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DISTRIBUTED COGNITION AND COLLECTIVE INTELLIGENCE IN THE CONTEXT OF CYBERCULTURE: AN ANALYSIS OF HYBRID TEACHING PRACTICES MEDIATED BY DIGITAL TECHNOLOGIES

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ABSTRACT

This article explores the use of digital tools to promote distributed cognition and collective intelligence in hybrid education. The research, conducted with mind maps and educational robotics, reveals how these technologies facilitate collaboration, knowledge organization, and collective learning, both in-person and remotely.

Keywords: Distributed cognition, Collective intelligence, Hybrid education, Digital technologies, Mind maps.

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COGNIÇÃO DISTRIBUÍDA E INTELIGÊNCIA COLETIVA NO CONTEXTO DA CIBERCULTURA: UMA ANÁLISE DAS PRÁTICAS DE ENSINO HÍBRIDO MEDIADAS POR TECNOLOGIAS DIGITAIS

RESUMO

Este artigo explora o uso de ferramentas digitais para promover cognição distribuída e inteligência coletiva no ensino híbrido. A pesquisa, realizada com mapas mentais e robótica educacional, revela como essas tecnologias facilitam a colaboração, a organização do conhecimento e o aprendizado coletivo, tanto presencial quanto remotamente.

Palavras-chave: Cognição distribuída, Inteligência coletiva, Ensino híbrido, Tecnologias digitais, Mapas mentais.

COGNICIÓN DISTRIBUIDA E INTELIGENCIA COLECTIVA EN EL CONTEXTO DE LA CIBERCULTURA: UN ANÁLISIS DE LAS PRÁCTICAS DE ENSEÑANZA HÍBRIDA MEDIADAS POR TECNOLOGÍAS DIGITALES

RESUMEN

Este artículo explora el uso de herramientas digitales para promover la cognición distribuida y la inteligencia colectiva en la educación híbrida. La investigación, realizada con mapas mentales y robótica educativa, revela cómo estas tecnologías facilitan la colaboración, la organización del conocimiento y el aprendizaje colectivo, tanto presencial como a distancia.

Palabras clave: Cognición distribuida, Inteligencia colectiva, Educación híbrida, Tecnologías digitales, Mapas mentales.

1. INTRODUCTION

The advancement of digital technologies and the widespread use of the internet have brought new possibilities to education, expanding the horizons of collaborative learning and enabling the emergence of concepts such as distributed cognition and collective intelligence. In the context of

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cyberculture, these technologies have facilitated the creation of interactive environments where knowledge can be dynamically constructed and shared among participants. This transformation creates a scenario in which teaching extends beyond physical boundaries, promoting hybrid educational practices that integrate both face-to-face and remote interactions.

Distributed cognition, as proposed by Hutchins (1995), suggests that the cognitive process is shared between human agents and artifacts, including digital technologies. This concept challenges the traditional view of cognition as an exclusively individual process by suggesting that the environment and external artifacts play fundamental roles in organizing and carrying out cognitive tasks. In the educational context, distributed cognition manifests, for example, when students use digital tools to construct knowledge collaboratively, promoting the organization and externalization of ideas in a collective manner.

In parallel, Pierre Lévy's (1999) theory of collective intelligence complements this approach by defining learning as a collaborative process in which the intellectual capacities of a community are enhanced through cooperation and the exchange of information. Collective intelligence takes on new significance in the digital age, as online networks and platforms enable the continuous sharing and co-construction of knowledge, transforming learning experiences and expanding access to a wide range of resources.

These approaches become particularly relevant in hybrid teaching, an instructional model that combines both in-person and remote learning. In addition to having been consolidated during the COVID-19 pandemic, hybrid teaching emerges as a crucial strategy for dealing with emergency situations, such as natural disasters. Recent flooding events in the state of Rio Grande do Sul illustrate how disasters can disrupt access to educational institutions. In such cases, exploring the potential of hybrid teaching allows pedagogical activities to continue remotely, ensuring flexibility and continuity of learning.

For hybrid teaching to reach its full potential, it is necessary to conceive it as a process that can be significantly enhanced by collective intelligence as a manifestation of distributed cognition. These concepts allow learning to become more collaborative, dynamic, and adaptable, transforming hybrid teaching into a truly integrated approach that not only meets pedagogical needs but also becomes a resilient solution in times of crisis.

This article explores the contributions of digital technologies to the promotion of distributed cognition and collective intelligence in hybrid teaching, highlighting the potential of these tools to transform pedagogical practices and foster more collaborative and effective learning.

2. THEORETICAL FRAMEWORK

2.1 Establishing Some Basic Concepts

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Distributed cognition is a theory that departs from the traditional view of cognition as an exclusively internal process of the individual. This perspective was initially developed by authors such as Hutchins (1995), who argue that cognition is not limited to the human brain, but is a process involving interaction with the environment, artifacts, and other individuals. In his words: "Cognition is distributed across human and technological agents, transcending the boundaries of individual actors" (HUTCHINS, 1995, p. 18). This concept implies that cognitive actions are organized through interaction with the external environment and other agents, whether human or non-human.

In the educational field, the theory of distributed cognition is particularly relevant, as learning environments are increasingly mediators of collaborative processes through digital technologies. Hollan, Hutchins, and Kirsh (2000) explain that cognition can be distributed in various ways: among the members of a group, between an individual's mind and external artifacts, or even over time, with the creations of past events affecting the present. They state that "all cognition is distributed, even when it appears to be isolated" (HOLLAN, HUTCHINS, and KIRSH, 2000, p. 10). In a digital educational environment, technological tools, such as mind maps and online collaborative platforms, act as these external artifacts that facilitate the distribution of cognition among participants.

This concept also extends to the organization of cognitive activities in hybrid educational environments, where digital resources are used to complement students' physical presence. For example, Scaife and Rogers (1996) introduce the concept of offloading, which refers to the ability to externalize cognitive processes into external representations, such as digital tools, to reduce an individual's cognitive effort and distribute these functions across available technological resources. They argue, "External representations can reduce cognitive effort, allowing students to focus their attention on other aspects of learning" (SCAIFE and ROGERS, 1996, p. 28).

In the educational context, offloading manifests when students use digital resources to share the process of problem-solving and knowledge construction, as seen in the case of collaborative mind maps. According to Hutchins (1995), the use of technological artifacts is crucial to the process of distributing cognition, and this becomes evident in educational contexts, where digital tools serve as an extension of the students' minds.

The concept of collective intelligence, formulated by Pierre Lévy (1999), is closely tied to the idea that knowledge is not an isolated construction but a collaborative and shared process. Lévy defines collective intelligence as "the ability of a community to cooperate intellectually to produce, share, and use knowledge" (LÉVY, 1999, p. 29). This concept is central to cyberculture, where the sharing of information in digital networks amplifies the potential for collective learning.

Cyberculture, in turn, is characterized by interactivity and the constant exchange of information in digital environments. For Lévy, cyberculture "promotes a new form of intelligence, based on the interconnectivity of networks and access to a multitude of sources of knowledge" (LÉVY, 1999, p. 17). In the educational context, this translates into the use of digital platforms and social networks as spaces for interaction, where students can collaborate, discuss, and collectively and continuously construct knowledge.

In Costa's (2021) study, collective intelligence is manifested during the implementation of

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collaborative activities using digital mind maps and educational robotics resources. These activities provide a learning environment where students work together to build knowledge, utilizing digital technologies as support. As noted by Jenkins (2008), digital convergence allows producers and consumers of knowledge to interact in ways that were previously impossible. "Collaboration among participants in cyberculture not only expands access to knowledge but also transforms the way it is produced and shared" (JENKINS, 2008, p. 45).

Collective intelligence and distributed cognition complement each other in educational environments mediated by technologies, where students share their ideas and benefit from the different perspectives and knowledge brought by others. Digital tools facilitate the externalization of thought, allowing knowledge to be visualized, discussed, and reorganized in real time, fostering a continuous process of collaborative learning. As highlighted in Costa's (2021) research, "the use of collaborative mind maps in educational robotics activities showed a clear increase in student engagement and idea sharing, fostering the creation of a collective intelligence environment" (COSTA, 2021, p. 67).

Distance Education (EaD), as outlined in the National Education Guidelines and Framework Law (LDB), has evolved significantly in recent decades, driven by the rapid development of digital technologies. In its Article 80, it is defined as "an educational modality that, through information and communication technologies, enables interaction between teachers and students, and among students themselves, without the need for physical presence in a common temporal space for all."

Although the LDB (National Education Guidelines and Framework Law) mandates that Elementary Education be in-person, it allows for Distance Education (EaD) to be used as a complement to learning or in emergency situations, as seen during the pandemic. In this context, hybrid teaching in Basic Education emerged as a solution to combine moments of in-person and remote interaction, integrating the use of digital tools to create a flexible and accessible learning environment.

According to Moran (2020), hybrid teaching "integrates the best of in-person and remote learning, utilizing digital technologies to facilitate communication, collaboration, and access to diverse content" (MORAN, 2020, p. 22). This methodology has proven effective in promoting collective intelligence and distributed cognition, especially when platforms are used that enable synchronous and asynchronous collaboration among participants.

Digital technologies, such as videoconferencing platforms, collaboration tools, and mind mapping resources, are essential for the success of hybrid teaching. They not only expand access to knowledge but also facilitate interaction between students and teachers, allowing learning to occur regardless of the participants' physical location. As noted by Costa (2021), "hybrid activities, which combined in-person and remote meetings, proved effective in promoting collaborative learning, mediated by digital tools that facilitated the distribution of cognition among students" (COSTA, 2021, p. 72)..

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2.2 Relationships Between Collective Intelligence, Distributed Cognition, and the Process of Implementing Hybrid Teaching

Collective intelligence and distributed cognition are fundamental concepts for understanding the process of implementing hybrid teaching in educational environments. Distributed cognition refers to how knowledge is constructed and shared among individuals, artifacts, and the environment, while collective intelligence manifests when groups of people collaborate, using digital technologies to amplify the cognitive potential of all involved (LÉVY, 1999, p. 29). In the educational context, these theories are critically interconnected to support innovative pedagogical practices that involve the interaction between students, technologies, and hybrid learning environments.

In hybrid teaching, cognition is distributed among students and technological artifacts, such as digital platforms, collaborative mind maps, and videoconferencing resources. These elements allow knowledge to be constructed collectively, even when participants are physically distant. As highlighted by Hollan, Hutchins, and Kirsh (2000), "distributed cognition involves coordination between individuals' minds and external resources, whether technological or material" (HOLLAN, HUTCHINS, and KIRSH, 2000, p. 15). During the process of implementing hybrid teaching, this dynamic of distributed cognition becomes an essential factor for the success of pedagogical practices.

Collective intelligence, in turn, manifests in hybrid teaching when students use these digital tools to collaborate and share knowledge, resulting in a learning environment that goes beyond individual capabilities. Pierre Lévy (1999) points out that collective intelligence "is the ability to coordinate knowledge and skills through digital interconnection, creating a collective force that overcomes individual limitations" (LÉVY, 1999, p. 17). In hybrid teaching, this digital interconnection occurs through platforms that allow for the exchange of ideas and knowledge construction in real time or asynchronously, such as through the use of mind maps and other collaboration tools.

The process of implementing hybrid teaching heavily relies on the ability to integrate these two dimensions: distributed cognition and collective intelligence. During the COVID-19 pandemic, many educational institutions adopted hybrid models to ensure the continuity of educational activities, revealing the importance of technologies that support these practices. The internet and its digital tools become essential in this context, enabling students to connect and collaborate, regardless of whether they are physically present in the same space. The flexibility provided by hybrid teaching allows cognition to be distributed among students, and collective intelligence to flourish in a collaborative environment, fostering learning.

In summary, distributed cognition and collective intelligence are key components in the process of implementing hybrid teaching, which, even after the pandemic, continues in higher education institutions. They enable students to work together, share knowledge, and expand their cognitive capabilities through interaction with technological artifacts. The internet, as a mediator of this process, provides the necessary infrastructure for these interactions to occur efficiently, fostering a learning environment that is adapted to contemporary needs for flexibility and collaboration.

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3. METHODOLOGY

This study used an exploratory and qualitative approach, with the aim of investigating how digital tools from cyberculture can promote distributed cognition processes and foster experiences of collective intelligence in collaborative educational activities. The methodology was structured based on participatory research, allowing direct interaction between the researcher and the focus group, enabling a richer analysis of the observed phenomena.

The participants in the study were five 8th-grade students from a public elementary school in the city of Passo Fundo, Rio Grande do Sul. These students, aged between 13 and 14, were involved in a hybrid teaching project that included both in-person and remote activities, using digital tools to collaborate in groups. The selection of this group was strategic due to the hybrid teaching format adopted by the school, as well as the students' availability and familiarity with the use of digital technologies in educational activities.

The school in question already had a minimal infrastructure for the use of digital technologies, such as internet access and computer labs, which facilitated the implementation of the research activities. All students had prior experience with the use of electronic devices and some digital tools, although at varying levels of proficiency. The group was composed of a diverse sample in terms of technological and academic skills, with different degrees of interest in the fields of exact sciences and technology. This diversity allowed for the observation of how students with different profiles interacted with digital tools and collaborated with each other to construct knowledge.

Student participation in the study was voluntary, and all legal guardians signed the Informed Consent Form (ICF), permitting data collection during the activities. Furthermore, the school provided logistical and technical support for the execution of the activities, ensuring that all students had access to the necessary digital tools, both in the in-person and remote activities.

The research activities were distributed over four sessions, conducted over the course of a semester, each lasting approximately 1 hour and 30 minutes. During these sessions, the students participated in collaborative activities focused on the use of digital mind maps and educational robotics. The development of these activities was structured to promote distributed cognition and allow students to experience processes of collective intelligence in the hybrid teaching environment. In total, the activities were spread across 4 sessions, detailed below.

During Session 1, the students were introduced to the concept of digital mind maps as a tool to organize and share their ideas. They learned how to use a collaborative digital platform, such as Google Jamboard or Miro, to create and edit mind maps in groups. The goal of this session was to promote the students' first interaction with the technology, highlighting how this tool could facilitate communication and the organization of knowledge in a visual manner, allowing ideas to be structured collectively.

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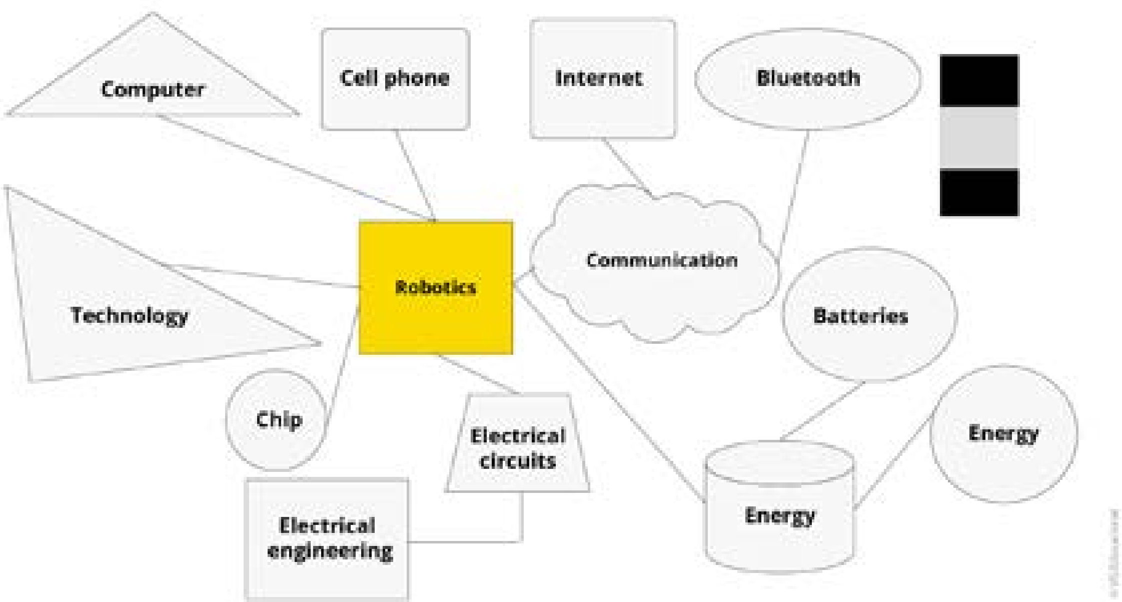
Figure 1: First Mind Map Created by the Students



Source: The Authors (2024).

Session 2 was held remotely, through a videoconferencing platform. The students continued working on the robotics project, collaborating both asynchronously and synchronously in the revision and updating of the mind map. In this stage, the focus was on understanding how cognition was distributed in a fully digital environment, analyzing the students' ability to coordinate their actions and construct knowledge, even without being physically present. The researcher observed the impact of technology on the synchronicity of interactions and the collective construction process, highlighting the flexibility of digital tools.

In Session 3, held in person, the students were challenged to apply the mind maps in the planning and programming of a robot, using robotics kits such as Lego Mindstorms. Each student group organized their ideas on the mind map (Figure 1), distributing tasks related to the project. This stage was designed to explore how distributed cognition processes emerged during collaboration, as students externalized their ideas and planned the project steps in a shared manner, allowing for a clear division of responsibilities and better coordination of actions.

Finally, in Session 4, also held in person, the students reviewed the final mind map and discussed the results of the robotics project, reflecting on the challenges faced throughout the process. At this stage, the focus was on evaluating the collective intelligence that emerged from the first digital collaboration, highlighting how the students organized their ideas, solved problems collaboratively, and shared their learning throughout the activities, consolidating the knowledge acquired and recording it in the mind map (Figure 2).

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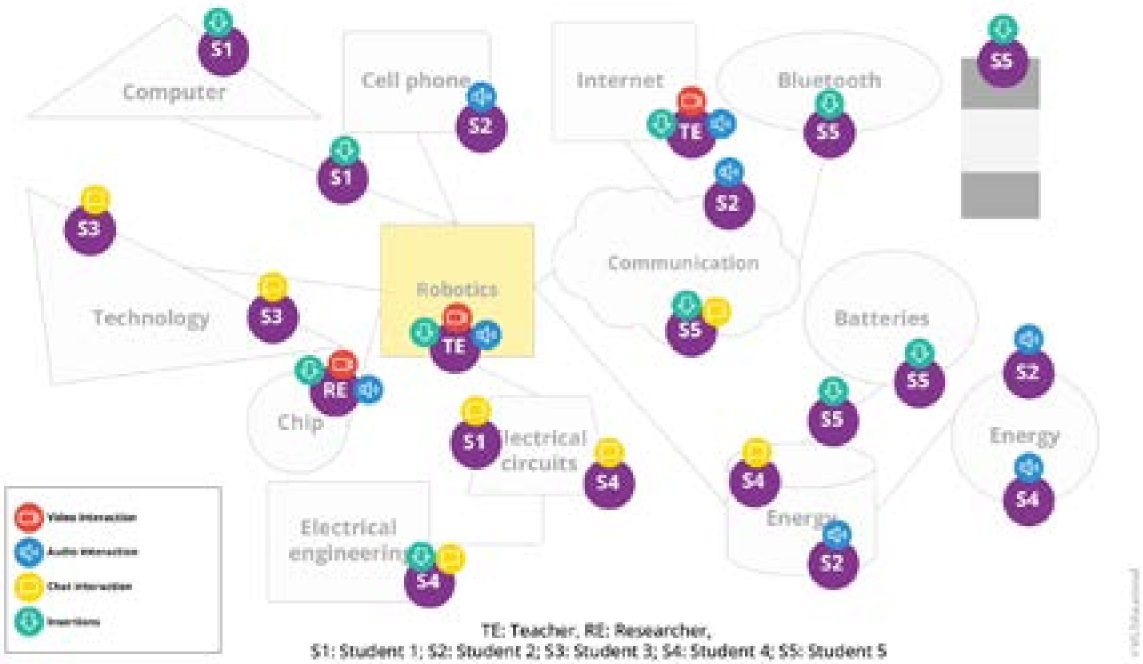
Figure 2: Detailed analysis of the first collective mind map on robotics



Source: The Authors (2024).

The data from this study were analyzed qualitatively, using the categories previously described. The analysis process followed three main stages, each playing a crucial role in organizing and understanding the collected data.

The first stage involved Data Organization and Coding. During this phase, the observation data, mind maps, and interview transcriptions were organized according to the thematic categories previously established in the methodology. The initial coding aimed to identify emerging patterns and recurring themes, such as the role of digital tools in collaboration among students, the way tasks were distributed in the hybrid learning environment, and the impact of these tools on the organization and construction of knowledge. Each of these aspects was carefully coded, providing an overview of the interactions and dynamics present in the observed educational activities. The organization of the data was essential for structuring the subsequent analysis, ensuring that all relevant information was categorized clearly and accessibly.

The second stage was Thematic Analysis, which involved a deeper and more detailed approach to the coded data. During this phase, the focus was directed toward the interactions between students and the digital tools used, with particular attention to how distributed cognition manifested in the learning environment. The thematic analysis aimed to understand how students used technologies, such as mind maps and collaborative tools, to divide tasks, share ideas, and collaboratively construct knowledge. This stage was crucial for identifying how digital technologies not only facilitated communication among participants but also played an active role in structuring collective thinking. The thematic analysis revealed valuable insights into the impact of distributed

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cognition on educational activities, highlighting both the benefits and challenges faced by students when using these technologies.

The final stage, Interpretation and Discussion, was dedicated to a critical analysis of the data in light of the theoretical framework presented earlier. The focus of this phase was to understand how digital interactions mediated the process of collective knowledge construction and how these interactions align with the theories of distributed cognition and collective intelligence. The analysis sought to relate empirical findings to theoretical concepts, highlighting the implications of the results for pedagogical practice in hybrid learning. The interpretation of the data allowed for exploring not only the role of technologies in promoting collaboration but also the factors influencing the success or challenges in implementing these tools in educational settings. This stage provided a solid foundation for discussing how the study's findings can be applied to future educational contexts and suggesting improvements in the use of digital technologies to promote collective learning. It is worth noting that each of these stages was essential for developing a comprehensive analysis of the data, ensuring that the nuances of interactions and the use of technologies were fully explored.

The analysis of the collected data was organized into four central categories, in accordance with the theoretical framework adopted by the author, which aims to understand how digital tools and hybrid learning promote distributed cognition and collective intelligence within the educational environment.

The first category, Distributed Intelligence, explored how cognition is shared among various actors, artifacts, and the educational environment. The focus was on identifying how the use of digital technologies, such as mind maps and educational robotics, facilitated the distribution of knowledge between students and technological resources, promoting a collective process of knowledge construction. From this perspective, the research sought to understand how the interaction between students and digital tools expanded the possibilities for collaboration and learning in a hybrid environment.

The second category, Valuing Intelligence, examined how educational activities and digital tools promoted the recognition and appreciation of individual intelligences within the group. The study observed how technology-mediated collaboration allowed each student to contribute their specific skills, enriching the collective work. This appreciation was evident as students had the opportunity to apply their competencies meaningfully, both in organizing activities and in carrying out practical tasks.

In the third category, Real-Time Coordination, the study investigated the students' ability to coordinate their actions synchronously, especially in activities involving the use of digital technologies. Moments were observed when digital tools facilitated efficient communication and appropriate task management, both in face-to-face and remote meetings. The ability to make real-time adjustments and share information instantly highlighted the role of technologies in facilitating distributed cognition and collective intelligence in the educational process.

Finally, the fourth category, Mobilization of Effective Skills, analyzed the students' ability to mobilize their skills effectively during task execution, particularly in practical activities such

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as programming and assembling the educational robot. The research aimed to understand how digital tools allowed students to apply their knowledge collaboratively and in an organized manner, facilitating learning and the joint solution of problems. The interaction between the students' skills and the technologies used demonstrated the potential of digital tools in promoting a more dynamic and cooperative learning experience.

Thus, the four categories form an interdependent cycle: Distributed Intelligence facilitates the Valuation of Intelligence, which in turn is sustained through efficient Real-Time Coordination, culminating in the Mobilization of Effective Skills. Together, they explain how digital technologies can mediate complex educational processes, promoting a more collaborative, dynamic, and effective learning experience in hybrid teaching contexts.

The data were analyzed qualitatively, using the categories described above. The analysis followed three main stages. First, there was the Organization and Coding of Data: the observation data, mind maps, and interview transcripts were organized and coded according to the thematic categories. The initial coding allowed for the identification of patterns and emerging themes, such as digital collaboration, task distribution, and the impact of digital tools.

The second stage was the Thematic Analysis. During this phase, an in-depth thematic analysis was conducted, focusing on the interactions between students and digital tools. The analysis sought to understand how distributed cognition manifested during the activities and how students used digital tools to collaborate and construct knowledge efficiently.

Finally, the Interpretation and Discussion phase took place. In this last stage, the data were interpreted in light of the theoretical framework presented earlier, with the aim of understanding how digital interactions mediated the process of collective knowledge construction. The analysis discussed the findings in the context of the theories of distributed cognition and collective intelligence, highlighting the implications of these results for hybrid learning.

4. RESULTS AND DISCUSSION

Distributed cognition, as described by Hutchins (1995), occurs when cognitive processes are shared among agents (students), digital tools (artifacts), and the learning environment. During the observed activities, this distributed cognition was clearly facilitated by the digital mind maps, which acted as external supports for storing and organizing the knowledge in progress.

In Meeting 1, students were introduced to the creation of collaborative mind maps, and from the outset, it was possible to observe how the cognitive process was distributed between individuals and the digital tool. As they collaboratively added information to the mind map, the students externalized their ideas, allowing the entire group to visualize and interact with each member's thinking. The externalization of thought, a central concept in distributed cognition, became evident as the students organized topics on the mind map and used the diagram as a reference for discussions and decision-making.

This externalization also facilitated greater fluidity in communication and collaboration. Throughout Meeting 3, when the students began using the mind map to plan the construction of the robot, it became evident that the use of this artifact reduced the individual cognitive load. The mind map served as an external resource for storing information about the project's stages, freeing the students' memory so they could focus on specific tasks such as programming and assembling the robot. This process is described by Scaife and Rogers (1996) as "offloading," where external representations (in this case, the mind map) reduce cognitive effort, enabling students to work more effectively and in an organized manner.

Furthermore, cognitive distribution among the students was observed in how tasks were divided based on each participant's individual skills. For instance, a student with higher proficiency in mathematics took the lead in the calculations and measurements of the project, while another student, experienced in programming, focused on coding the robot's functions. This task division illustrates how distributed cognition manifests in collaborative contexts, where each individual's knowledge and skills complement one another, resulting in more efficient collective work.

During Meeting 2, which was held remotely, distributed cognition was observed in the virtual environment. Even at a distance, the students continued to collaborate through the videoconferencing platform and the digital mind map, which remained an external representation of shared knowledge. During this stage, the mind map served as a common point of reference, where each student could add, review, and reorganize information as needed. This collaborative editing process demonstrated how each student's ideas were integrated into the collective knowledge, reinforcing the distributed nature of cognition, both in the in-person and remote environments.

4.2 Manifestations of Collective Intelligence

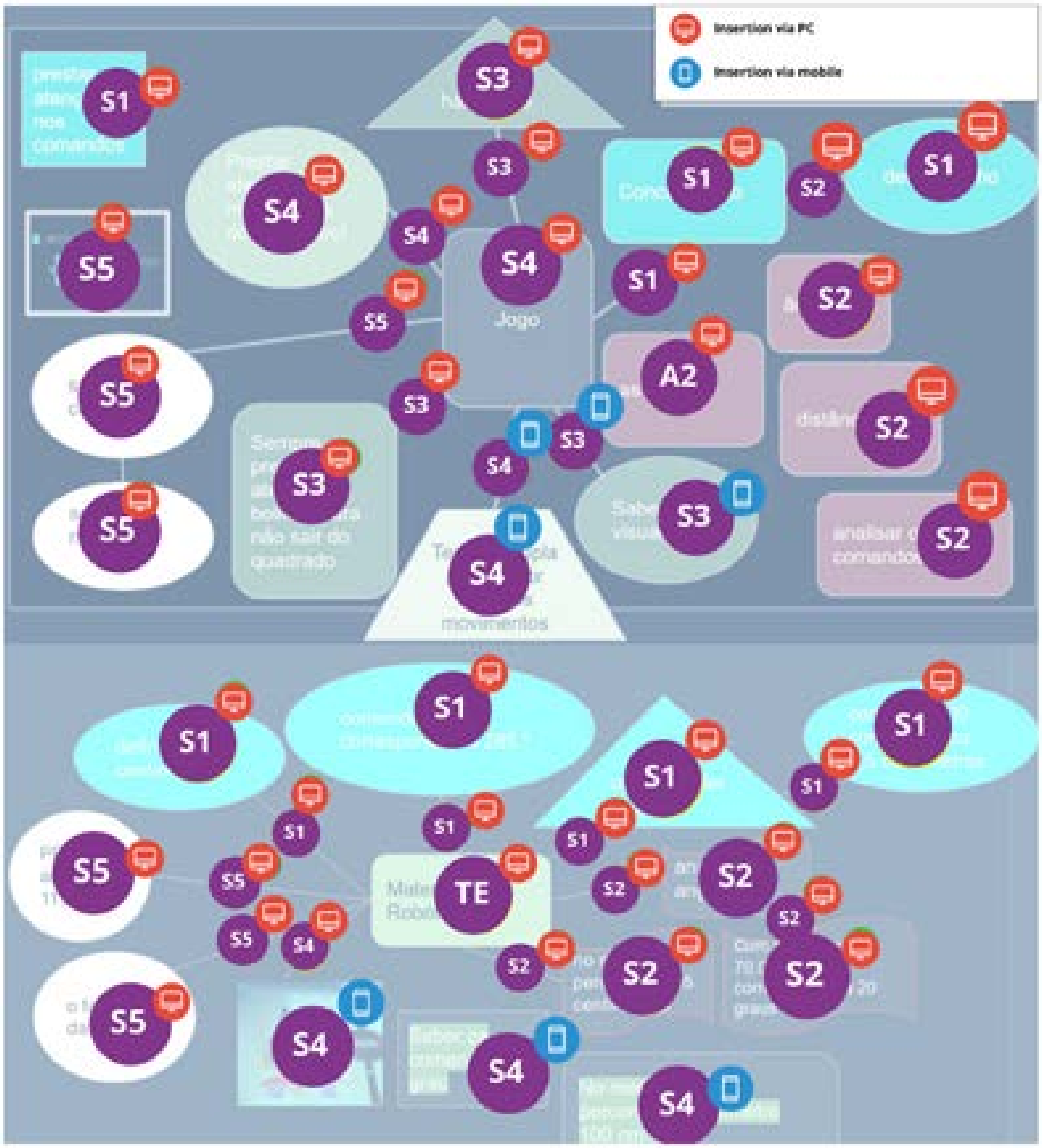
Collective intelligence, as defined by Pierre Lévy (1999), involves the ability of a group of individuals to coordinate their knowledge and skills to achieve results that surpass the sum of the individual contributions. During the meetings, the manifestation of collective intelligence became particularly evident as students collaborated to solve problems and complete the educational robotics activities, utilizing digital technologies as tools.

Even at a distance, the group was able to maintain coordination and cohesion, using the mind map as a tool to support both distributed cognition and collective intelligence. The students' ability to collaborate efficiently, despite the limitations of the remote environment, highlights the crucial role of digital technologies in facilitating collective intelligence in hybrid learning contexts.

Another example of collective intelligence was observed in Meeting 3, conducted in person, in a technological environment, where the process of building and programming the robot required intense collaboration among the students. They used the digital mind map to distribute tasks and track the progress of each stage of the project. Collective intelligence emerged as the students, with varying levels of knowledge and skills, made complementary contributions to the completion of the task. One student remarked: "I knew how to program, but I wasn't as good with measurements and calculations, so my classmate helped me with that. Together, we were able to make the robot work." This statement reflects the central role of collective intelligence, where the group, as a whole, was able to integrate individual contributions to solve a complex problem that no single student could have resolved alone.

This collective intelligence was particularly evident when the students reviewed the mind map during Meeting 4, reflecting on their individual contributions and how they were integrated into the final work (Figure 3). The mind map, which at the beginning of the activity was fragmented and contained disconnected information, evolved into a cohesive representation of the planning and execution of the robotics project, demonstrating the success of collaboration and collective intelligence in the learning environment.

Figura 3 - Analysis of the final collective mind map on robotics, created during the last two meetings



TE: Teacher, RE: Researcher,
S1: Student 1; S2: Student 2; S3: Student 3; S4: Student 4; S5: Student 5

Source: The Authors (2024).

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During the four meetings, it was possible to observe the three key elements present in processes of distributed cognition (HOLLAN, HUTCHINS, & KIRSH, 2000). The first element refers to the cognitive processes being distributed among the members of a social group, which in this case are the students and the teacher. The second element involves the coordination between internal and external structures, meaning both cognitive and environmental elements. Throughout the activities, students were encouraged to employ effective skills such as communication, logical reasoning, empathy, collaboration, and technological expertise.

The third element is related to the processes being temporally distributed, such that the results of previous events can transform the nature of subsequent events. This point became evident in the evolution of the students' handling and understanding of the mind maps over each session. The mind maps helped to distribute the cognitions produced during the first and second remote meetings to the activities carried out during the third and fourth in-person meetings. In this way, each activity influenced the progression of the next, and the final collaborative outcome would not have been achieved without the previous steps.

We also observed the presence of collective intelligence processes across the four activities. Real-time coordination occurred in the management of activities, with the first one being conducted by the researcher and the subsequent meetings being led by the teacher, in addition to the coordination between the students, which intensified throughout the sessions. The valuation of intelligence was particularly evident in moments when students realized what they could accomplish through technologies, along with small insights on how to apply various mathematical elements within a digital culture context. The mobilization of effective skills manifested in the digital and emotional competencies employed during the activities, both in handling technological artifacts and in teamwork.

The implementation of the Flipped Classroom (Sala de Aula Invertida, SAI) in educational activities promoted greater autonomy and developed students' collaboration abilities. According to Oliveira, Macedo, and Rauta (2023), *"the Flipped Classroom contributed to the enhancement of the teaching and learning process, making it more dynamic, faster, and enjoyable"* (OLIVEIRA; MACEDO; RAUTA, 2023, p. 45). This aligns with the findings of the current study, where digital tools facilitated the externalization of ideas and the joint construction of knowledge.

Digital technologies, particularly collaborative mind maps, played a central role in the success of the collaborative activities, facilitating both distributed cognition and collective intelligence. The mind maps provided a visual and intuitive interface that allowed students to externalize their ideas, organize information, and collaborate in real time, both in face-to-face and remote sessions.

The results showed that, in the hybrid learning environment, digital tools offer the necessary flexibility for students to collaborate effectively, regardless of their physical location. The ability of students to access and edit the mind map both synchronously and asynchronously demonstrated how distributed cognition can transcend temporal and spatial limitations, fostering collective intelligence in a flexible learning environment.

The students' testimonials indicated that digital tools not only facilitated the organization of group work but also increased engagement and motivation, as everyone could visualize the progress of the project and contribute meaningfully. One student reported: "It was good to see on the mind map what everyone was doing, because that way we knew we were heading in the right direction." This feedback confirms the importance of digital artifacts in promoting a shared vision of ongoing work, a central element in both distributed cognition and collective intelligence.

Despite the positive results, the research also revealed challenges in the implementation of the activities. One of the main challenges was technological accessibility. During Meeting 2, some students faced difficulties with internet connectivity, which hindered the continuity of remote collaboration. These obstacles highlight the need for a robust technological infrastructure to ensure that all students can fully participate in activities, especially in hybrid learning contexts, where remote participation is essential.

Another challenge observed was the level of familiarity students had with the digital tools. Although mind maps proved to be effective as tools supporting distributed cognition and collective intelligence, some students initially had difficulty using the digital platform. However, as the sessions progressed, these students began to feel more comfortable with the technology, indicating that continuous practice and technical support can help overcome these barriers.

5. FINAL CONSIDERATIONS

This study explored how the use of digital technologies, particularly collaborative mind maps and educational robotics resources, can promote distributed cognition and collective intelligence in hybrid learning environments. The research revealed that these tools not only facilitate interaction among students but also contribute to a reorganization of pedagogical practices, where the distribution of cognition and the co-creation of knowledge become central.

A fundamental aspect that emerges from this investigation is the role of digital technologies as mediators, not only of learning but also of the transformation of the educational environment. By providing spaces where students collaborate in real-time and externalize their thinking, digital tools demonstrate the potential to reduce reliance on the traditional teaching format, which still prevails in many educational contexts. This study proposes that hybrid learning, supported by technologies, offers an innovative and adaptable response to emerging scenarios, whether they are public health crises, such as the COVID-19 pandemic, or natural disasters that disrupt physical access to schools.

Another central element, still underexplored in other studies, is the ability of hybrid learning to create a culture of collective learning, where collective intelligence develops in a self-sustaining manner. It was observed that throughout the activities, students not only engaged with the tools but also began to value and promote group learning, integrating more actively into the process of knowledge construction. This development goes beyond conventional pedagogical goals and suggests that the continuous use of practices based on distributed cognition can shape a new generation of learners, prepared to navigate collaborative, interconnected, and complex environments.

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Furthermore, by conceptualizing hybrid learning as a continuous process of improvement, the study points to the need for educational institutions to invest in enhancing these environments, exploring the more sophisticated use of collaborative tools to support the comprehensive development of students. The adoption of hybrid learning as a permanent practice should be accompanied by a constant review of the technologies and methodologies employed, ensuring that the potential for distributed cognition and collective intelligence continues to expand.

The results of the research also raise several questions that deserve further exploration in future studies. One relevant area for investigation is the analysis of how different specific technologies impact the development of collective intelligence and distributed cognition across various disciplines. Additionally, it would be important to examine whether the continuous practice of collaborative activities in hybrid environments can permanently impact students' teamwork and problem-solving skills.

Another important issue would be to explore the perceptions of students and teachers regarding the effectiveness of hybrid learning mediated by digital technologies in promoting more collaborative and resilient learning. Finally, a longitudinal analysis of hybrid learning practices over the course of an entire school year could provide a more comprehensive view of how distributed cognition and collective intelligence evolve and solidify as pedagogical practices.

Finally, this study suggests that hybrid learning, mediated by distributed cognition and collective intelligence, goes beyond temporary adaptations for crises and becomes a transformative teaching model, catering to a student profile that is increasingly digital and connected. The exploration of these technologies, when properly integrated into the curriculum, can create more resilient, collaborative, and future-oriented educational environments, equipped to address the demands of a constantly changing world.

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