
Student 17	There isn’t	No	0.13029	Regular	0.168651	Regular	0.136396825	Regular
Student 18	There isn’t	No	0.074683	Bad	0.018111	Bad	0.092103968	Bad
Student 19	There isn’t	No	0.051484	Bad	0	Bad	0	Bad

Table 6. Quantitative and qualitative analysis. Source: Authors' elaboration

For this evaluation, the following Table 7 was obtained:

doi.org/10.32388/9ESFCM.3

	ACI				Percentage ACI			
	B	**R**	**G**	**E**	**B**	**R**	**G**	**E**
Second Year	7	3	0	0	70	30	0	0
Third Year	7	6	5	1	36.84211	31.57895	26.31579	5.263158
Fourth Year	7	6	5	1	36.84211	31.57895	26.31579	5.263158
Fifth Year	7	8	2	1	38.88889	44.44444	11.11111	5.555556
Typical Deviation	0	1.375	2	0.375				

Table 7. Student numbers by category and percentage. Source: Authors' elaboration.

The results of the second year are expected, as students have only covered basic cycle subjects and programming up to data structures. Database modelling is introduced in the second semester, but it is not until the first semester of the third year that requirements engineering is studied, marking the beginning of a computer engineer's training. Analysis and design are studied in the third year, and the cycle is completed with software testing in the fourth year. The standard deviations between the categories indicate that the differences are relatively small, particularly in the 'satisfactory' and 'poor' categories, where 67% to 73% of students are concentrated. This suggests that there is a low level of creative learning development in degree programs. Additionally, it is noteworthy that the proportion of students with grades in the 'poor' and 'okay' categories is concentrated in the fifth year. However, the final years of study, namely the 4th and 5th years, are of the greatest concern. To gain a more accurate understanding of this phenomenon, it is necessary to analyse the selection process for each student.

Table 3 in the following Appendix provides information on the selection process for each item. As can be seen, students selected the items that are most relevant to the core comprehension processes associated with creative learning (with mean values of 11 or more: 1.1.1–1.1.5, 3.4.1–3.4.5). This indicates that students are able to synthesize information at an appropriate level by expressing their ideas using computer symbols and comparing basic elements of computer content.

Students' choices have the fewest number of options (6 or fewer on average: 1.3. 1, 1.3.2, 1.3.3, 1.3.4, 1.3.5, 1.4.1, 1.4.2, 1.4.3, 1.4.4, 1.6.1, 1.6.2, 1.6.3, 1.6.4, 2.3.1, 2.3.2, 2.3.3, 2. 3.4, 3.3.1, 3.3.2, 3.3.3, 3.3.4). These aspects to be evaluated relate to subjective production, which involves creating a new project, searching for arguments for tensions discovered during the project, individualizing the form of computer content, and identifying information. This choice means that generating new projects and organizational forms of computer content, such as new models and algorithms in educational contexts and working practices, is impossible. The meanings generated by this process indicate that teachers aim to understand the content they teach rather than transcend it.

The voting results show a smaller difference between grades 4 and 5, particularly in the creation of new subjective products related to computerized content and going beyond the given. Only a few students in these grades were able to create new computer content, indicating that more grade 3 students learn about subjective meaning-making, which is at the heart of creative learning. This implies that the curriculum, teaching methods, and media used do not facilitate the subjective meaning-making required for creative learning. The higher level of creative learning in the third year is attributed to the students' historical development rather than the course itself. The learning process is integrated, allowing individuals to comprehend, apply, and retain the information provided.

Weaknesses

- The text highlights a lack of perception towards forms of creative learning such as generating ideas, confronting given problems, and finding new solutions.

- Additionally, there is a lack of confidence, trust, and commitment towards learning computer science. Many comments refer to the subject's usefulness in achieving other goals rather than the enjoyment of learning something new.
- The value of project- and role-based learning is not recognized by students who often struggle to accept mistakes as part of the learning process, have poor communication skills, and show little initiative in creating their own projects.
- There is no evidence to suggest that teachers have implemented integrated learning in a creative manner.
- The current organizational structure of the curriculum does not facilitate the transition from integrated to creative learning.

Strengths

- Students show a preference for teamwork.
- Students are familiar with computer symbols and signs.

The above text demonstrates the ability to promote and discuss ideas of interest. It is supplemented by the following statistical analysis.

Statistical analysis

		I11		I12		I13		I14		I15		I16	
		0	1	0	1	0	1	0	1	0	1	0	1
		%	%	%	%	%	%	%	%	%	%	%	%
Year	2	0	100	70	30	90	10	80	20	30	70	90	10
	3	5	95	79	21	95	5	84	16	42	58	63	37

Table 8. Comparison Second and Third Year. Source: Authors' elaboration.

		ED1
N		29
Normal parameters	Media	.3908
	Standard deviation	.18514
More extreme differences	Absolute	.205
	Positive	.174
	Negative	-.205
Kolmogorov-Smirnov's Z		1.104
Sig. asymptotic (bilateral)		.174

Table 9. Kolmogorov-Smirnov test for one sample. Source: Authors' elaboration.

This table allows us to affirm that it behaves in a normal way; it is not rejected that the distribution is not normal, which allows us to apply the t-test. To compare the assessment of the first dimension between the second and the third year, the t-test is applied.

doi.org/10.32388/9ESFCM.3

	Year	N	Media	Standard deviation	Standard error of the mean
ED1		10	.4000	.14055	.04444
			.3860	.20826	.04778

Table 10. t-test. Source: Authors' elaboration

Levene's test for equality of variance: F = 1.304 Sig. = 0.264, it is concluded that the variances are equal.

doi.org/10.32388/9ESFCM.3

T	Gl	Sig. (bilateral)	Difference in averages	Standard error of the difference	95% Confidence interval for the difference	
					Inferior	Top
0.191		0.85	0.01404	0.07361	-.13700	.16507

Table 11. Independent samples t-test. Source: Authors' elaboration

Since the interval contains zero and the alpha value is greater than 0.85, H0 is not rejected, which means there is no significant difference between second- and third-year students; there is no significant difference in the assessment of aspect 1 between second- and third-year students; there is no significant difference in the assessment of aspect 1 between second- and third-year students. In other words, even if there are differences among students, the curriculum, teaching, self-study orientation, and forms of assessment could not change students' creative learning in computer science. Repetitive teaching is the norm, where students only receive what they are taught, and their knowledge is assessed by instructors through tests and other forms of assessment.

doi.org/10.32388/9ESFCM.3

		I21		I22		I23		I24			I25		
		.0	1.0	.0	1.0	.0	1.0	.0	.8	1.0	.0	.8	1.0
		%	%	%	%	%	%	%	%	%	%	%	%
Year	2	40	60	90	10	100	0	70	0	30	70	0	30
	3	5	95	32	68	68	32	16	5	79	26	5	68

Table 12. Frequency tables for the indicators of the second dimension. Source: Authors' elaboration.

		ED2
N		29
Normal parameters	Average	.5486
	Standard deviation	.32467
More extreme differences	Absolute	.125
	Positive	.125
	Negative	-.125
Kolmogorov-Smirnov's Z		.676
Sig. asymptotic (bilateral)		.752

Table 13. Kolmogorov-Smirnov test for one sample. Source: Authors' elaboration.

To compare the assessment of the second dimension between the second and third year, we applied the t-test.

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	Year	N	Media	Standard deviation	Standard error of the mean
ED2		10	.2600	.25033	.07916
			.7005	.24901	.05713

Table 14. Group statistics. Source: Authors' elaboration.

Levene's test for equality of variance: F = 0.041 Sig. = 0.841, it is concluded that the variances are equal.

doi.org/10.32388/9ESFCM.3

T	Gl	Sig. (bilateral)	Difference in averages	Standard error of the difference	95% Confidence interval for the difference	
					Inferior	Top
-4.520		0.0	-0.44053	0.09746	-0.64049	-0.24056

Table 15. Independent samples t-test. Source: Authors' elaboration

There is a significant difference in the assessment of dimension 2 between the second and third years, which means that the third year is facing more of what they receive as curriculum than the second year. However, since there is no significant difference in the assessment of dimension 1, which is the basis for dimension 2, between years, we cannot be sure that this is due to teacher influence. This is due to group characteristics rather than to the presence or absence of a creative learning construct in computer science.

 doi.org/10.32388/9ESFCM.3

		I31		I32		I33		I34	
		0	1	0	1	0	1	0	1
		%	%	%	%	%	%	%	%
Year	2	70	30	70	30	100	0	60	40
	3	58	42	53	47	68	32	47	53

Table 16. Frequency tables for the indicators of the third dimension. Source: Authors' elaboration.

		ED3
N		29
Normal Parameters (a,b)	**Average**	.3707
	Standard deviation	.31068
More extreme differences	**Absolute**	.203
	Positive	.203
	Negative	-.165
Z de Kolmogorov-Smirnov		1.093
Sig. asymptotic (bilateral)		.184

Table 17. Kolmogorov-Smirnov test for one sample. Source: Authors' elaboration.

Due to the normality of the variables, t-tests were applied to compare the mean scores of each dimension between years 2 and 3. T-tests were applied to compare the scores of the third dimension between years 2 and 3. There were no significant differences in the scores of the three dimensions between years 2 and 3. This means that, as in dimension 1, neither educational activities with students, nor contact with IT content in senior courses, nor evaluation of the final project or work experience lead to their own new ideas. This means that educational activities do not lead to a shift from other forms of learning to creative learning.

Finally, the levels of creative learning in the second and third years are compared

doi.org/10.32388/9ESFCM.3

	Year	N	Average	Standard Deviation	Typical Error Average
ED1	**2**	10	.4000	.14055	.04444
	3	19	.3860	.20826	.04778
ED2	**2**	10	.2600	.25033	.07916
	3	19	.7005	.24901	.05713
ED3	**2**	10	.2500	.26352	.08333
	3	19	.4342	.32105	.07365

Table 18. Group statistics. Source: Authors' elaboration.

doi.org/10.32388/9ESFCM.3

		Levene's test for equality of variances		T-test for equality of means						
		F	Sig.	t	gl	Sig. (bilateral)	Average difference	Typical error of difference	95% Confidence interval for the difference	
		lower	Upper	lower	Upper	lower	Upper	lower	Upper	lower
ED1	Equal variances assumed	1.304	.264	.191	27	.850	.01404	.07361	-.13700	.16507
	Equal variances have not been assumed			.215	25.076	.831	.01404	.06525	-.12034	.14841
ED2	Equal variances assumed	.041	.841	-4.520	27	.000	-.44053	.09746	-.64049	-.24056
	Equal variances have not been assumed			-4.513	18.329	.000	-.44053	.09762	-.64536	-.23569
ED3	Equal variances assumed	1.899	.180	-1.556	27	.131	-.18421	.11841	-.42717	.05875
	Equal variances have not been assumed			-1.656	21.878	.112	-.18421	.11122	-.41493	.04651

Table 19. Independent samples test. Source: Authors' elaboration.

Here it can be seen that there are no significant differences between the second- and third-year groups with respect to dimensions 1 and 3, but in dimension 2 there are significant differences, with the third-year group being better evaluated.

doi.org/10.32388/9ESFCM.3

Year	N	Media	Standard deviation	Standard error of the mean
EC	10	.2774	.17684	.05592
		.5054	.20456	.04693

Table 20. Differences between the second- and third-year groups. Author's elaboration.

Levene's test for equality of variance: F = 0.071 Sig. = 0.792,
it is concluded that the variances are equal.

doi.org/10.32388/9ESFCM.3

T	gl	Sig. (bilateral)	Difference in averages	Standard error of the difference	95% Confidence interval for the difference	
					Inferior	Top
-2.981		0.0.006	-0.22802	0.07648	-0.38495	-0.07110

Table 21. Independent samples t-test. Source: Authors' elaboration.

There is a significant difference in the creative learning scores between second- and third-year courses, with a higher score in the third year. This means that the difference in creative learning between second- and third-year students is two-dimensional, that is, students are confronted with given and other learning spaces. This difference shows that third-year students are more likely to question the concepts, procedures, models, and computer systems they learn than second-year students. However, this difference does not mean that creative learning in the third year has reached the high level that it should be, both qualitatively and quantitatively, after another year of study.

Higher education in Cuba has moved from a five-year to a four-year system, which has led to the coexistence of the last two years of study: the fourth and fifth years are interesting to compare because they are the last years of study in different curricula. This raises the first question of whether the subject system itself guarantees creative learning for students. At the same time, taking the two different curricula as a basis, it is possible to compare whether the efforts of the course instructors have generally contributed to the development of creative learning as a goal for students to achieve.

Comparison of creative learning indicators between the 4th and 5th years of study

<table>
<tr><td colspan="2"></td><td>EC</td></tr>
<tr><td colspan="2">N</td><td></td></tr>
<tr><td rowspan="2">Normal parameters</td><td>Media</td><td>.4249</td></tr>
<tr><td>Standard deviation</td><td>.25833</td></tr>
<tr><td rowspan="3">More extreme differences</td><td>Absolute</td><td>.124</td></tr>
<tr><td>Positive</td><td>.124</td></tr>
<tr><td>Negative</td><td>-.110</td></tr>
<tr><td colspan="2">Kolmogorov-Smirnov's Z</td><td>.757</td></tr>
<tr><td colspan="2">Sig. asymptotic (bilateral)</td><td>.616</td></tr>
</table>

Table 22. Kolmogorov-Smirnov test for one sample. Source: Authors' elaboration.

doi.org/10.32388/9ESFCM.3

	Year		N	Media	Standard deviation	Standard error of the mean
EC				.4521	.25732	.05903
		5		.3963	.26366	.06215

Table 23. Group statistics. Source: Authors' elaboration.

Levene's test for equality of variance: F = 0.015, Sig. = 0.904, it is concluded that the variances are equal.

T	Gl	Sig. (bilateral)	Difference in averages	Standard error of the difference	95% Confidence interval for the difference	
					Inferior	Top
0.652	35	0.519	0.05584	0.08566	-0.11805	0.22973

Table 24. Independent samples t-test. Source: Authors' elaboration.

The results indicate that there is no significant distinction in the evaluation of creative learning between the third and fourth years. This suggests that despite the inclusion of different curricular designs, varying subjects, work projections, and increased preparation time for fifth-year students, the development of creative learning remains elusive. This analysis implies that the primary challenge lies in the theoretical shortcomings regarding the implementation of creative learning in computer science, impeding effective teaching in two essential aspects. Firstly, there exists a deficiency in the teacher's preparedness to approach computer science education using theoretical and methodological foundations derived from extensive research that incorporates psychological theories (Bonvillani, 2023; González Hernández, 2021a; González Rey & Mitjáns Martínez, 2022). Secondly, the application of practical work and other learning environments fails to fulfil their dynamic role in fostering students' engagement in research-oriented projects. Furthermore, the difficulties faced by the instructors highlight that the methodological framework of the degree program is insufficient in supporting the teachers to facilitate the development of creative learning in computer science. Additionally, it can be argued that the teaching of software engineering and management, as a vital component of the curriculum, does not contribute significantly to the cultivation of creativity in computer science, as its primary focus lies in the academic training of computer engineers. Ultimately, it is evident that the computer engineering program at the University of Matanzas falls short in producing innovative computer engineers, underscoring the necessity for ongoing attention and improvements in this regard. In order to achieve this objective, it is imperative to incorporate the university as a training institution for aspiring professionals within the leading computer organizations where these students will be assigned. Additionally, it is crucial to establish comprehensive support systems for these graduates throughout their training duration.

	Year	N	Media	Standard deviation	Standard error of the mean
ED1			.5000	.22906	.05255
	5		.4074	.26948	.06352
ED2			.4105	.29419	.06749
	5	18	.3783	.26476	.06240
ED3			.4605	.30349	.06963
	5	18	.4028	.28619	.06746

Table 25. Group statistics. Source: Authors' elaboration.

		Levene's test for equality of variances		T-test for equality of means						
		F	Sig.	t	gl	Sig. (bilateral)	Difference in averages	Standard error of the difference	95% Confidence interval for the difference	
									Top	Inferior
ED1	Equal variances have been assumed	.708	.406	1.128	35	.267	.09259	.08207	-.07402	.25920
	Equal variances have not been assumed			1.123	33.440	.269	.09259	.08244	-.07505	.26023
ED2	Equal variances have been assumed	.973	.331	.349	35	.729	.03219	.09219	-.15496	.21935
	Equal variances have not been assumed			.350	34.914	.728	.03219	.09192	-.15443	.21882
ED3	Equal variances have been assumed	.022	.884	.595	35	.556	.05775	.09710	-.13938	.25487
	Equal variances have not been assumed			.596	35.000	.555	.05775	.09694	-.13906	.25455

Table 26. Independent samples test. Source: Authors' elaboration.

The insignificance of the differences in mean values across each year indicates that the creative learning of computer science in computer engineering can be classified as poor. This finding contradicts the extensive body of literature that recognizes the strong creative nature of technology learning (Medina-Chicaiza et al., 2022; Ogawaa et al., 2020). The rating obtained further reinforces the findings from the comparison between the fourth- and fifth-year groups. It also emphasizes that the mere inclusion of teaching content, such as computer science, does not guarantee creative learning. Resolving the tension between students' goals and aspirations, the expectations of teachers regarding the computer engineer's role, and the social objectives outlined in the curriculum plays a crucial role in fostering creative learning. The statistical analysis conducted supports the qualitative analysis presented in the initial section.

Discussions

To comprehend the diagnosis of the current situation, it is crucial to position oneself within the social context of development in which these students are situated. In their youth, individuals structure and elaborate their assessments of reality and their interaction with it based on their understanding of the phenomenon, their perception of what it should be, and the existing research on it. The tension arising from these processes compels them to engage in disagreements and seek understanding in order to shape their own ideas. Consequently, they engage in constant arguments with those who allow them to do so, focusing on the branches of human knowledge that captivate their interest. At this stage, they immerse themselves in environments where they can debate and discuss subjects that excite them, enabling them to construct their own worldview and act accordingly. Throughout the process of constructing their worldview, subjective meanings emerge that will influence their path into adulthood, making it essential to diagnose their attention towards it. Admission to university represents the culmination of a series of tensions between their desired field of study, the possibilities available in the entrance exam, and their academic performance. Within this process, subjective meanings emerge in relation to the potential professions they can choose, and those who opt for computer science do not always possess an accurate understanding of the professional landscape in this field (Chaipidech et al., 2022; Pulley, 2021). Hence, individuals enter the field with a strong inclination towards creativity in design and other IT processes (Mellor, 2023; Rice et al., 2022). This indicates that their computer learning configuration is predominantly characterized by subjective senses inherent to creative learning. However, as they progress into the second year, the obtained results contradict various studies (Joon Kim & Chen-Bo, 2017; Stolaki & Economides, 2018) that emphasize the significance of creative learning in technology. One notable finding from the study is the role played by fundamental subjects, particularly mathematics, in computer science education.

Mathematics is indispensable for acquiring computer science knowledge (Dogucu et al., 2023; Humble, 2023). Surprisingly, it is the subject with the poorest performance in the first year of the course (Hernández et al., 2020). Mathematics provides the foundational content necessary for a well-rounded education and serves as support for subjects that delve into the profession's specific content. It is within these subjects that the initial personalized information related to the specialization is introduced, building interdisciplinary connections primarily with programming. Unfortunately, the emergence of negative subjective meanings associated with learning mathematics adversely affects programming education (Jamil & Bhuiyan, 2021; Verdú et al., 2012). This marks the first instance in higher education where subjective meanings strain the creative learning configuration of computer science. As highlighted in the research conducted by (Bueno Hernández et al., 2020), these subjective senses undergo transformation, shifting towards a search for new information and challenging the given knowledge due to the frustration experienced in learning mathematics.

Students′ practice in potentially employable organizations does not provide the space students need to seek knowledge beyond what they have been taught. They are limited to applying what is taught in the course and do not constitute a learning space where the search for knowledge, deviating from the given and creating new algorithms relevant to their work as computer scientists, can take place (González Hernández, 2021b). The search for solutions to the tensions between computing organizations and universities in the case of computer technicians has not yet been fully resolved in the existing literature, although solutions linked to science and technology parks have been created (González Hernández, 2022; Triadó-Ivern et al., 2015), but this is not a generalizable approach. Not all universities that train these professionals have parks at their disposal, nor do all parks involve students in their development processes. This point needs to be analysed and resolved from a theoretical perspective. In the survey, students from all grades responded to the statement ″My work experience should be available on ____″.

The use of an integrated project approach and a problem-solving approach are ways to develop creativity (Diyah Syaibana et al., 2022; González-Hernández, 2013). However, when asked in a survey, 75% of students indicated that there was a lack of knowledge about IT projects and that the project approach was not used correctly. The literature (González-Hernández, 2016; Ortiz-Pimiento & Diaz-Serna, 2020) also includes theoretical conclusions regarding the integration of subjects throughout each year and degree course for project-based learning in computer engineering.

Classrooms for studying computer science are virtually non-existent, access to materials provided by the teacher is commonplace, and information management leaves much to be desired. Despite free access to the Internet at universities, few students search for information (25%), and only 15% use scientific search engines such as Google Scholar or Scopus. This percentage indicates that professors do not use these sites in class and do not inform students about them; the main source of information for students is the Moodle course.

However, it may also be the case that the symbolic content of the creative teaching of computer science is not the most correct. In the answer to the last question of the questionnaire, 80% of the students answered that computer science consists of learning how to install antivirus software and repair computers, and this does not correspond to the professional image of computer science. In these situations, the emotions associated with computer science may or may not make students continue their studies. In the case of the students in the degree programme, 75% say that they like being a computer scientist; however, there are 25% who do not like the content of the profession. This is the first moment of confirmation or denial of the subjective construction of learning a profession according to the drama of the situation created.

The second moment of formation of creative learning occurs during the study of the basic subjects that constitute the foundation of the professional subjects that they will study later. In the second year, it became evident that the so-called basic subjects do not establish an interdisciplinary connection with the degree, as 90% of the students surveyed stated, while the literature suggests that they do (Moreno García, 2019). However, no studies have been found in relation to mathematics (Betancourt Ávila et al., 2009). The rest of the first- and second-year subjects, such as philosophy and economics, should be integrated into this work through problem situations and exercises that demonstrate their relevance, as proposed by 80% of the students in the degree programme. This will allow students to develop subjective senses such as the importance of these subjects for their profession, their liking for these subjects, and their satisfaction in receiving them.

Service learning is a key element of computer science education to stimulate creative learning in computer science (Marcilla-Toribio et al., 2022). It can be structured in courses, and there are isolated experiences (González Hernández, 2022), but in computer engineering, the year and the level of the degree course do not allow it due to the small number of subjects in the speciality.

In order to integrate subjects, it is necessary to go beyond the contents of each one of them; they must be integrated taking into account a problem in which each one of them contributes part of the solution, as stated in the literature (Pekrun, 2022; Tsai et al., 2023). This is the first link that confronts the content taught with the need to find new information and incorporate it into the project. This is a pathway that is interesting for 85% of the students to whom it is proposed. An analysis along these lines can be found in the literature (Azambuja, 2019; Bonfim & Rossato, 2023), but it is not computer science-oriented. The adoption of employing entities that provide real projects is very incipient at the moment; the students' proposal was to integrate into projects of students from higher years and collaborate with their solutions. This process would be enjoyable for the students in terms of the content discovered, the integration of the content created, and the personalized way of achieving integration.

The emergence of subjective social meanings related to the communities of interest in relation to the contents, the distribution of roles, the joint discussion of common and uncommon points between acquired and already known information, and the critical organization of the report of the results led to the emergence of subjective social meanings in favour of teamwork, as in the case of the diagnosis, where the highest score was given to the students. After this, degree courses typically blend basic subjects with those focused on computer engineering. For computer engineering students, this starts with a subject called 'requirements engineering', which provides an understanding of the initial steps IT professionals must take before beginning the computerization process. This subject is typically taught at the beginning of the third year of study. The course covers software engineering, software project measurement, and test management, as well as other engineering disciplines.

It is important for teachers to pay special attention to the emotional processes that may arise during the learning process, as this is when the fundamental elements of the profession are introduced. Extensive literature exists on the teaching of specific subjects and the creative process, both in pedagogical and computer science fields (Humble, 2023; Southworth et al., 2023). However, there is a lack of research on integrated subject work in general, where modelling is a crucial component. This limits teachers' ability to explore subjective meanings, question models, propose new models of computerization, create new computer projects, and engage in creative learning in computer science.

The third stage of creative learning formation in computer science occurs when students exclusively take professional subjects, which should be fully integrated to solve real-world projects. This is because each professional subject has a specific role to play, and different subjects provide the necessary content for their implementation. The act of assigning students to perform different roles highlights the subjective meanings associated with each action and enables them to choose their preferred profession. However, the level of student participation in the year-long interdisciplinary project, which included questions and texts aimed at integrating subjects, was low. The literature search indicates that integrative practice questions are not utilised in computer science research (Ferreira et al., 2023) or computer science education

(Anisimova et al., 2021; Tay et al., 2023). Therefore, these sources do not take into account all the necessary elements of managing and organising the learning process required to integrate multiple subjects into a complex problem.

During this stage of computer science education, students are presented with real-world projects of varying complexity. They are expected to demonstrate their ability to organise their work and provide effective and efficient solutions. It is important to avoid subjective evaluations unless clearly marked as such. It is evident that some students (an average of 3.75) are not aware of the emergence of unfavourable subjective meanings when proposing new projects. Few of the projects solved in the diploma course were proposed for this reason. Additionally, it is not demonstrated how to address possible contradictions that may arise in the project. Therefore, it can be concluded that tensions are not utilised to teach computer content annually. The process of teaching creative learning in computer science culminates in the preparation of exercises that demonstrate students' ability to implement expert behavioural models. The final exercise is a crucial component of this development and a fundamental learning space for assessing the formation of creative learning in informatics. During the diagnostic phase, it was found that 80% of the students did not have a topic for researching the process of computerisation.

Based on the preceding discussion, it can be concluded that there are three stages of emergence in the creative learning of computer science among professionals in this field.

The first stage involves developing new algorithms to solve typical programming problems or competitions, creating problems that can be solved using the studied computer science content, or generating new ideas on the practical applications of computer science. The objective of this study is to explore the emergence of a subjective sense of creative learning in core subjects. Personalized synthesis, questioning of model concepts, and other forms of computer representation are used in these subjects. The selection of people to form teams and collaboration with other members of a project are also important. Additionally, the identification of relevant knowledge and the recognition of mathematics and programming as core roles are crucial. This period leads to a more general subjective understanding of computer content, including the proposal of new hypotheses in which the computer plays an important role.

It is necessary to focus on the development of computerisation processes while taking into account the views of other team members on the chosen computer content for the project. At this stage, it is important to consider the objective use of computer content in problem-solving. Additionally, it is important to develop computer content that is clear, concise, and necessary.

Creative learning of computer science occurs when practising in an organization related to one's profession. At this stage, the text discusses the subjective meanings of individualizing computer science content and the contradictions that arise during decision-making in computer science projects. It also selects the most efficient and effective way to implement a computer science project and proposes generating new projects that integrate computer science content.

Teaching and learning computer science can be a non-linear process due to the emergence of subjective meanings. This study reveals that these subjective meanings can disrupt integration.

The first hypothesis has been rejected for the following reasons:

- Firstly, the number of students rated as 'good' or 'excellent' in creative learning in computer science is very low in relation to the total number of students and does not differ significantly between the four different year groups assessed.
- Secondly, student responses showed that very few students reported having a subjective sense of creative learning, and the standard deviation from the mean was also very low. There is little variation in the sample, with most students not perceiving creative learning in computer science.

The proportion of students in each year in which creative learning is developed is low. Third-year students recognized more subjective senses associated with creative learning than fourth-year students, suggesting that creative learning can develop without the intervention of the teaching-learning process.

The second hypothesis is rejected because it indicates that students taking the computer engineering course at the University of Matanzas are not in the final stages of creative learning in computer science. This is because only nine final-year students (25% of 19 and 18 students, respectively) rated their creative learning in computer science as 'good' or 'excellent'. It cannot be denied that the comparison of the two groups indicates insufficient formation of creative learning in computer science.

The study concluded that 75% of the students in this course were in the first or second stages of their education. In a doctoral study by Hernández et al. (2020), ambivalence towards mathematics was found. Students recognize the value of studying this subject in order to understand areas such as software engineering, programming, databases, and artificial intelligence, and acknowledge gaps in their education. However, they may be unwilling to take other mathematics courses that would enable them to overcome their perceived deficiencies.

The analysis of the students' trajectories reveals that work placements and other learning experiences do not contribute to their ability to engage creatively in full-scale research projects. This finding is supported by the majority of students' inability to identify a field or moment during their undergraduate studies when they participated in a full-time original project.

Some methodological structures of teachers' careers may be weak in ensuring ACI development. Additionally, the study by Anaya Hernández et al. (2019) suggests that training in software engineering and management may not be crucial, as it primarily focuses on the academic training of computer engineers. The questionnaire responses regarding life course were analysed and supported by qualitative interviews with students who were assessed as excellent in both groups. Additionally, an equal number of students rated as 'poor' and 'average' were selected from each group, and their results were compared. The students' statements were corroborated by interviews, all of which indicated their interest in the course due to their previous experience with computers. They completed all tasks assigned by their teachers with confidence and demonstrated proficiency in applying their knowledge. Additionally, they actively sought out opportunities to apply their skills and expand their understanding of the subject.

This assumes an initial stage where an individual's positive attitude towards computer science knowledge allows for the development of a career in this field. However, several studies have evaluated the case of students enrolled in undergraduate courses (Casas Delgadillo, 2020; Garita-González et al., 2021). They found that the feeling of being a computer science professional is related to being a user of technology, a topic not covered in the literature on subjective constructs as the first stage in the formation of creative learning in computer science (Bonvillani, 2023; Toledo Méndez et al., 2021).

The initial years of undergraduate education are dedicated to studying fundamental topics that become ingrained in a teacher's professional experience. During this period, subjective evaluations are formed and integrated with those from the previous phase. It is crucial for teachers to address professional issues that are incorporated into the core subject at this stage. Favourable subjective evaluations for these topics arise during this process.

Integrating the content of mathematics subjects with their own areas of expertise until they reached 'discrete mathematics', which plays an important role in programming subjects, was an interesting approach. This allowed students to learn more about this subject (Faura-Martínez et al., 2022; Gamarra Astuhuaman, 2021), which is considered difficult and complex for students, especially in computer engineering (Hernández et al., 2020).

The students' behaviour was focused on acquiring new knowledge about the topics, which resulted in the emergence of subjective interpretations related to deviation from the norm. Simultaneously, these mathematical concepts were integrated into programming topics, allowing for the inclusion of mathematical content in subjects that are motivated to learn and have a positive subjective interpretation of the mathematical content.

The inclusion of topics with both positive and negative connotations has been found to aid in the learning of rejected topics. This finding differs from previous studies that only analysed the subjective meanings of the topics (Martins-do-Carmo-de-Oliveira & Massot-Madeira-Coelho, 2020). It enables the customization of knowledge in a distinct manner from that suggested by Mitjáns Martínez (2013b).

By introducing specialized subjects, students are exposed to content that exemplifies the anticipated behavioural patterns in the organization where they are employed. They are directed towards resolving professional issues in the organization where they practice their profession, recognizing that this is the third milestone in their professional training. During this process, the meaning of learning a profession is shaped by life trajectories and negotiations. This meaning is subjective and can differ from other subjective structures of learning (Maceo Vargas & Tamayo, 2017; Toledo Méndez et al., 2021).

A new subjective perception that can emerge is the perception of the future as a computer technician, which is part of the personalization of knowledge. This tension arises when the organization's need for efficiency and effectiveness conflicts with the learning process, where students' mistakes are viewed as a natural part of learning (González Hernández, 2022). Students who are rated as 'excellent' or 'good' attribute their success to the support provided by the organization's experts and teachers, which helps them make fewer mistakes.

Subero and Esteban-Guitart (2020) suggest that seeking help from others can assist students in dealing with mistakes and their emotional impact, leading to increased emotional stability. Additionally, studies by (Accenture, 2007; Kusters et al., 2023) have shown that aligning the goals of employer organizations and universities can reduce tensions and prevent mismatches in expectations. Student support is an essential element in the development of creative learning in computer science.

Continuous problem-solving with appropriate support can elicit a subjective feeling that favours the creation of new ideas. According to student reports, the choice of technology, methodology, and development model is rewarding and brings new elements to the computerisation process in their institutions. The article introduces a new concept for computer technicians - the creation of models to guide the computerization process. This is a novel idea that has not been explored in the existing literature on computer science education (Claro et al., 2018; Garita-González et al., 2021).

The lack of modelling in the literature on computer science education is a problem that has not been addressed in model-driven software development. This is due to the crucial role of modelling in the computerization process, as highlighted by (López et al., 2022; Ngadiman et al., 2023), and the absence of modelling in the theoretical analysis of the training processes of these professionals, as noted by (Syafril et al., 2022; Wang, 2022).

Institutional computerization modelling involves constructing different models to represent the reality to be computerized and the systems developed to be incorporated into institutional processes subject to digital transformation (Zhao et al., 2023). The integration of symbols and signs developed in the field of informatics has been constructed differently to solve the relevant problems of enterprise computerization.

It is acknowledged that modelling is a unique and unrepeatable process in computerisation. However, the creativity and computer science literature do not address this issue (Ciriello et al., 2024; Zielínska et al., 2023). According to the students, modeling is inadequate or non-existent in their institutions, while those who are considered excellent model in practice. The analysis presented in these two paragraphs confirms that software process modelling is one of the factors that influence creative learning in computer science.

During the preliminary and transversal research phase, students conduct research on professional behaviour forms to solve problems guided by the scientific method. Connecting students from the preliminary stage to the real project creates a sense of satisfaction in solving the problem, implementing the solution to improve the process, and evaluating the results.

In the preparation phase, (Muñoz Pentón et al., 2018) suggest using basic questions as the main teaching approach. This allows for the integration of academic topics into increasingly complex answers over time. During the assessment process, students are evaluated on their understanding of the year's topic, including practical application issues.

The use of projects in professional practice often results in small new findings that are integrated and used to hypothesize about the new results needed to achieve the final outcome. This process characterizes the production of new ideas (Willemsen et al., 2023). Similarly, each project involves a unique combination of techniques, tools, and development models, making it a subjective production that involves new ideas. Thus, it is argued that solving real problems that lead to research is another element that constitutes creative learning in computer science.

Conclusions

While creativity is explained in various ways by different psychological streams, the Subjectivity Theory, as an aspect of the cultural-historical approach, successfully explains creativity by resolving the dichotomy between extrinsic and intrinsic, cognitive and affective. According to this theory, creativity is a configuration of three fundamental learning processes.

Creative learning in computer science is either a social or personal process, depending on the unit of analysis. The project provides the social context in which the basic process configurations recognized in the theory of subjectivity take place. Each of these processes has distinctive qualities and characteristics that stand out in the field of computing.

This text presents the weaknesses of the computer engineering undergraduate program and faculty at the University of Matanzas in implementing creative learning in computer science. Two analyses were conducted, which identified some theoretical

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inadequacies related to the preparation of the faculty and the learning area, where creative learning in computer science should be promoted.

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Conflicts of Interest

There is no conflict of interest.

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