KNOWLEDGE MANAGEMENT IN THE STEM/STEAM TEACHING SYSTEM

A GESTÃO DO CONHECIMENTO NO SISTEMA DE ENSINO STEM/STEAM

GESTIÓN DEL CONOCIMIENTO EN EL SISTEMA DE ENSEÑANZA STEM / STEAM

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ABSTRACT: STEAM education ("Science, Technology, Engineering, Art and Mathematics" in Portuguese, "Science, Technology, Engineering, Art and Mathematics") aims to cultivate model-literate citizens by empowering students with knowledge, skills and values for the 21th century. Knowledge Management (KM) offers resources to enable these connections between disciplines and professors. This study has as general objective to analyze the possibility of the Ba environments (physical and virtual) to be mediated by the GC. The research is applied in nature with a qualitative approach through a hypothetical-deductive model with data collection via literature review. As a result, an analysis is presented on the possibility of physical and virtual environments being mediated by the KM, where the importance of establishing an environment conducive to the creation and sharing of knowledge was verified. In addition, efficient and systematic methods must be applied to manage knowledge within the teaching organization.

KEYWORDS: STEAM. STEM. Education. Knowledge Management.

***RESUMO**: A educação STEAM ("Science, Technology, Engineering, Art and Mathematics", em português "Ciências, Tecnologia, Engenharia, Arte e Matemática") pretende cultivar cidadãos alfabetizados no modelo através da capacitação dos alunos com conhecimentos, habilidades e valores para o século 21. A Gestão do Conhecimento (GC) oferece recursos para viabilizar essas conexões entre disciplinas e docentes. Este estudo tem como objetivo geral analisar a possibilidade dos ambientes Ba (físico e virtual) serem mediados pela GC. A pesquisa é de natureza aplicada, com abordagem qualitativa, através de modelo hipotético-dedutivo com coleta de dados via revisão da literatura. Como resultado, apresenta-se uma análise sobre as possibilidades dos ambientes físico e virtual serem mediados pela GC, onde constatou-se a importância de se estabelecer um ambiente propício para criação e*

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compartilhamento do conhecimento. Além disso, deve-se aplicar métodos eficientes e sistemáticos para gerenciar o conhecimento dentro da organização de ensino.

PALAVRAS-CHAVE: *STEAM. STEM. Educação. Gestão do conhecimento.*

RESUMEN: *El objetivo de la educación STEAM ("Ciencia, Tecnología, Ingeniería, Arte y Matemáticas") es formar modelos de ciudadanos alfabetizados dotando a los estudiantes de conocimientos, habilidades y valores para el siglo XXI. La Gestión del Conocimiento (GC) ofrece recursos para posibilitar estas conexiones entre disciplinas y profesores. Este estudio pretende analizar la posibilidad de que los entornos Ba (físicos y virtuales) estén mediados por la KM. La investigación es de naturaleza aplicada, con enfoque cualitativo, mediante modelo hipotético-deductivo con recogida de datos a través de revisión bibliográfica. Como resultado, se presenta un análisis sobre las posibilidades de los ambientes físicos y virtuales de ser mediados por la GC, donde se constató la importancia de establecer un ambiente propicio para la creación y compartición del conocimiento. Además, deben aplicarse métodos eficaces y sistemáticos para gestionar el conocimiento dentro de la organización educativa.*

PALABRAS CLAVE: *STEAM. STEM. Educación. Gestión de Conocimiento.*

Introduction

Economic growth and social development are related to the skills of the population: one of the goals of knowledge development in education should be for all young people to achieve at least a foundation for work, not just to have access to traditional education (LUDGER, 2015). In addition, the World Economic Forum mentions the importance of empowering people to have skills for today's business world, such as: problem solving, human management, and emotional intelligence (SOFFEL, 2016). Consequently, it is detected that the STEAM proposal has been applied in the academic, political, and economic spheres. It should be noted that the term STEAM is an acronym for Science, Technology, Engineering, Art, and Mathematics. Understanding this world of diversity becomes relevant to ensure global competitiveness.

Regarding the education sector, Kuenzi (2008) and Sanders (2009) point out that STEAM is an outstanding educational movement. Moreover, it is detected that in STEM/STEAM Education, teachers have great responsibility in analyzing, developing, and implementing their curriculum goals. However, the absence of a clear and procedural language to describe the teaching practice, which should be developed by their students, limits how these teachers can capture and accumulate their professional knowledge to thus analyze, understand, and recapitulate the successes and failures during their students' learning processes. This highlights the importance of collecting information in order to later share experiences in a comparative, analytical, and cumulative way that allows the improvement of pedagogical practices.

According to Servin (2005), Knowledge Management (KM) comes to contribute to the process of building and leveraging knowledge, comprising all its phases, acting to improve access to and use of resources, applying efficient and systematic methods to manage knowledge within the organization. Ba spaces (or environments), according to Tonin (2018), provide a suitable context for the continuous creation of new knowledge.

The concept of Ba was originally proposed by Japanese philosopher Kitaro Nishida and was further developed by Shimizu. 'Ba', which in the Japanese language is represented by the kanji 場, whose meaning is the radical for 'place', is here defined as a shared context in which knowledge is shared, created and used. In knowledge creation, Ba provides the energy, quality, and place to perform the individual conversions and for the subject to travel the knowledge spiral. Ba is a place where information is interpreted to become knowledge (NONAKA *et al.*, 2000). In addition, it is emphasized that every participant in a Ba space cannot be a mere spectator, he must be engaged, through action and interaction, in order to be a protagonist.

This study aims, therefore, to analyze the possibility of Ba environments (physical and virtual) being mediated by KM.

Methodology

This study is of applied nature, with qualitative approach, developed through exploratory research. The applied nature, according to Prodanov and Freitas (2013), involves local interests, generating knowledge that enables practical application in order to solve problems. The qualitative approach, according to Denzin and Lincoln (2006, p. 17), involves the "study of the use and collection of a variety of empirical materials, [...] that describe routine and problematic moments and meanings in the lives of individuals." For Creswell (2010), it is a means of understanding and exploring the meaning of a social or human problem, by groups or individuals. This author indicates that it is based on philosophical conceptions, research, methods of collecting, interpreting, and analyzing text and image data. Furthermore, this same author points out that, from an inductive style, one focuses on the importance of interpreting the complexity of a given situation and individual meaning.

The exploratory research, according to Prodanov and Freitas (2013), allows flexible planning, which enables looking at the theme from various aspects and angles, involving bibliographic survey and analysis of examples that stimulate understanding. This study follows the methodological proposal of Quivy and Campenhoudt (1995), such that, from bibliographic research and reading of texts, the systematization of ideas arising from readings allows the researcher to perceive aspects of an initial question resulting from readings and/or experiences.

It is emphasized the exploration of the theme in an effective way, which naturally directs the researcher to the elaboration of the problem, and the objective is not to validate preconceived ideas, but to discover other ideas. These same authors indicate that the scientific research elaboration process has three central axes: (1) rupture - consists in breaking both with traditional and pre-established logics and with false evidence that gives the illusion of understanding the object to be researched; (2) construction - allows the logic, which is supposed to be the basis of the study, to be expressed through the construction of an explanatory proposal of the object of study: without this theoretical construction there is no valid research; and (3) verification or experimentation - allows the research proposal to be verified based on information from reality; (4) verification or experimentation - allows the research proposal to be verified based on information from reality; (5) verification or experimentation - allows the research proposal to be verified based on information from reality; (6) verification or experimentation - allows the research proposal to be verified based on information from reality.

Development

This section presents Quivy and Campenhoudt's (1995) seven steps: formulating the initial question, exploring the initial question, elaborating the problem, building an analysis model, collecting data, analyzing the information, and drawing conclusions.

Step 1 - Formulation of the initial question

The chosen theme relates Knowledge Management to the STEAM education system. If there is a consensus about the social consequences of increased access to information, it is that education and lifelong learning have become essential resources for good performance at work and personal development. Although learning is broader than education, schools still have much to do regarding the education system.

The STEAM education system has been advancing and conquering a place among the great nations and their educational policies for the development of citizens' autonomy and protagonism, fostering a set of very useful skills through learning with transversal themes between disciplines to solve real problems.

For this process to occur effectively, KM promotes the creation and sharing of knowledge among the disciplines that comprise the STEAM teaching system with the intention of effective learning and the development of multi and interdisciplinary skills of the individual, because the student needs a broad development that enables him to be prepared for a world in constant evolution.

Therefore, the initial question of this study is: "What are the practices implemented by Knowledge Management that can help the teaching and learning processes in the STEAM education system?".

Step 2 - Exploring the initial question

According to Neuman (1997), exploratory studies are used to investigate a new research topic and may, in many cases, be the first stage of a set of study steps. Furthermore, Saunders *et al.* (2009) point out that exploratory studies are primarily developed through literature searches, with dense diagnosis in the literature.

Step 3 - Elaboration of the problem

After the exploration stage, the initial question was refined to the following problematization: "How Knowledge Management can collaborate in the teaching and learning processes in STEM, STEAM and Maker Education?".

Step 4 - Building an analysis model

This step follows the hypothetical-deductive method proposed by Quivy and Campenhoudt (1995). It begins with a scientific problem (or gap in knowledge), is followed by the formulation of hypotheses and then by a process of deductive inference that tests the prediction of the occurrence of phenomena covered by that hypothesis. It is based on bibliographic research on the theme and topics related to: KM practices and tools; knowledge cycle; and application of the STEAM teaching system in schools that have adopted this system. To this end, were defined (i) Keywords: "Knowledge Management", "STEM", "STEAM", "STEM education", "STEAM education", "ICTs" and "Maker education"; (ii) Scientific databases: Capes journals, Springer Open, Dimensions, Directory of Open Access Journals, Capes' Brazilian Digital Library of Theses and Dissertations (BDTD), and Google Academic;

and (iii) Inclusion criteria: consider full articles published in conference proceedings, dissertations, theses, and journals (national or international), during the period from January 2010 to December 2020, that reference strategies and variables for STEM/STEAM education.

Step 5 - Data Collection

For study selection, the inclusion criteria were applied in three stages: reading of the title, abstract, and keywords; reading of the full article; and finally, adherence to the theme. At this point, some points were highlighted: the term STEM refers, in medical literature, to a type of cell (stem cell); KM is still a new theme and, therefore, when searched together with the term STEM, not many articles resulted.

Many mentions and studies were found when searching for the keywords "STEM" and "Maker", such as accessibility opportunities, gender and class equity provided by the Maker movement. Searching for the terms "STEM-Maker", there were many occurrences about Makerspaces in libraries. Searching for the terms " ICTs" and "STEM" yielded results in the medical field where the acronyms refer to Tumour-initiating cells and stem cells, respectively.

More success was obtained when searching international journals, mostly in North American publications. This is justified because STEAM education originated in the United States. Contents referring to educational policies dedicated to the introduction of STEAM literacy were found in the STEM Center of the International Technology and Engineering Educators Association Foundation - ITEEA[5]

Google Alert was also used with the keywords: "STEM", "STEAM", "STEAM Education", "STEM Education" and "Maker". As a result, we received referrals to news, blog references and specialized sites, such as: STEAM Edu[6], STHEM Brasil[7], Maker Ed[8] and FabLearn[9].

In news sites, one can follow the relevance and impact of STEAM teaching worldwide. We also conducted searches on blogs and social networks (Facebook, LinkedIn and Instagram), which allowed us to locate teachers specializing in STEAM teaching and, consequently, to exchange information and perceptions on this topic.

[5] Available at: https://www.iteea.org/STEMCenter.aspx. Access on: 10 Jan. 2022.
[6] Available at: https://steamedu.com. Access on: 10 Jan. 2022.
[7] Available at: https://www.sthembrasil.com. Access on: 10 Jan. 2022.
[8] Available at: https://makered.org/. Access on: 10 Jan. 2022.
[9] Available at: https://fablearn.org. Access on: 10 Jan. 2022.

Step 6 - Analysis of the information

The interaction between analysis, hypotheses of the research problem and data collection will invariably refer to verification or at least reflection on the construction of the analysis model (pertinence and coherence), as the data collection (pertinence and accuracy).

Step 7 - Conclusions

According to Quivy and Campenhoudt (1995, p. 247-253), the conclusion of a research study comprises three parts: (1) Synthesis of the main research lines - moment of text production, being necessary to present the research problem, i.e., the initial question in its final formulation; present the main characteristics of the analysis model, especially the hypotheses; present data collection, the chosen methods and the collection of information carried out; compare the results expected by the hypothesis with the results obtained and carry out a brief description of the main distances found between both; (2) New contributions of the knowledge produced - can be of two types: (a) new knowledge produced concerning the object - these are those that can be evidenced by answering two questions: "What do I know more about the object of analysis? "and "What do I know in addition to the object of analysis?". The more the researcher distances himself from the preconceived ideas of current knowledge and is concerned with the problematic, the greater are the chances that the new knowledge produced, relative to the object, will bring his contributions; and (b) new theoretical knowledge to deepen the knowledge about a concrete domain of reality - the researcher defines the problematic and elaborates an analysis model consisting of hypotheses and concepts. Throughout the work, the concrete domain is being explained, and the relevance of the problem and the model of analysis are being tested. In this way, a research paper must provide an evaluation of the problem and the model of analysis. The optic here is transformation; and (3) Practical perspectives - the researcher intends his study to contribute to society. However, rarely does the conclusion of a research study led to a clear and indisputable practical application. Many researchers expect practical results that constitute intervention guides for actions and decisions, but, as a rule, the relationship between research and action is not so direct.

Results and Discussion

It is detected that the STEAM education system has been advancing and, increasingly, gaining a place among the great nations and their educational policies for the development of autonomy and protagonism of the citizen, fostering a set of very useful skills through learning with cross-cutting themes between disciplines to solve real problems. In order for this process to be improved, it is detected that KM promotes the creation and sharing of knowledge among the disciplines that comprise the STEAM teaching system with the intention of effective learning and the development of multi and interdisciplinary skills of the individual, because the student needs a broad development that enables him/her to be prepared for a world in constant evolution. It should be noted that STEAM supported by KM methods and tools, like all other teaching techniques, are subject to the conceptions of home, world, school, and education, among others, that end up basing the pedagogical practices. If these conceptions are traditional, any technique will not change the teaching and learning processes, and the results will remain with the knowledge transmitted by the teachers and assimilated by the students.

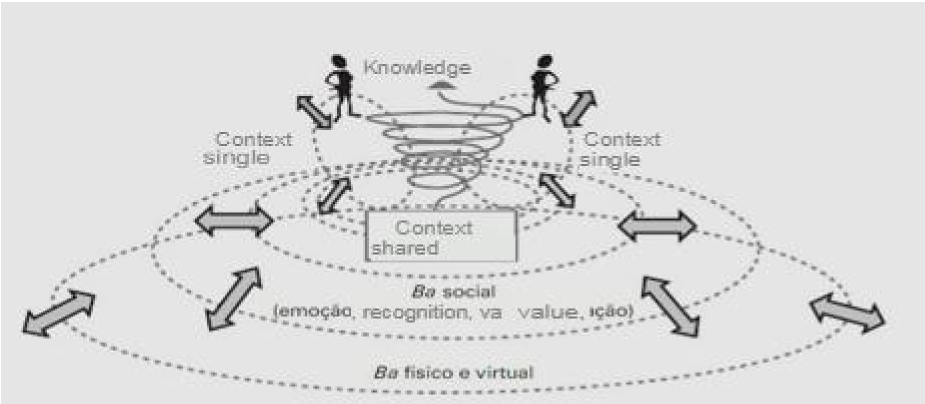
It is common among authors who discuss KM to find mention of the three pillars of KM: people, processes and technology. According to Dalkir (2011), it can be compared to art, due to its multidisciplinary approach.

Thus, incorporating the potential of new technologies allied to the process of knowledge construction with the development of the student's emotional senses can contribute to a better dynamic in the development process of the citizen's individual and social life, under the perspective of global citizenship.

For an effective knowledge sharing, KM has some tools to be adopted aiming its implementation and maintenance. Nonaka (2008) says that knowledge needs a place where information receives meaning through interpretation to become knowledge; Ba is then defined as a shared context in motion, where knowledge is created, shared and used. To understand how organizations create knowledge in this dynamic, Nonaka *et al.* (2000) propose a three-element model of knowledge creation. That is, Ba is time and space, are interactions that occur in a specific time and place and can be physical, virtual, mental or a combination of all these processes.

The effective creation and sharing of knowledge depends on a promoting context, a shared space that fosters relationships among members. A Ba should provide a shared, accessible language that ensures good communication (NONAKA, 2008). In this "Ba" context, individuals gather, meet, and communicate. From the meeting and mutual communication, the individual shares his own knowledge and acquires new knowledge in a continuous process in which a spiral of knowledge is being improved, as shown in Figure 1.

Figure 1 - Conceptual representation of Ba



Source: Nonaka *et al.* (2000)

For Buunk *et al.* (2018), the types of Ba that we can find in virtual space are:

(a) socializing (Originating) Ba - an existential space in which users can share their experiences through a socialization process; (b) internalizing (Exercising) Ba - a space that is used to share knowledge and skills through an externalization process; (c) externalizing (Dialoguing) Ba - a space in which the absorption of new knowledge happens through an internalization process; and (d) combining (Systemizing) Ba - a virtual space for activities such as networking, collaboration, and online consensus building.

Moreover, Sanders (2012) states that integrative education in the STEAM pedagogical approach allows establishing experiments in a learning ecology in the context of authentic technology/engineering project-based problem solving. This is a broader reflection of the proposal of education and development of the student's protagonism, under the perspective of CG and also immersed in the maker culture, stimulating the student's autonomy as a global, conscious and responsible citizen.

STEAM education is, therefore, an innovative pedagogy that presents a huge opportunity with the establishment of a wide range of conjectures in a learning situated in the context of technological/engineering design, based on problem solving, improving students' interest, understanding and skills in each of the STEAM disciplines (MARTIN, 2015; SANDERS, 2012).

While many disregard the possibility of this interdisciplinarity between STEAM areas, the fact is that there is convergence between the areas in projects that we encounter on a daily basis and have long been developing collaboratively. This synergy was evidenced in great thinkers such as the legendary Leonardo Da Vinci, who accumulated skills and competences from different areas, such as: science, mathematics, engineering, inventions, anatomy, painting, sculpture, architecture, botany, music, and literature.

In the methodological approach proposed by STEAM, integrality is implicit, through multi and interdisciplinarity. The breadth of this proposal may cause some discomfort to supporters of verticalized and traditional education, as it invokes the holistic view on the situation, giving no room for instructionalist and technical unilateralism, according to Ortiz-Revilla *et al.* (2018). However, there is no doubt that contemporaneity elicits a latent need for breadth in all spheres, the transposition of barriers and boundaries of knowledge, marred by the method that legitimized learning. Moreover, contemporary society is increasingly digital, increasingly mobile and connected, there is no way to think of them as anything but part of the pedagogical and curricular activities of the classroom (BLIKSTEIN; VALENTE; MOURA, 2020).

Concerns that STEAM proficiency is declining in some countries such as the US and intensifying in other nations such as China point to a threat in the future of economic and scientific leadership among nations. To maintain sovereignty over rivals, it will disappoint the nation that achieves a high level of scientific and engineering aptitude and understanding, not only of designers, but also of producers and experts in advanced technologies such as Artificial Intelligence (AI), cybernetics, quantum technology, robotics, hypersonic weapons, and even 3D printing.

Educational policy has high weight in a country and is portrayed in the formation of a qualified population, prepared for development and productivity. It is worth pointing out the complexity of the educational policy that goes from adherence to student dropout.

There are important studies that indicate how technology, used in an intentional way, can contribute to effective student learning. In situations where the use of technology is associated with inquiry-based pedagogies, there is a positive effect, especially on children's learning, and there is better performance on mobile devices and specific software (SUNG *et al.*, 2016).

Knowledge made available in an organized way contributes to better performance, connecting people to other people, delivering content to the actors involved in an accessible way, allowing the association between disciplines and technical and professional skills training. Another important point is to validate and measure the acquired knowledge, thus evaluating whether the goal of performing that activity for the discipline involved was achieved (O'DELL; HARPER, 2020).

As seen in Choo (2003) and Davenport and Prusak (1998), knowledge is based on the accumulation of experience, on the attribution of meaning, and through the knowledge cycle process the information and insights experienced through the Maker practices and the inter- and multidisciplinary nature of STEM/STEAM are converted into knowledge.

According to Choo (2003), KM unites three strategic processes for STEAM: meaning making, knowledge building, and decision making. Furthermore, according to Nonaka *et al.* (2000), one must consider the appropriate context, conducive to creativity, innovation, and learning, where information is interpreted to become knowledge.

The place where knowledge is created and shared is a decisive factor in the KM process. Knowledge cannot be separated from Ba, otherwise it becomes information. Information resides in the media and is tangible, while knowledge resides in Ba and is intangible. Thus, by highlighting Ba, we favor the conversion of information into knowledge.

Chart 1 presents the multidisciplinarity for knowledge sharing proposed by STEAM with the use of Knowledge Management practices and relating it to the four modes of knowledge conversion proposed by Nonaka and Takeuchi (2008), identifying the types of Ba (BUUNK *et al.*, 2018), how the environment promotes knowledge and what its management processes are.

Quadro 1 – Knowledge Management from the perspective of the teaching process

KM Practices	KM Tools	Ba
Teaching process		
Analysis - Identifying and sharing knowledge by experts		
Narratives and Expert Finder; Communities of Practice or Technical Networks: teachers come together in a group - may be face-to-face or virtually - in which they share applied activities and insights on other opportunities to explore knowledge with that activity. Sharing experiences, ideas, best practices, and learning from each other about applying the STEAM approach in their classes, also pointing out gaps in other perceived areas for the success of the activity. Sharing learning and knowledge assists novices in acquiring competencies and developing skills in less time. They can also set standards and instructions regarding the content, enabling high-quality delivery, and foster innovation and the development of new processes and improvements.	Webinars, groups or mailing lists on social networks.	***Dialoguing* Ba** Conceptual knowledge, experts share their tacit knowledge, making it explicit.
Design - Creating knowledge by sharing the experts' knowledge		
Mentoring: process of advising, training and/or mentoring the less experienced. The sharing of knowledge by the more experienced individual occurs while there is greater agility in the acquisition of knowledge and the development of competencies and skills by the less experienced. In some companies learning goals, scope of work, expectations and objectives are established.	*Chat*, Forum.	***Systemizing Ba:*** Systemic Knowledge. Explicit knowledge is shared and combined in a systematic way.
Development - Knowledge sharing and application		

<table>
<tr><td>Lessons Learned and After-Action Review: reflection and capture of lessons and approved practices for reuse at appropriate times and improvement of the project and processes.</td><td>Blogs, Wikis.</td><td>Exercising Ba: Operational Knowledge Absorption of new knowledge through the internalization process. Explicit knowledge is converted into tacit.</td></tr>
<tr><td colspan="2">Implementation - Creating, storing, sharing, and applying knowledge.</td><td rowspan="4">Originating Ba: Shared knowledge. There is sharing of experiences through the socialization process.</td></tr>
<tr><td>Knowledge retention and transfer: aims at sharing tacit knowledge about content and processes, which aims at socializing the approved practice among experts or experienced people. Important is the use of tools for recording and storing shared knowledge.</td><td>Wikis</td></tr>
<tr><td colspan="2">Assessment - Creation, storage, sharing, and application of knowledge.</td></tr>
<tr><td>Advanced Content Management: structured process to store, make available and facilitate access to content. By sharing the criteria evaluated in the activity, the performance achieved and the result, teachers, through search, will be able to relate and connect activities to further explore the activity.</td><td>Relational databases; cognitive search and search results.</td></tr>
</table>

Source: Adapted from Alarcon (2015), O'dell and Harper (2020)

Promoting a multidisciplinary or integrated approach, emphasis should be placed on providing students with high-quality interdisciplinary STEAM learning experiences to solve real-world problems, involving the design of shareable technologies and the development of technological expertise.

Collaboration and communication should be developed by providing students with opportunities to engage in collaborative problem solving or tasks. Students should be encouraged to use real-world tools (e.g., digital cameras and digital video cameras) to communicate their ideas. In addition, they should be encouraged to communicate information or ideas effectively in various formats (orally, graphically, textually, etc.).

It is important to engage students in argumentation through scientific argumentation and design justification. Like STEAM practitioners, students are engaged in learning through inquiry. In this process, students make assertions based on evidence, listen to the contributions of peers, and defend their assertions using well-reasoned justifications.

STEM education should incorporate practices of STEM practitioners to develop students' understanding of the nature of science, technology, engineering, and mathematics, which include scientific inquiry, mathematical thinking, design thinking, and engineering thinking.

With the intensified use of technology, creating an environment for knowledge sharing within the group is essential. We listed KM practices and tools (Chart 2) that, when applied, provide a favorable environment for knowledge:

Chart 2 – Knowledge management from the perspective of the Learning Process

<table>
<tr><th colspan="2">KM PRACTICE</th></tr>
<tr><th>VIRTUAL KM TOOLS</th><th>PHYSICAL KM TOOLS</th></tr>
<tr><th colspan="2">BA SPACE</th></tr>
<tr><th colspan="2">21ST CENTURY ABILITIES</th></tr>
<tr><td colspan="2">BRAINSTORMING - students work in groups, encouraging risk-taking and creative thinking to generate new ideas and solutions; debating different ideas provides important opportunities for development and deeper understanding of the topic at hand, increasing student involvement.</td></tr>
<tr><td>FORUM - Online discussions reveal the complexity of the problems and help students understand that there are multiple solutions. Anonymous or not, one can ask for clarification, ask questions to deepen understanding of content. Allows instructors to see how well learners are understanding content and where they need further guidance. Suggestion: forum in virtual learning environments, video conferencing, and chat.</td><td>PRESENTATIONAL DISCUSSION GROUPS - students get together and discuss possible solutions to a problem, according to each one's reality, sharing different ideas. Suggestion: post it, board or blackboard.</td></tr>
<tr><td colspan="2">ORIGINATING BA - Environment where students share ideas (Ba mental) through a process of socialization.</td></tr>
<tr><td colspan="2">Collaboration, communication, creativity, critical thinking, resilience, social and/or cultural skills (including citizenship), problem solving.</td></tr>
<tr><td colspan="2">AFTER ACTION REVIEW – AAR - after the activities the teacher can review with the students the lessons learned and insights.</td></tr>
<tr><td>FORUM - the teacher creates a discussion forum sharing with students the main themes learned and reviewing the content.</td><td>Meeting with students to review main points and insights.</td></tr>
<tr><td colspan="2">EXERCISING BA - environment in which new knowledge is absorbed through the process of internalization. Knowledge made explicit by the teacher is converted into tacit by the student.</td></tr>
<tr><td colspan="2">Collaboration, communication, Information and communication technology (ICT) literacy, social and/or cultural skills (including citizenship), problem solving.</td></tr>
<tr><td colspan="2">KNOWLEDGE COFFEE - with a relaxed proposal, students can share ideas about a theme.</td></tr>
<tr><td>The teacher creates a closed group - FB, Telegram or WhatsApp - and the students share ideas about the content.</td><td>Students gather in a relaxed atmosphere to share insights and knowledge.</td></tr>
<tr><td colspan="2">SYSTEMIZING BA - environment in which explicit knowledge is shared and combined.</td></tr>
<tr><td colspan="2">Collaboration, communication, creativity, critical thinking, resilience, social and/or cultural skills (including citizenship).</td></tr>
</table>

Source: Prepared by the authors

Final remarks

The contribution of technology in the educational environment expands the possibilities of different types of content delivery, promoting accessibility and considering the differences between students. Knowledge becomes the primary element of the classroom, centered on students and on promoting a broad environment for the creation and sharing of Ba knowledge. Notable also is the need for a multifaceted teaching workforce, with varied skills, that can establish relationships between areas of knowledge and technology. The most transformative discoveries and innovations happen at connections where disciplines converge, connect, and are catalyzed by an education system that integrates knowledge and methods in STEAM, requiring students to ask and answer questions that cross traditional disciplinary boundaries. By relating this conception to pedagogical practice, the delivery of a curriculum that goes beyond the individual content of the five disciplines results. Moreover, with the environment itself being convergent, people with different perspectives, life experiences, knowledge, and understandings innovate and drive development. The results of this study foster, in order for students to become STEAM literate, that teachers of STEAM disciplines be supported to explore the ways in which they can promote synergy between activities with their STEAM counterparts, leading to the creation of interdependent content, a cooperative and symbiotic curriculum.

It is important to emphasize that this study is theoretical in nature and did not take into consideration the living and study conditions of the less favored strata, which is a reality experienced in many Brazilian schools. The research aimed, through a bibliographic survey, to foster discussion about the STEM/STEAM education system, and to reflect on how this education system can help the teaching and learning processes to occur more effectively when allied with CG. However, studies are needed to detect how it should be implemented in schools.

This research allows us to propose, as a future work, the refinement of the proposed survey so that it can be adapted to the private reality, but mainly to the public reality of schools. In addition, to evaluate the contributions of these practices when implemented to improve the educational process, always taking into consideration the plurality found in the Brazilian education scenario.

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How to reference this article

TEIXEIRA, F. D. A.; BORTOLOZZI, F.; ALMEIDA, I. C.; ZAGONEL, Y. T. T. Knowledge management in the STEM/STEAM teaching system. **Revista Ibero-Americana de Estudos em Educação**, Araraquara, v. 17, n. 4, p. 3013-3019, Oct./Dec. 2022. e-ISSN: 1982-5587. DOI: https://doi.org/10.21723/riaee.v17i4.15549

Submitted: 24/11/2021
Revisions required: 18/03/2022
Approved: 07/09/2022
Published: 30/12/2022

Processing and publication by the Editora Ibero-Americana de Educação.
Correction, formatting, standardization and translation.