Innovative Teaching of Physics in the Digital Technology Era

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Abstract: Digital technology has been gradually introduced into the Romanian education system in recent decades, with reluctance and hesitant steps at first, but with growing confidence and enthusiasm nowadays, leading to promising results in the future. Open educational resources illustrate that physics, a practical science par excellence, can study real-world phenomena in a creative and active way, using virtual tools. In this paper we illustrate the multiple possibilities and options that digital resources can offer to the physics teacher and highschool students. We also present some of our own contributions to modernizing physics lessons, emphasizing the importance of digital skills as integral part of learning.

Keywords: Physics; innovative teaching; digital skills; modern education

1. Introduction

The 21st century has brought us a diverse range of visible challenges and we cannot discuss just one particular area as they all interact. At the same time, new opportunities in scientific research and education frequently arise. Online education is an expression of the progress and inevitable changes that characterize our contemporary age. The digitization process in education has been gradually introduced in schools for some time, and the numerous training courses are a real support for teachers in this new context.

This research aims to highlight a few innovative methods of teaching physics using digital technology tools. Didactic sequences with simulations of physics

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phenomena are presented, in which groups of students were engaged, together with specific details. The paper also emphasizes the significance of the physics teacher's professional competencies in the creation of the didactic approach based on digital technology and investigates the specific benefits of blended learning, that support a dynamic modern teaching.

2. The Innovative Approach of Physics Teacher Stimulates the Students' Interest

In a world where technology is evolving at an incredible speed, teachers must adapt and improve their skills to be effective in their professional activity. Being a teacher in the digital technology era is not just about teaching a subject and evaluating the students' knowledge, but being a mentor, a guide and a facilitator of learning.

Physics teachers face increasingly complex technological advances, therefore they must adapt to the digital teaching process, facilitating the development of students' scientific and digital skills. Therefore, teachers should offer a wide range of interactive activities, which can also be carried out in the online environment. The teachers must be flexible, being able to easily adapt to new situations and to deliver attractive lessons. In the same time, a continuous interaction, communication and collaboration between students and teacher leads to an atmosphere conducive to learning.

Consequently, education in the digital technology era is constantly evolving and innovating and requires teachers and students to be receptive to new ideas and to adapt to the variety of scenarious that may arise. Thus, to encourage innovation in classroom and to utilize open educational resources, new sets of teacher abilities and activities are required.

As the sources of knowledge have become so vast, teachers' role is increasingly complex, they must be able to teach technology-oriented, supporting students to identify useful technological applications. Hence, the teacher becomes **a** facilitator and a coordinator of the students' activity, a collaborator and mediator of learning, keeping students engaged.

The use of digital technologies, combined with flexible and personalized learning, represents the most promising solution in the future. More specifically, in teaching and managing classroom activities, the teacher must be able to:

- create an optimal learning environment, reflected in effective relationships with students and to facilitate student-centered activities;
- encourage and guide students in active participation and self-directed learning, stimulating their interest in online learning;
- offer opportunities for investigation through a dynamic learning process;
- improve the learning experience, increase conceptual understanding, and ultimately enhance learning outcomes, employing digital technology
- design, implement and evaluate digital learning.

The pedagogical practice proves us that the students have an increased interest and motivation in approaching topics that involve the use of digital technology, getting actively engaged in solving the proposed work tasks. Engaging students in experimental research projects has a positive effect on their interest in the study of Physics, along with the development of teamwork skills. The use of innovative experimental devices based on digital skills motivates and ensures the maintenance of interest in the study of physics, offering different opportunities than the theoretical and applied support in solving problems.

The teacher-students relationship acquires new values, based on mutual trust and communication freed from the constraints of classical didactic discourse. The students become builders of their own knowledge, while the teacher becomes the architect of the plan, of the project, adopting various roles as: content expert, technician, tutor, resource, author and evaluator. In the digital world, the students are impressed by the experiments carried out in the real environment, as well as animations or simulations of different phenomena. In this new context, the mission of the physics teacher will be to select and to combine the most suitable methods, techniques, learning environments, technologies and devices, which can make every lesson unforgettable for his students!

Currently, most students have developed advanced skills in digital technology, with a high degree of adaptability to the new. In addition, the effective learning methods, the abundance of information from Internet and the attractive manner of presentation, such as simulations of physical phenomena, or videos, could lead to an improvement of the results. Consequently, digital learning of Physics with integrated interactive activities has a positive impact in deepening concepts, creating a more attractive and interesting learning atmosphere.

Interactive digital learning, using multimedia devices, is integrated into the teaching and learning for a better understanding of concepts, using a combination of text, graphics, video and sound. Practical activities play an essential role, especially when using digital tools, the students being more involved and attracted to the world of science. Interactive digital learning leads to improved students' critical thinking and learning outcomes. Hence, an impactful online presence in achieving the educational goal leads to a real educational success.

3. The Role of Blended Learning in Physics Based on Digital Learning

Since students' understanding of physics phenomena might be difficult, studying physics in the modern context of digital technology facilitates a better understanding of complicated phenomena. Digital learning involves variety of particular learning techniques using digital technology, as well as a combination of these techniques. Blended learning, e-learning, using computers and the Internet, are examples of digital learning, which are expected to lead to an effective teaching process.

For the purposes of achieving the learning objectives, physics teachers take on new roles as learning partners and facilitators. The instructional process must be followed in accordance with ***the main features of the digital classroom***, as shown in *figure 1*.

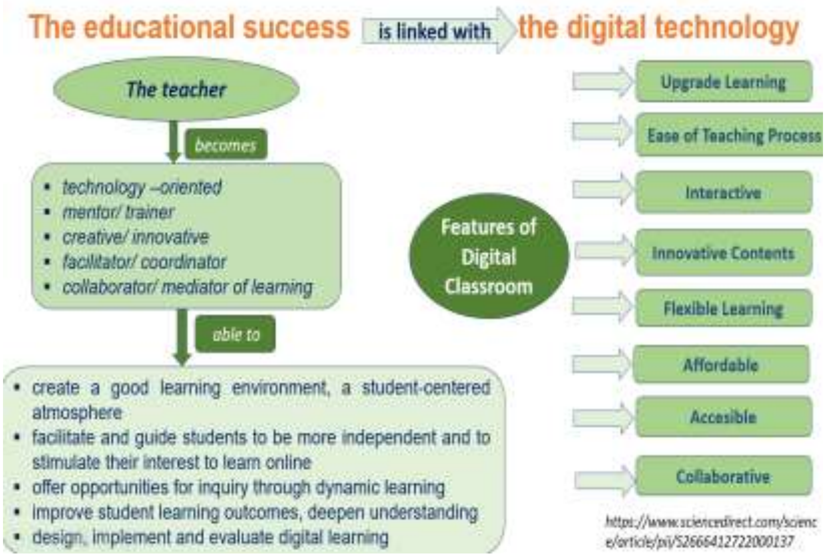


Figure 1.

It seems that e-learning, as it was originally understood, has passed its peak. Experts recommend combining different learning sites in hybrid learning models. Although there are many different learning contexts, blended learning recently merged the benefits of traditional and online educational approaches, as shown in *figure.*

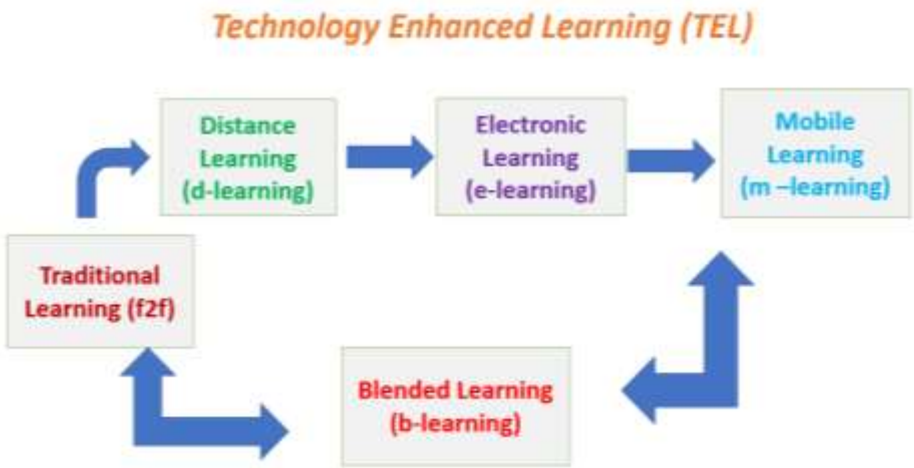


Figure 2.

"*The opportunities to gain learning experiences anytime and anywhere became possible through online instructions" (Temizel, 2018).*

"*Technologies are just some tools that can be used in several fields, especially in education, but the most important thing is how it is applied. It is known that in education media technologies are used in various combinations, and the six media pillars are: face-to-face learning, text, (style) graphics, audio (including speeech), video, the computer (including animations, simulations and virtual realities)" (Bates, Anthony Williams, 2015)*

Blended Learning is a mixed education, combining online and offline, which seems to be the most desired and widespread form of e-learning in the world at the moment, more effective than traditional or online methods used separately.

Blended Learning is an umbrella term for a mix of learning modes, a combination of traditional education with information and communication technology (ICT). It interweaves varied applications (software) and diverse teaching methods, most often a mix of web-based/online learning with traditional face-to-face learning *(Staker & Horn, 2012).*

This approach is a new learning experience, based on combining the advantages of modern communications and IT with the traditional way of learning.

Education in the BL context encourages the implementation of didactic activities to be carried out synchronously or asynchronously in different percentages. The teacher decides the type of interaction, in relation to the particularities of the topic he teaches, of the students he works with, because each method of communication presents both advantages and disadvantages.

Blended Learning refers to a mix of:

- *ways of learning* (face to face learning, web-based learning, learning at your own pace);
- *learning methods* (lectures, investigations, practical exercises, case studies, problematization, face-to-face or technology-based projects);
- *means of transmitting information* (Internet, Web courses, video, e-book, electronic presentations, books, class sessions);
- *online technological resources synchronous and asynchronous* **(**videoconferences, webinars, websites, blogs, Learning Management System, textbooks or online courses).

Open Educational Resources (OER) refers to learning, teaching and research materials that are available in any format and medium, in the public domain or under open licenses and that allow free access, reuse, adaptation and redistribution *(Stracke et al., 2019; UNESCO, 2019).*

The design of a didactic activity in a Blended Learning system, requires *the adaptation of the documents to BL teaching:*

- selecting appropriate platforms, applications and digital resources
- identifying/ creating accessible digital materials/ OER
- involving the students in the creation of digital contents;
- promoting online tutoring, training the social/emotional skills of the students;
- identifying the learning styles correlated with the specific digital tools or applications.

- using didactic strategies: collaborative training, project-based learning, flipped class;
- developing alternative plans to compensate the technical deficiencies.

The development of Computer Assisted Instruction has given us the chance to overcome the barriers imposed by traditional instruction. The computer contributes to the success of learning, being a tool that facilitates the transmission of knowledge and offers the possibility of interactive presentation of new knowledge. The rational use of CAI is an optimizing factor in teaching Physics and the integration of educational software in the teaching process of Physics has a main role with spectacular and obvious results.

The animations/simulations integrated into the physics teaching process show a better understanding of the concepts. The students have access to the visualization of phenomena that either cannot be easily reproduced in the laboratory (the apparatus is complicated, expensive and inaccessible, or it represent a danger to the real laboratory environment), or occur at too high speeds to be directly perceived. ***Simulations*** or ***virtual experiments*** compared to real experiments have the advantage that the students use them unlimited and repeatedly. Combined with face-to-face activity, differentiated activities with educational software provides:

- new possibilities for stimulating cognitive interest;
- new ways of active and interactive involvement of students in the learning process;
- a successful strategy in the teaching-learning-evaluation process.

In the recent years has been created numerous programs for creating simulations and animations useful in presenting physics phenomena/notions, with different functions, like GeoGebra, Cmap Tools, Inkscape, Animaker, Krita, Tracker, Adobe Animate, Flash, etc. The implementation of investigative methods based on computer programs and modern applications attracts students even to the study of physical phenomena with an increased degree of complexity of the notions. The transmission of information can be done with the help of video resources. Generally, the teachers can make video resources:

- recording short videos with dedicated apps;
- making various tutorials by recording the screen;
- reusing videos from Youtube, KhanAcademy, etc.

4. Creating Teaching Strategies in Physics

The conditions for teaching physics through experiments may not always be favorable due to possible obstacles. In schools with less equipped laboratories the teachers cannot implement physics experiments, either the laboratory is not properly equipped, or the time allocated to the subject is limited, either it is not always possible to divide the class into groups. In these circumstances, some experiments can be transferred in a virtual version, and not only by digitizing the real phenomenon, it is also possible following a path that involves merely moving within an IT environment. This method is applied by using well-tested applets, simulations, animations, physlets – collectively called computer (physical) models.

My college's theoretical framework supports employing an innovative strategy to teach and learn physics following inquiry-based learning and digital technology, in a STEM setting. The students from the real profile are interested to learn more about physics topics, during being encouraged to take an interdisciplinary approach. They are directed to do basic scientific study, concentrating on the applications of physics phenomena, which will help them in choosing their future fields of employment. We intend to encourage students' creativity, investigative ability and practical skills and to give them the chance to use digital technology in the analysis and better understanding of different physical phenomena.

Capitalizing on students strengths from the mathematics-informatics profile, their various multiple intelligences and skills, we created ***an interactive web-page - Elements of thermodynamics*** *(Figure 3)*.

Figure 3.

The web page contains a set of thermodynamics topics, theoretical notions and virtual experiments, the simulation of diffusion and Brownian motion phenomena, the transmission of heat by conduction, convection and radiation, animations that reproduce the operation of heat engines as well as some tests that provide feedback on assimilated knowledge.

The web-page was structured in three parts, intended for teacher, student, respectively for anyone who has access and manifests an interest in publishing useful physics materials. The covered topics have sequences organized according to the typical course of a lesson. Through its content and form of presentation, it is a good tool for students to deepen and test their knowledge.

By simulating interactive experiments, the students have the opportunity to observe and analyze the unfolding of phenomena, discover and describe, compare and debate and finally explain, define and draw conclusions. In general, visualizing an experiment, the students can observe the unfolding of the phenomenon and, analyzing the results, they can deduce the laws that describe the respective phenomenon.

In the following are depicted a few sequences with animations, that have been integrated into the Physics lessons. Each simulation is associated with a question that stimulates students' critical thinking and the expected answer.

4. Experiments that Highlight the Thermal Movement of Molecules

The learning process could be initiated through directed discovery, starting with a provoking question and visualizing real or virtual experiments. After discussions and analysis, the students are able to characterize and to define the phenomenon.

Simulation of the phenomena of diffusion in gases, liquids, solids can be visualized to describe and define the phenomenon, with the specific characteristics, making a comparison in the case of the three states of aggregation. The simulations illustrate diffusion in gases, liquids, solids and Brownian motion, in order to clarify the characteristics of thermal motion. These simulations can be used to refresh students' knowledge about the states of matter and also to compare the behavior of the molecules.

Some excerpts from the web page are exemplified below (*Figures 4, 5,6,7*).

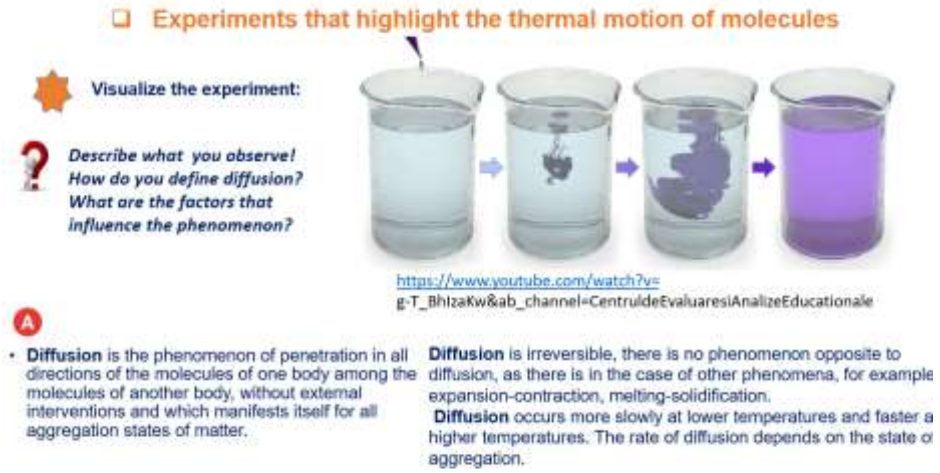
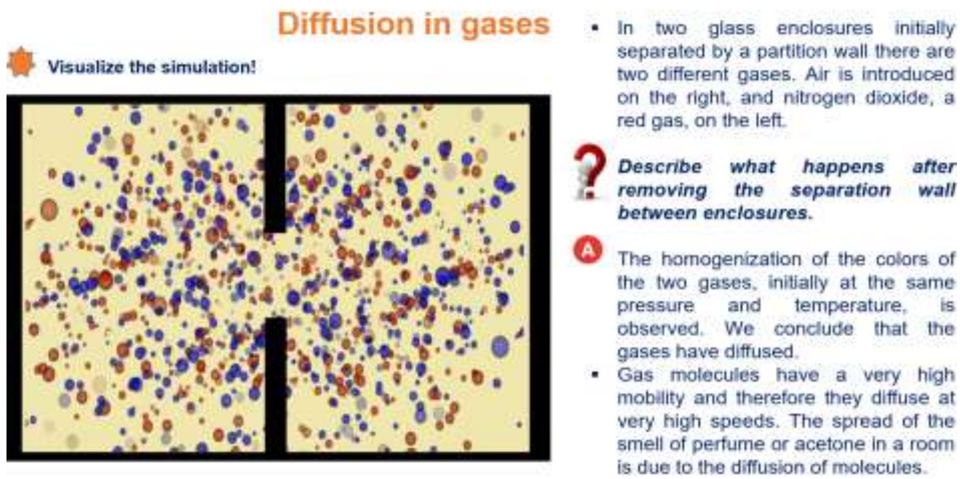


Figure 4



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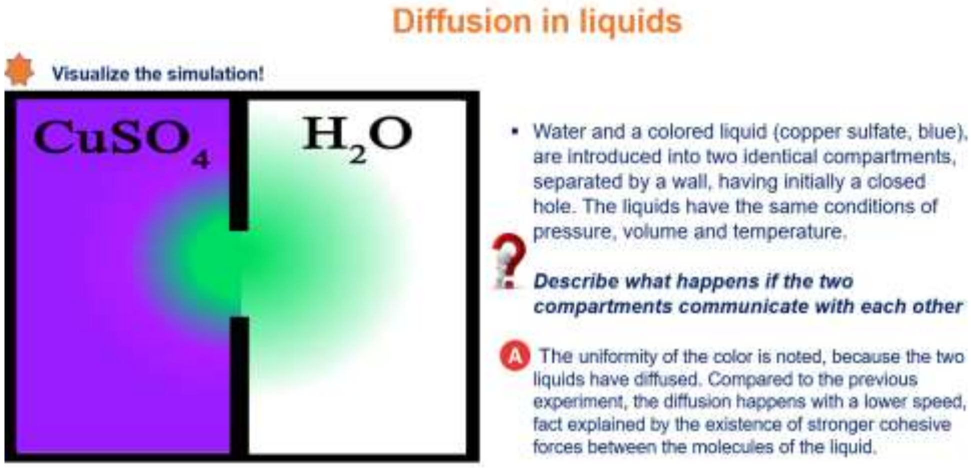

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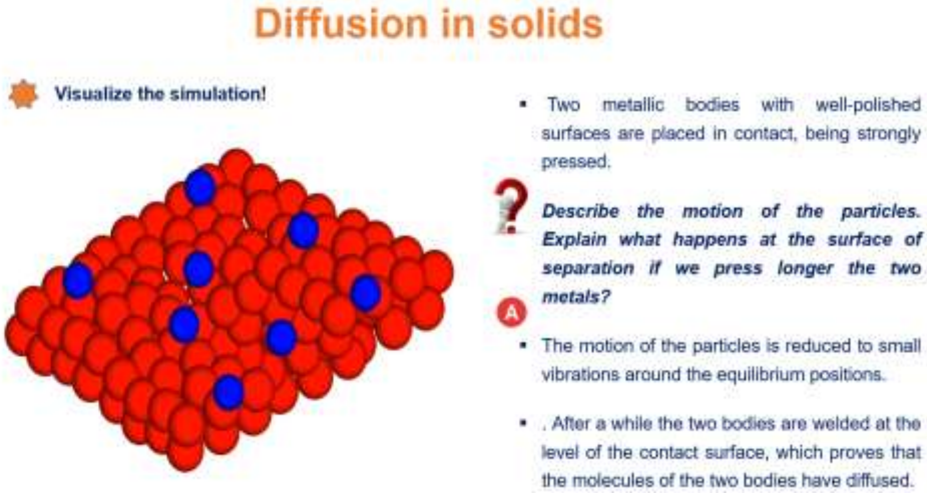

Figure 7.

Brownian motion of the tiny pollen particles can be analysed using a video, through which the students can observe, analyze, compare and define the phenomenon (*Figure 8)*.

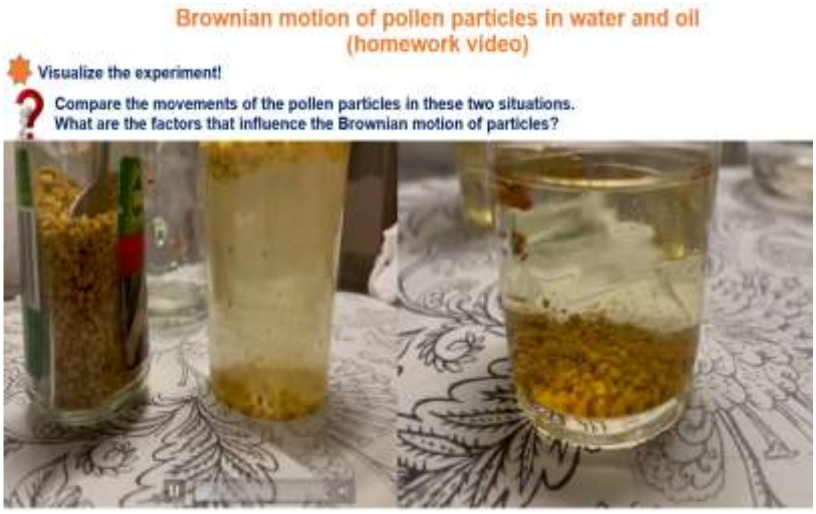

Figure 8.

In the same way, animations illustrating the transfer of heat by conduction, convection and radiation, are made with the purpose to define and explain the concepts (*Figures 9, 10,11)*.

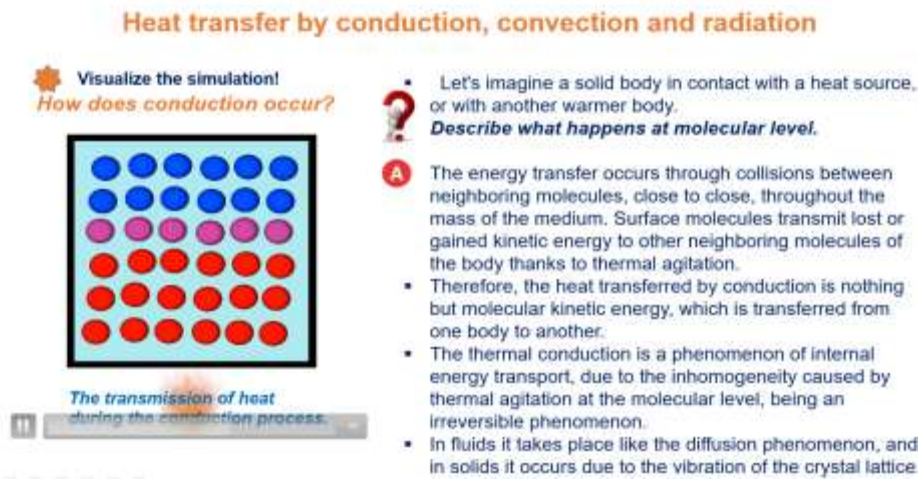

Figure 9.

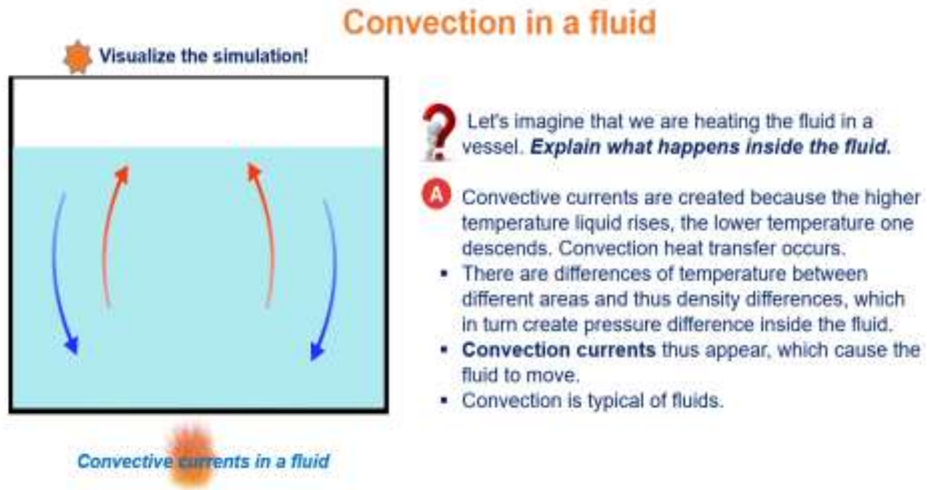

Figure 10.

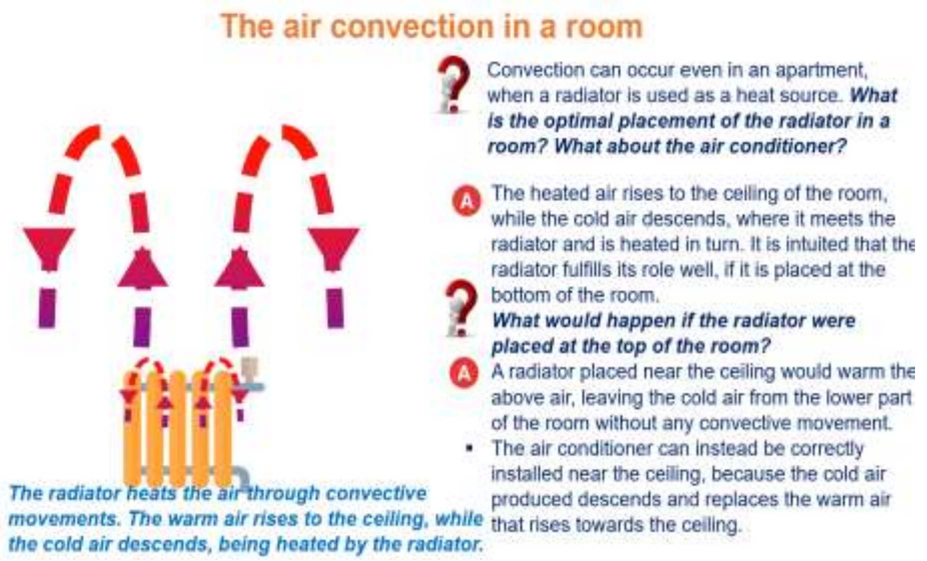

Figure 11.

5. The Use of Concept Maps in the Didactic Process

A concept map is a tool that can be seamlessly integrated in didactic strategies, which helps us to conceptualize, organize, rank and connect specific contents. It allows the information to be visualized and organized in logical structures, highlighting the links between them. The factor that favors the learning process is the graphic arrangement of the notions, their presentation in spatial structures.

Complex concept maps can be obtained based on specific programs, with links to multiple types of resources. The maps are easily corrected and completed with new notions, being distributed and used in the teaching-learning process. Concept maps realised with specialized programs can be used in all the stages of a didactic process. Concept maps can be used for presenting information in a structured way, calling on different resources for detailing contents, for exemplifying or illustrating physics phenomena.

Thus, we used concept maps during the thermodynamics lessons, based on the *scientific investigation method,* according to the following stages:

- *evocation* - that involves the inventory of previous knowledge, based on accessing some simulations, in order to visualize physical phenomena;

- *thought provoking and generating discussion* - the stage in which teacher-moderated discussions and experiments are carried out to highlight phenomena and to determine specific laws;

- *application* – the students practice by solving training tests and the proposed problems;

- *summarization* –in which the students summarizes the concepts with a concept map.

Concept maps are useful *during the learning process*, the students can structure their information, completing the connections step by step and discovering new connections between them. The students are stimulated to work in teams, this approach coming with additional learning opportunities. Each member of a team is encouraged to explain and justify his ideas to his colleagues, which leads to their clarification. The student listens and internalizes the explanations of his colleagues, developping his ability to negotiate the optimal option which leads to the formation of useful skills for personal development.

The concept map can be used *in evaluation* to determine if the concepts are well correlated and ranked, identifying and correcting misunderstood things. Here, it is mainly a matter of conceptual learning, not the ability to apply theoretical notions in solving problems.

First of all, the students are encouraged to use IT resources for their academic work. Secondly, the generated resources are simple to disseminate, allowing the students to benefit from them not only in the first stages - the introduction of the new knowledge, but also in the phase of in-depth study or when completing individual asignments. Additionally, concept maps can serve as examples of methods for studying certain physics concepts. This educational tool promotes the growth of analytical thinking, practical skills, analytical and creative thinking and knowledge organization.

Thus, it was discovered that the use of concept maps enhances comprehension of the concepts, developping thinking, reveals misunderstood concepts, and determines the acquisition of knowledge. Although the concept map provides clues about how much information the student has accumulated, the type of knowledge (conceptual or procedural) or the relationship between the types of knowledge is not highlighted.

We can use different instruments to make concept maps, starting from Word, Power Point, to programes as Xmind, SmartDraw, MindMeister, Canva, Mindomo, Creately, etc.

An example of a concept map that summarizes the notions studied about thermal movement is shown in *figure 12.*

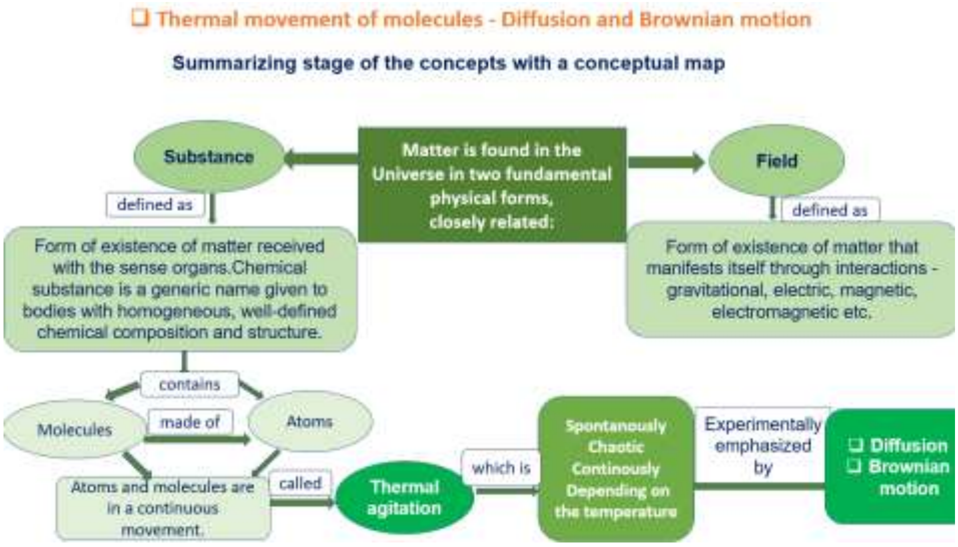

Figure 12.

6. Conclusion

In this paper are presented some options for using digital technology, and the importance of developing digital skills, illustrated in the case of thermal phenomena. The webpage created with a group of students contains a set of thermodynamics topics, theoretical notions and virtual experiments as well as tests that provide a feedback on the acquired knowledge. The focus is mainly on applications that require a creative approach based on students' digital skills. We simulated physics experiments, following the model of thermal processes in the real world, and we also emphasized the importance of using conceptual maps in physics during different moments of the didactic activity. We applied the interconnection between the real world and the virtual experiment on the topic of "thermal motion", heat engines, etc. The students, coordinated by their teacher, successfully created simple animations of physical phenomena, demonstrating their passion, creativity and digital skills.

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