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THE SCIENCE LABORATORY OF THE FUTURE SCHOOL. EMERGING TECHNOLOGIES AND CONTENT

O LABORATÓRIO DE CIÊNCIAS DA ESCOLA DO FUTURO. TECNOLOGIAS E CONTEÚDOS EMERGENTES

EL LABORATORIO DE CIENCIAS DE LA FUTURA ESCUELA. TECNOLOGÍAS Y CONTENIDOS EMERGENTES

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ABSTRACT
This paper investigates the current trends in the transformation of STEM laboratories in the age of digitization due to the integration of digital technologies and the recognition of the importance of developing metacognitive skills. The paper examines the role of metacognition and its impact on the learning process, as well as the use of digital technologies such as remote labs, virtual labs, augmented reality, virtual reality, and mobile devices in STEM education. Results from this research suggest that the use of these digital technologies can be beneficial for science learning in both higher and secondary education. Additionally, these technologies can be used to promote student engagement, collaboration, and access to scientific knowledge. Furthermore, metacognition is an important skill for both teachers and students and can be developed through the use of the knowledge pyramid, emotional intelligence pyramid, metacognitive pyramid, and giftedness pyramid models.

KEYWORDS: S.T.E.M. Remote labs. Metacognition. Augmented reality. Mobile devices. Pyramid Models.

RESUMO
Este artigo investiga as tendências atuais na transformação dos laboratórios STEM na era da digitalização devido à integração de tecnologias digitais e ao reconhecimento da importância do desenvolvimento de habilidades metacognitivas. O artigo examina o papel da metacognição e seu impacto no processo de aprendizagem, bem como o uso de tecnologias digitais como laboratórios remotos, laboratórios virtuais, realidade aumentada, realidade virtual e dispositivos móveis na educação STEM. Os resultados desta pesquisa sugerem que o uso dessas tecnologias digitais pode ser benéfico para o aprendizado de ciências tanto no ensino superior quanto no ensino médio. Além disso, essas tecnologias podem ser usadas para promover o engajamento, a colaboração e o acesso dos alunos ao conhecimento científico. Além disso, a metacognição é uma habilidade importante tanto para professores quanto para alunos, e pode ser desenvolvida por meio do uso de modelos de pirâmide de conhecimento, pirâmide de inteligência emocional, pirâmide metacognitiva e pirâmide de superdotação.

PALAVRAS-CHAVE: S.T.E.M. Laboratórios remotos. Metacognição. Realidade aumentada. Dispositivos móveis. Modelos de Pirâmide.

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RESUMEN
Este artículo investiga las tendencias actuales en la transformación de los laboratorios STEM en la era de la digitalización debido a la integración de tecnologías digitales y el reconocimiento de la importancia de desarrollar habilidades metacognitivas. El documento examina el papel de la metacognición y su impacto en el proceso de aprendizaje, así como el uso de tecnologías digitales como laboratorios remotos, laboratorios virtuales, realidad aumentada, realidad virtual y dispositivos móviles en la educación STEM. Los resultados de esta investigación sugieren que el uso de estas tecnologías digitales puede ser beneficioso para el aprendizaje de ciencias tanto en la escuela superior como en la secundaria. Además, estas tecnologías se pueden utilizar para promover la participación de los estudiantes, la colaboración y el acceso al conocimiento científico. Además, la metacognición es una habilidad importante tanto para profesores como para estudiantes, y se puede desarrollar mediante el uso de modelos de pirámide de conocimiento, pirámide de inteligencia emocional, pirámide metacognitiva y pirámide de superdotación.

PALABRAS CLAVE: S.T.E.M. Remote labs. Metacognition. Augmented reality. Mobile devices. Pyramid Models.

INTRODUCTION

As technology and globalization continue to shape our cities and workplaces, educational institutions are being disconnected from the realities and expectations of diverse economies and cultures. To ensure that students have the skills they need to thrive in this new environment, educational techniques must evolve. The article "Schools of the Future: Defining New Models of Education [1] presents a new framework (Figure 1) to define quality education within the current economic and social context and to promote comprehensive, creative effort.

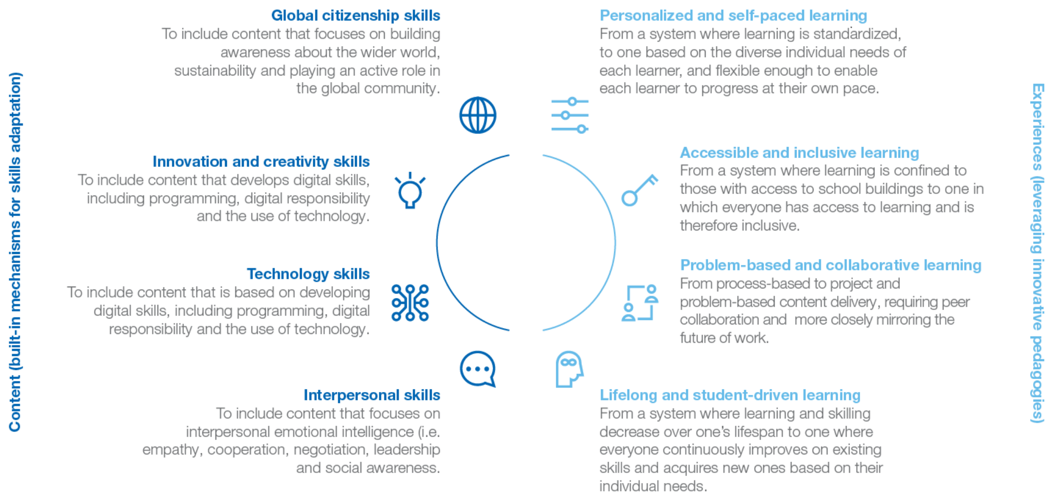

Figure 1. The World Economic Forum

Technology is used as a tool for knowledge access and approach at all times and from any location at The School of the Future. The school changes to meet the demands of time because it is a location where educators, trainees/students, parents, and the community (local stakeholders in education) actively approach knowledge. The school of the future will need to employ identical

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strategies, practices, resources, and policies to those used in traditional schools in order to ensure that everyone involved in the educational process has access (WORLD ECONOMIC FORUM, 2020).

According to the Oxford English Dictionary (OED), digitalization is “the adoption or increase in use of digital or computer technology by an organization, industry, country, etc.”, and apparently is a condition that affects the contemporary world in several ways: “it facilitates the globalization of the economy, reshapes conceptions of materiality and place, facilitates new circulations of culture, capital, commodities, and people, creates changes in national economies and occupation patterns, and bears wide-ranging effects on social life”(GOBBLE, 2018)

The OECD focuses on three categories of cognitive and metacognitive abilities: critical thinking, creative thinking, learning for learning, and self-regulation. a) Interpersonal and technical skills. b) Practical and physical skills; c) socioemotional skills. (SKOVSGAARD et al., 2018).

The role of science laboratory in science education. Stem+ for the 21st century

Based on the above, it becomes clear that the role of STEM (science, technology, engineering, and math) education through digitization acquires a central role in the school of the future. STEM was created to address issues in the twenty-first century, when pupils needed to be competent as well as cognitively clever. The goal of STEM education is to prepare students for competition and job readiness in their chosen fields. Applying STEM education helps students become more creative, rational, innovative, productive, and immediately tied to real-world situations (WIDYA et al., 2019).

Science educators have indicated that conducting laboratory activities provides rich learning benefits, and the laboratory has been assigned a fundamental and distinctive position in STEM education (HOFSTEIN; LUNETTA, 2004). Science laboratories are essential for the effective delivery of science education in the 21st century. According to a study by the National Center for Education Statistics, laboratory activities have been shown to provide students with hands-on experience that allows them to explore, think critically, and develop problem-solving skills. Furthermore, laboratories can be used to enhance the teaching of STEM (Science, Technology, Engineering, and Mathematics) disciplines, which are increasingly important in the 21st century.

Among other things, cognitive and metacognitive abilities as well as motivation are necessary for scientific literacy (HERSCOVITZ et al., 2012). For finding, choosing, reading, monitoring, and evaluating various information sources, it specifically depends on cognitive and metacognitive skills (WANG et al., 2014; YORE; TREAGUST, 2006). Researchers contend that metacognition is a critical component of lifelong learning in general and science education in particular, and that metacognitive involvement is essential for fostering a deeper conceptual comprehension of scientific concepts (ANDERSON; NASHON, 2007; BLANK, 2000; GEORGHIADES, 2004; KOCH, 2001).

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METHODOLOGY

The purpose of this research is to investigate the current trends regarding the transformation of STEM laboratory in the age of digitization. The transformation which is due both to the integration of digital technologies, and to the recognition of the importance of developing metacognitive skills as a key part of the educational process.

The selection of the document is based on a well-established set of papers from important publications in the field. For this investigation, the key terms "Education Metacognition," "Emerging Technologies STEM Education," "ICTs STEM Education," "Emotional Intelligence," "Metacognition Pyramid Models," and "Digital Technologies STEM Education" were used to search the Google Scholar and Science Direct databases. To reveal all studies in the field, no specific year was included in the search terms.

From the results of the search, the main pillars that are transforming the STEM laboratory emerged. In the results we present the trends in a concise way, since our purpose is to show the trends but not to analyze them thoroughly, so that the reader can form an image of what we can expect as teachers in the future of the STEM laboratory.

The role of metacognition

The development of metacognition is regarded to have significant positive effects on the learning process. According to Drigas & Pappas the eight levels of the knowledge pyramid represent the eight steps required to achieve transcendence (DRIGAS; PAPPAS, 2017). Reaching the top level to complete the process of "building" the knowledge pyramid (Figure 2), teachers should also reach the top level of transmission to their students by enhancing their cognitive control skills and enhancing their awareness: the capacity to carefully observe thoughts, feelings, even artificially induced emotions, and at the same time awareness to better our lives.

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Figure 2. The pyramid of knowledge

Since it enhances daily life, emotional intelligence has been hailed as a highly significant talent for the twenty-first century. A person needs to acquire an emotional intelligence hierarchy of skills in order to reach emotional self-actualization. The nine pillars of the emotional intelligence pyramid (Figure 3), which are self-awareness, recognition, expression, and management of emotions, empathy, communication, cooperation, and conflict resolution, all contribute to the development and improvement of social skills meant to strengthen inter-personal, interpersonal, and professional relationships (DRIGAS; PAPOUTSI, 2021).

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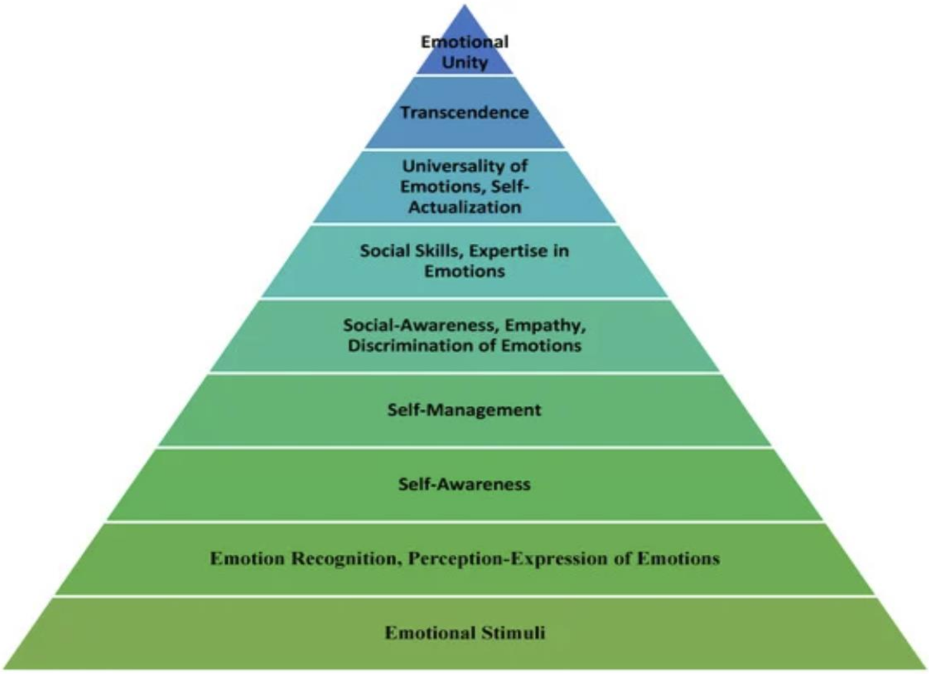

Figure 3. The pyramid of emotional intelligence

The eight pillars of metacognition (Figure 4) may serve as a highly helpful foundation for the development of these skills in both present and future teachers (DRIGAS; MITSEA, 2020, 2021). These pillars establish the capacities of awareness and self-awareness, the development of intelligence in all areas, and the appropriate functioning of cognitive and psychophysiological systems. They are helpful tools for self-learning, self-growth, self-healing, and self-consciousness. Each pillar employs a range of techniques to assist students in developing and enhancing particular metacognitive talents and characteristics in order to achieve the maximum levels of self-organization, intelligence, and consciousness. Through self-regulation approaches, teachers teach their pupils these abilities throughout the learning process (DEMBO, 2001). Through anti-aging, stress reduction, neuroplasticity, brain rewiring, and other techniques, students also acquire, develop, and improve metacognitive skills.

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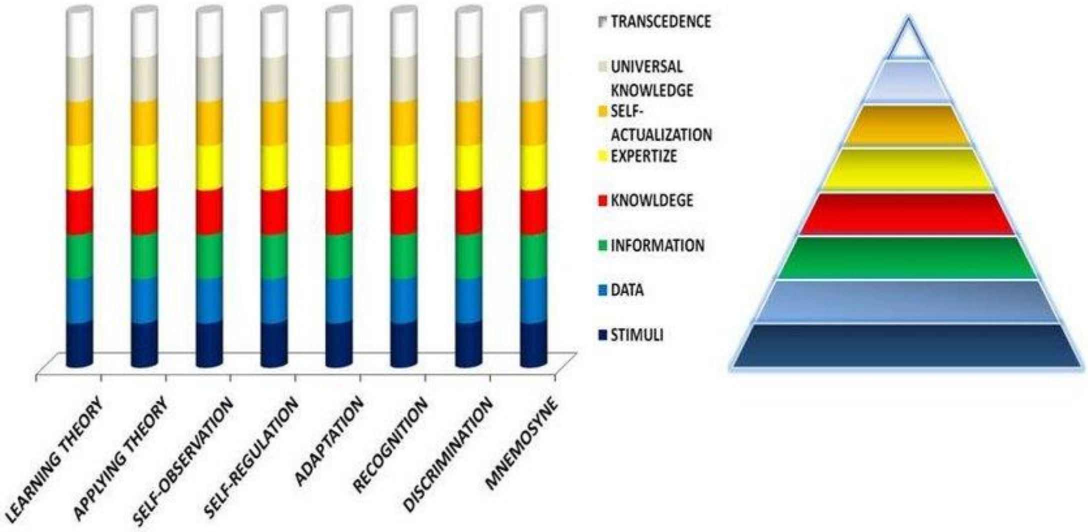

Figure 4. The eight pillars of metacognition

The pyramid model of giftedness (Figure 5) shows a number of abilities that are ranked in a hierarchy according to how difficult they are to learn and how important they are in multilevel cognitive experiences (DRIGAS et al., 2017), which will benefit the next teacher's well-being and effectiveness just as much as the students', since the teacher will pass the baton. Future teachers' giftedness will also develop as a result of their cognitive, metacognitive, affective, and other talents.

Figure 5. The pyramid model of giftedness

Digital Technologies and STEM Education

Remote Labs

Users can conduct tests and other laboratory chores online in remote laboratories without being close to the physical equipment. In a conventional proximal laboratory, the user interacts with the apparatus directly by physically manipulating it (e.g., by pressing buttons or twisting knobs) and observing the results (visual, audio and tactile). This identical encounter occurs remotely in a remote laboratory with the aid of the remote infrastructure. This is a brand-new layer that is placed between the user and the lab apparatus. It is in charge of transmitting user actions and receiving sensory data from the apparatus.

Since managing a laboratory involves trained personnel, ongoing equipment upkeep, and high overhead costs, the number of laboratories is frequently constrained, in part owing to economic considerations. Additionally, because of these factors, colleges are increasingly considering the use of alternative access methods, such as remote laboratories (LUSE et al., 2020).

Lowe et al., (2013) recognized the fact that although the use of remote laboratories in the classroom has attracted the interest of researchers, the majority of research concerns higher education rather than secondary education. They also claimed that there are strong reasons for speculating that when used in K–12 education as opposed to higher education, remote laboratories have different design objectives and a better potential for impact compared to traditional laboratories. In order to examine these issues, they conducted a multi-site pilot research. The goal of the pilot project was to investigate students' (and teachers') reactions to this form of access and how the laboratories should be built to take these reactions into consideration rather than how the laboratories might promote learning in secondary schools. Two phases of the experiments were carried out. In the first phase, which took place from October through December of 2010, 85 students from years 9 through 11 from nine different schools in New South Wales participated, while during the last term of the 2011 academic year, there was a second follow-up phase that featured 27 kids, all from years 9 to 11, although this time they came from four Western Australian schools. The activities were organized in the following way: the teachers received a series of instructions on how to carry out the virtual experiments and in general the activity with their students. After the activities were carried out, both students and teachers answered a series of questions. The students' questionnaire was intended to investigate the students' reaction, Student Learning, Laboratory Design and also the comparison with the traditional laboratories. The professors answered questions that mainly had to do with the design of the remote labs. According to their results students view their interactions with remote access experiments as legitimate practical experiences that produce easily accessible, trustworthy, real-world, reproducible experimental data. They place a great deal of faith in the information the apparatus produces. They point out advantageous learning results for both conceptual comprehension and skill acquisition. The instructors came up with a variety of options for using distant laboratories to help students' learning. The most frequent application is as a substitute for practical work that is done by students in the classroom. They are more likely to envision the delivery of a remote laboratory session as a small group experience in this regard.

Tho and Yeung (THO; YEUNG, 2018) conducted a research in order to identify if secondary students can actively and competently participate in science learning through a Remote Laboratory system. They used a mixed-method approach that combined quantitative and qualitative research techniques, pre- and post-survey questionnaires, as well as interview questions were used. 32 students from a public school in Hong Kong aged 12 to 14 took part in the research. Five weeks in total were set aside for the implementation. Students answered to a pre-survey in the first week. Following this, the students learned about the RL system in the second week completed the remote experiments according to the guided inquiry-based worksheets. They had the option to carry out the allocated remote tests in the third and fourth weeks at their own pace. The researcher presented the underlying scientific concepts in the final week, and the students discussed their observations, feelings, and experiences with the remote experiments as well as the challenges they faced. The questionnaire survey was used to assess the students' opinions, attitudes, and remarks regarding the Remote Laboratory system. In order to confirm the aforementioned findings, additional observations of student interactions during classroom classes as well as interviews with a select group of students and the teacher after the Remote Laboratory experiment session were carried out. According to their findings, following learning with the Remote Laboratory system, students' personal motivation in learning science and their capacity for science practices both grew to a level of statistically significant difference. This demonstrated that Remote Laboratory learning environments may be the cause of a beneficial transformation. The outcome was triangulated, and it was discovered that it was very consistent with the results of the student and teacher interviews. Through the hands-on engagement of those cutting-edge experiments, the Remote Laboratory system can support a student-centered learning approach, particularly for students interested in science, according to teacher and student comments. The Remote Laboratory system should therefore be improved and evaluated in order to accommodate more diverse science experiments and demonstration kits. In fact, it can be a resource for upcoming science learning and teaching, especially as an addition to traditional science experiments in the classroom.

Evangelista et al., (2017) has made an effort to examine the didactic experience with VISIR, an accessible remote lab for testing electrical and electronic circuits, in the specified environment of a secondary school in Rosario from two angles: motivation of high school pupils and class cooperation and teamwork. 37 students took part in the research which lasted a total of 4 weeks. During the research, the students carried out 4 activities in which they used the VISIR virtual laboratory in subjects related to the study of simple electrical circuits. Three key factors were considered when determining whether the remote laboratory was successful in boosting students' motivation and fostering teamwork: students' access to the virtual laboratory, their opinions of VISIR, and teachers' assessments of the implementation, as revealed by a Teacher's Satisfaction Questionnaire. Their findings suggest that a remote laboratory like this one could be a good tool for piquing high school students' interest in learning about DC circuits. The fact that a remote laboratory was a novel experience for pupils simply increased motivation. ICT integration in teaching is highly valued by high school pupils, and they also like activities that are different from what they often do in class.

Xie et al., (2022) as an attempt to bring the authentic experience of a science laboratory chemistry course, during Covid 19 pandemic restrictions, created Telelab. They recognized that the majority of remote labs, which are designed for educational use, operate in a centralized manner, as such they offer students and teachers a few degrees of freedom in what they can explore. To overcome this disadvantage, they proposed the implementation of a kind of remote laboratory which is decentralized, the remote labs 2.0. They created Telelab a branded framework of remote labs 2.0 as a proof of concept. Instead of offering a full platform that tries to cover numerous content areas with all the available technologies, their research sought to establish the viability with a few key technologies and key considerations. In two online chemistry classrooms with a total of 44 students from various parts of the US, they ran pilot research to see if the Telelab platform would aid high school students in learning concepts and procedures related to chemical reactions. The three different types of data sources they examined for their assessment were mostly focused on student outcomes: Pre- and post-tests; lab results; and data logs. According to their exit surveys, students were interested in one or more of the following three features: 1) Practical experiments; 2) apparatus; and 3) interpersonal relations. Results from pre- and post-tests reveal that students' evidence-based reasoning abilities considerably increased, which is a crucial benefit anticipated from learning through laboratory experiences. The lab reports of the students offer insight on how they used data gathered from Telelab to reason and justify the outcomes of the distant chemical reaction experiments. The students' active participation throughout the live experiments was substantiated by the logged process data on their interactions with the software and with others in the Telelab environment.

Virtual Labs

A virtual teaching and learning environment designed to improve students' laboratory skills is referred to as a virtual lab. In contrast to the limitations of real labs, they are one of the most significant eLearning tools since they let the learner conduct a variety of experiments at anytime and anywhere. Virtual laboratories use a variety of instructional strategies to aid students in understanding the theoretical material. These methods include storytelling, gamification, visual learning, active learning, recall-based learning, and active learning. Additionally, they give students access to a real-world lab setting where they may conduct experiments and hone their abilities in a safe and engaging learning environment.

Dyrberg et al., (2017) conducted a pilot research to examine the potential for using Labster, a virtual laboratory application, to supplement the traditional laboratory exercises in two undergraduate biology courses. Their main goal was to gauge the level of motivation and evaluate the many aspects of motivation that students would acquire through the use of this virtual lab. A student survey was used to assess the virtual laboratory, in which a total of 73 students took part. Their findings indicate that virtual laboratories may strengthen pre-laboratory preparation to ensure more assured pupils and possibly improve the evolution of the lab exercises carried out.

Simon (2015) conducted a quantitative quasi-experimental study to ascertain how the use of inquiry-based, virtual, and simulated science laboratory experiments increases learner perception of depth of learning via Higher-Order Learning Skills, Critical Thinking skills, and Cognitive Load among participant learners at a 2-year community college. The Scientific Attitude Inventory (SAI II), the Revised Two-Factor Study Process Questionnaire (R-SPQ-2F), and the Motivated Strategies for Learning Questionnaire (MSLQ) were the tools they used. In their study participated 150 students and were divided into two pre-existing groups using a random selection of course sections. The first group was the test group, that received the treatment by using the inquiry based virtual labs while the second acted as a control group by using the traditional face-to-face laboratory experiments. Their findings indicate that the treatment group's use of simulation and virtual labs increased perceptions of comprehensive employment of higher-order learning skills and increased use of critical thinking skills, but that the treatment group did not statistically demonstrate a significant increase in cognitive load.

Bogusevschi et al., (2020) conducted a case study of a virtual learning environment combining virtual reality and virtual laboratories on the topic of the Water Cycle in 27 students (12 and 13 years old) of a public secondary school in Dublin. First the students answered a Pre-test in order to evaluate their prior knowledge on the topic. Then the students took part on a Lesson regarding Water Cycle in Nature. After that they answered a Learner Satisfaction Questionnaire in order to evaluate the usability of the tools used and finally answered a Post-test in order to evaluate the knowledge they have gained from the activity. According to their findings students may gain knowledge when using the application, compared to the control group while the majority of students (70%) stated that they would like to have more lessons using this kind of approach.

Augmented Reality

Augmented reality (AR) is a technology that superimposes a computer-generated image on a user's view of the real world, providing a composite view. It is used in a variety of applications, including gaming, entertainment, education, navigation, and industrial/commercial uses. In gaming, it allows users to interact with virtual objects in a real-world environment; in entertainment, it can be used to overlay information on the user's view of the real world; in education, it can serve as a powerful tool for visualizing complex concepts; and in industry, it can provide workers with a more immersive experience when performing tasks. This technology can be used to teach science concepts in a more immersive and engaging way. For example, AR can be used to visualize complex scientific processes and data, as well as provide students with a more interactive way of learning.

In a study by Salmi et al., (2017) in an informal learning environment, the motivational and cognitive effects of learning with Augmented Reality (AR) technology were examined. 146 students (12 to 13 years old) took part on the study. These students came from 7 schools in Helsinki who were randomly selected and visited a science park in which there were 5 augmented reality exhibits. The researchers administered a number of pre-tests one month prior to the students' visit. With these tests they wanted to assess students' motivation and pre-existing knowledge, while they also collected data related to students' school performance. One week after the exhibition visit a number of post-test questionnaires were performed by the students in order for the researchers to reevaluate students' motivations and knowledge. According to their results situational motivation in the setting of a science exhibition increases student interest in academic science. This resulted in superior cognitive learning outcomes on the post-knowledge test, and concurrently, following the AR experience, students' total science knowledge scores rise. At the same time while Boys scored more than girls on science knowledge tests prior to the AR demonstration. However, gender no longer has a direct impact on learning in the post-tests, suggesting that both boys and girls learnt equally. Lastly the lowest achievers who don't know as much as the others before the exhibition benefit the most from the concrete AR-learning session. This is true even though the better-performing students also learned throughout the exhibition.

Turan & Atila (2021) conducted a very interesting study in Turkey, in order to investigate the impact of teaching science using materials supplemented by augmented reality technology on the learning and perspectives of students with specific learning disabilities. For all participants, a multiple probe design was adopted, and data were collected through a students' evaluation form, an interview questionnaire and video recordings of the sessions. The results showed that AR technology boosted each student's learning levels and had a different impact on their learning experiences. Another observation was that students had overwhelmingly positive things to say about how AR technology was being used in their classes. The pupils desired resources supported by this technology to be used in other classes since they were pleased with the learning, they were receiving from it.

According to Sahin & Yilmaz (2020), who conducted a study to investigate the effect of Augmented Reality activities on both the improvement of performance in science courses and the attitudes towards science and AR technology itself in secondary education students, the use of activities which embed Augmented Reality may have a positive outcome to students. 100 students between 12 and 13 years old took part on the survey. Half of them received the treatment while the other half played the role of the control group. The science curriculum's unit on the "Solar System and Beyond" was studied by both groups. While the experimental group finished this unit using augmented reality technology, the control group finished it using conventional techniques and textbooks. The experimental group's students were found to have higher academic achievement levels and more favorable attitudes regarding the course than the control group's pupils did. This striking difference between the groups is proof that AR technology has a favorable impact especially in topics with mostly abstract concepts which make it very difficult for the students. Particularly under these circumstances, students can use augmented reality (AR) programs to experience these abstract notions physically through 3D virtual objects, which results in more meaningful learning and, as a result, higher academic accomplishment.

Virtual Reality

Virtual reality (VR) is a simulated experience that can be similar to or completely different from the real world. Using virtual reality technology, a user can interact with a three-dimensional environment and elements within it using a computer, special equipment, or a headset. It immerses the user in a completely realistic, artificially created environment and allows them to explore and manipulate the environment in a seemingly real way. Virtual reality in science education is an immersive technology that allows students to explore, interact with, and manipulate a simulated environment. It can be used to help students understand concepts and phenomena in physical, biological, and chemical sciences. It can also be used to simulate hazardous environments, allowing students to practice safety protocols without risk to themselves. Virtual reality in science education can be an invaluable tool for encouraging hands-on learning and increasing student engagement.

The way in which different areas of the brain associated with cognitive functions such as critical thinking, attention and memory are affected through the use of virtual reality in the context of a STEM laboratory was the subject of Lamb et al., (2018). The sample of their research was 100 students of a university in America who were randomly divided into four groups. Each group was taught the topic of DNA replication in different presentation modes related to video lecture, hands on activities, Virtual Reality and Serious Games. The researchers used Functional Near-Infrared Spectroscopy in order to measure differentiation of hemodynamic activations, swift blood flow to the brain's neuronal tissue to stimulate particular brain regions for cognitive processing, and cognitive dynamics, the interaction of several signals and processing units of a person as they are processing information and performing activities. Resulting from their analysis compared to the group that just used regular video lectures, using Serious Games and Virtual Reality resulted in a higher score rise on the end assessments. But more importantly, there was no difference between the Virtual Reality group and the hands-on group. The review of standardized hemodynamic data obtained reveals considerably higher hemodynamics in the prefrontal cortex during engagement in the Virtual Reality and Serious Games conditions as compared to the video lecture and hands-on conditions in the areas of memory and critical thinking. More significantly, the Serious Games and Virtual Reality hemodynamic activation sites were constant across all hands-on circumstances. This shows that each condition makes use of the same fundamental functional tools.

Liou & Chang developed a virtual reality science classroom (LIOU; CHANG, 2018) and in order to evaluate the implementation, they conducted a survey involving 105 secondary school students from Taiwan. Their study's objective was to determine whether virtual reality apps may enhance students' learning outcomes and performance and in order to do that the divided their sample into three groups. The first two groups were the experimental groups, where the Virtual Reality learning system was implemented, while the third was the control group where a conventional teaching approach was used. A pretest and a posttest were answered from students and in order to determine whether there was a statistically significant difference between the three groups, one-way Analysis of Variance (ANOVA) was employed. According to their findings the Virtual Reality implementation had a very positive impact on student's performance.

Mobile Devices

Mobile devices are increasingly being used in science education, as they provide students with access to a wide range of educational content and activities. They can be used to explore the world around them, conduct virtual experiments, and even collaborate with classmates and teachers. With mobile devices, students can access information anytime and anywhere, which gives them the ability to learn at their own pace. They also can be used to simulate physical and chemical processes, measure physical parameters such as temperature, light, and sound, and analyze data. This allows them to develop a deeper understanding of scientific concepts and apply them in the real world.

Chu et al., (2021) explored the effectiveness of a sound STEM practical kit using free mobile apps on a smartphone to improve secondary students' understanding of science concepts. The kit is intended to be a cost-effective alternative to expensive laboratory equipment and to address teachers' lack of use of ICT as an instructional tool. The research question focused on the effectiveness of the kit for improving students' understanding of STEM concepts The ASSURE instructional model was used as a framework for the development of the kit, which included user manuals for free mobile apps, a guided STEM activity manual and the apparatus needed for the activity. The kit was implemented in the experimental group in a science laboratory and the comparison group was shown conventional sound experiment movies. The results showed that the sound STEM practical kit was effective in improving student understanding. A sample of 66 students in two intact classes from a mainstream school in Perak State, Malaysia, were tested using pretests and posttests. One of the classes was selected as an experimental group, with the implementation of the sound STEM practical kit, while the other class was used as a comparison group, receiving the conventional teaching method. Results from the Wilcoxon signed-ranks test indicated that the experimental group showed a significant improvement in their performance on the posttest ($p < 0.01$), while the comparison group did not show any significant differences ($p= 0.740$). Additionally, a survey using open-ended questions was administered only to the experimental group to collect student feedback on the sound STEM practical kit. Results showed that the suggested STEM practical activities were effective in improving student understanding and knowledge retention.

Stanley et al., (2017) presented the development of an outreach project for pre-college students to introduce them to chemical engineering kinetics and general concepts of chemistry, engineering, and scientific analysis, using a mobile application called ThermoHUE. The overall goal was to leverage the technology's accessibility and appeal to boost the students' learning experience. The District of Columbia Public Schools and the Department of Employment Services collaborated to provide select students with 6-week summer internships at host employers in alignment with their career aspirations. 30 students from two public high schools in the Washington metropolitan area participated in the ThermoHUE outreach program as part of their internship assignment. The students were split into groups of three or four and asked to register an account with their name, email, and a password so that the data collected with the App could be securely sent to them in an online spreadsheet. Safety precautions were taken to ensure the laboratory setup was safe for the students. At the start of an outreach program on chemistry and chemical reactions, there was a mix of students who expressed confidence and those who did not in their understanding of the concepts. After four days of the program, fewer students showed a lack of confidence and there was an increase in those expressing greater confidence in their grasp of the scientific thought process. ThermoHUE was well-received by students as it accurately and reliably measured colorimetric data. Through interacting with the App, students developed a deeper understanding of engineering principles and were able to articulate the results of their kinetics experiments to their peers and teachers.

CONCLUSION

In conclusion, remote laboratories offer a variety of advantages to students, such as increased motivation in learning and improved skills in evidence-based reasoning. Qualitative evidence from students and teachers suggest that the use of remote laboratories can be beneficial for science learning in both higher and secondary education. The capability to use remote laboratories to provide an authentic laboratory experience during Covid 19 pandemic restrictions was also demonstrated by the pilot research discussed in this review. Overall, it can be concluded that the use of remote laboratories can bring a range of benefits to students and teachers alike and should be further explored as a potential tool for science education. The use of virtual labs has been shown to be an effective way of improving students' laboratory skills. It has been demonstrated to increase motivation among students, as well as their understanding of the theoretical material. Additionally, virtual labs have also been found to increase students' perceptions of higher-order learning skills, critical thinking skills, and reduce cognitive load. Furthermore, students have reported satisfaction and enjoyment when using virtual lab applications. Therefore, virtual labs can be a valuable tool for educators and students alike. Augmented Reality (AR) technology has been shown to have a significant impact on students' learning experiences and outcomes, especially in areas of science with abstract concepts. AR can provide students with a more immersive and engaging way to learn, as well as a powerful tool for visualizing complex concepts. It can also help to bridge the gender gap in learning outcomes, as boys and girls can learn equally from AR activities. Furthermore, students with special learning needs can also benefit from AR technology, as it can help to boost their performance in science classes and improve their attitudes towards science and AR technology itself. Virtual reality in science education can be an invaluable tool for encouraging hands-on learning and increasing student engagement. The use of virtual reality in the context of a STEM laboratory has been shown to produce higher scores on end assessments compared to traditional video lectures. Additionally, Virtual Reality has been proven to enhance student learning outcomes and performance compared to a conventional teaching approach. Therefore, the use of virtual reality in science education is beneficial and should be further explored.

Smartphones have the potential to be a powerful tool in science education. They are cost-effective, easy to use, and provide an interactive platform for students to explore and learn. With their intuitive user interface, smartphones can be used to create engaging activities and experiments that appeal to students of all ages. Additionally, the use of smartphones in science education has the potential to increase student engagement, promote collaboration, and expand access to scientific knowledge.

Therefore, it is clear that smartphones can be used as an effective experimental tool in science education.

At the same time metacognition is a highly beneficial skill for teachers and students alike. It enables teachers to reach a higher level of transmission and provides students with the tools to better understand and enhance their cognitive and emotional skills. The pyramid of knowledge, emotional intelligence, metacognition, and giftedness are all important tools for developing the necessary skills for successful teaching and learning. With these tools, teachers and students can reach a higher level of self-awareness and self-regulation, which will lead to improved learning outcomes and a better quality of life.

Moreover, in recent decades, significant social changes have been observed, which are related to the role of A.I. and technology in people's daily lives. The most important of them concern communication, diffusion and management information’s and in the ability to assimilate and utilize the produced new knowledge. We have to underline that the role of Digital Technologies in education domain as well as in all the aspects of everyday life, are very productive and successful, facilitate and improve the assessment, the intervention, decision making, the educational procedures and all the scientific and productive procedures via Mobiles (STATHOPOULOU et al., 2018, 2019, 2020, KOKKALIA et al., 2016, DRIGAS et al., 2015, 2020, 2022, 2022, VLACHOU et al., 2017, PAPOUTSI et al., 2017, 2018, KARABATZAKI et al., 2018, ALEXOPOULOU et al., 2020, STAVRIDIS et al., 2020), various ICTs applications (DRIGAS et al., 2004; 2005; 2006; 2009; 2010; 2011; 2013; 2014; 2015; 2016; 2017; 2018; 2019; 2020; 2021; 2022; PAPPAS et al., 2015; 2016; 2017; 2018; 2019; PAPANASTASIOU et al., 2014; 2017; 2018; 2020; ALEXOPOULOU et al., 2019, KONTOSTAVLOU et al., 2019; CHARAMI et al., 2014, BAKOLA et al., 2019, KONTOSTAVLOU et al., 2019, ALEXOPOULOU et al., 2019, PAPOUTSI et al., 2016; 2017; 2018; 2019; 2020; 2021; 2022; KOKKALIA et al., 2014; 2015; 2016; 2017; 2018; 2019; KARYOTAKI et al., 2014; 2015; 2016; 2017; 2018; 2019; 2020; 2021; BRAVOU et al., 2019; 2022; LYTRA et al., 2021), via AI Robotics & STEM (DRIGAS et. al, 2004; 2005; 2009; 2013; 2014; VRETTAROS et al., 2009; ANAGNOSTOPOULOU et al., 2020; LYTRA et al., 2021; PAPPAS et al., 2016, MITSEA et al., 2020, CHAIDI et al., 2021), and games (CHAIDI et al., 2022; KOKKALIA et al., 2017, DRIGAS et al., 2021). The New Technologies (NT) and more specifically Digital Technologies provide the tools for access, the analysis and transfer of information and for its management and utilization new knowledge. Information and Communication Technologies (ICT), unprecedented technological capabilities of man, have a catalytic effect, create the new social reality and shape the Information Society (DRIGAS, 2015; 2016; KOUKIANNAKIS, 2004; 2006; 2009; DRIGAS; KONTOPOULOU, 2016; THEODOROU; DRIGAS, 2017; DRIGAS; KOSTAS, 2014; BAKOLA et al., 2019; 2022; DRIGAS; POLITI-GEORGOUSI, 2019, KARYOTAKI et al., 2022). Moreover, games and gamification techniques and practices within general and special education improves the educational procedures and environment, making them more friendly and enjoyable (DRIGAS et al., 2014; 2015; PAPANASTASIOU et al., 2017; KOKKALIA et al., 2016; 2017; DOULOU et al., 2022; CHAIDI et al., 2022; KEFALIS et al., 2020, PAPOUTSI et al., 2016).

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Concluding, it's necessary to refer that the combination of ICTs with theories and models of metacognition, mindfulness, meditation and emotional intelligence cultivation accelerates and improves more over the educational, productive, and decision- making practices and results (DRIGAS et al., 2014; 2015; 2016; 2017; 2018; 2019; 2020; 2021; 2022; KOKKALIA et al., 2014; 2015; 2016; 2017; 2018; 2019; PAPPAS et al., 2015; 2016; 2017; 2018; 2019; PAPOUTSI et al., 2016; 2017; 2018; 2019; 2020; 2021; 2022; KARYOTAKI et al., 2014; 2015; 2016; 2017; 2018; 2019; 2020; 2021; 2022; CHAIDI et al., 2020; 2021; 2022; MITSEA et al., 2019; 2020; 2021; 2022; ANGELOPOULOU et al., 2021; TOURIMPAMPA et al., 2018; KAPSI et al., 2020; GALITSKAYA et al., 2021; BAKOLA et al., 2020; BAMICHA et al., 2022). Finally, Driga et al., 2019, Stavridou et al., 2021 and Zavitzanou et al., 2021 suggest that various environmental and dietary factors can act as inhibitors or facilitators of the improvement of the mental abilities and strengths.

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