Digital Comics, a Visual Method for Reinvigorating Romanian Science Education

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Abstract: The Romanian science education reform is targeting a real literacy in science and technology among all graduates of the compulsory education. Writing, talking, and reading about science are desirable goals of scientific literacy, and also ways of achieving it. On the one hand, the current generation of pupils is a digital one, a YouTube Generation or Net Generation, which has grown up in an environment in which it is constantly exposed to digital technology and accustomed to the use of various media, short written texts, pictures and videos, for pleasure and sometimes for learning. On the other hand, hands-on learning activities based on ICT tools aim at increasing pupils' interest in sciences both during formal and non-formal education. In this context, the use of visuals and ICT, in particular, of digital comics, can be a suitable medium/method for science education and communication for this young generation. In this article, we describe and analyze how ICT-based formal and non-formal activities incorporating digital comics and other visuals can facilitate learning and can increase student enthusiasm/motivation for learning science. This article presents and analyzes example activities designed for secondary school pupils by students from the Faculty of Physics, from the West University of Timișoara, which are also enrolled in the pre-service teacher training program offered by this institution. The favorable feedback we have received from the pupils and preservice science teachers alike leads us to assert that such innovative ICT-based teaching methods can lead to a revival of the Romanian science education in general, and of the Romanian physics education in particular, at least as a result of raising pupils' interest in this discipline.

Keywords: *science education; creative teaching methods; ICT; comics.*

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1. Introduction. Why comics in Romanian Science Education?

The current society is characterized by globalization and internationalization, being mainly based on ICT, science and knowledge, which implies a literacy in these areas and the formation of specific competencies, is mandatory for graduates as they enter the labor market.

In the "The World Economic Forum, 2017, in the Future Work Skills 2020 Report", the competencies that they will need on the labor market are highlighted, among which the three top competencies are complex problem solving, critical thinking, creativity, respectively judgment and decision making or cognitive flexibility (Davies, Fidler & Gorbis, 2011). This implies, in addition to a literacy in science and an efficient / effective communication, respectively the development of science-learning skills based on critical reading and analyzing in various forms and from different sources.

We also observe in the OECD reports a spectacular increase in the importance of creativity and critical thinking as competencies required for a graduate in 2030 compared to 2015 (OECD Raport, 2018). This trend is also visible in the UNESCO report "The future of learning 2" (Scott, 2015), which highlights the four major dimensions of learning: "learning to know", "to do", "to be" and "to live together"; which in the case of the "to do" dimension emphasizes once again the acquisition of the above mentioned competencies (critical thinking, problem solving, communication, creativity, media and technology literacy, etc.). All of the above show that the required profile of the current graduate differs greatly from the one of a decade ago.

In Romania, as well as across Europe, pupils are digital natives (Prensky, 2001; Rowlands et. all, 2008), possess to a greater or lesser extent digital competencies (Timothy, 2016; Bennett & Maton, 2010) learn through / from various backgrounds, while informal learning is mostly based on visuals (Lin & Lin, 2016) which means that they have formed specific skills or need visual literacy, usually communicating in the virtual environment through short texts, pictograms which imply a need for the essence of the message / information transmitted.

With a change in the use of images and video for daily consumption and production of information, "**visual literacy**, the ability to understand pictorial information, became one of the basic skills required for communication in the twenty-first century" (Duncan, Smith, & Levitz, 2015). Both scientific and visual literacy occurs primarily in formal science education.

Following the direction observed both at the world and at the European level, Romania is facing a steady decline in student interest towards formal science education (Crăciun, Crăciun & Bunoiu, 2016), which was highlighted both by the results of Romanian students in the PISA tests (OECD Raport, 2016) and the various national studies (Hatu, 2010). Students consider science abstract, without being anchored by the teachers in everyday reality, these teachers using classical teaching, learning and assessment methods, that do not lead to the formation of skills needed by graduates in the current labor (Hatu, 2010). All these factors lead to students facing difficulties in understanding concepts, applying the studied topics / concepts in everyday life, and scientific communication becomes difficult. A reform of science education that should be based on hands-on and investigative activities and on a pertinent communication and use of information received through various media and learning situations (formal, non-formal or informal) is needed. In this direction, major steps have been taken through curricular reform of undergraduate education of Physics and Chemistry, by adopting curricula proposing learning physics through investigation and use of active and participative teaching methods based on ICT.

Taking into account the above, we consider that a change in the way of information communication is necessary, by adapting the traditional methods to form the abovementioned competences.

This is the context in which we introduce science digital comics as a form of sequential art, but also a narrative / visual communication of the scientific message, relying on the fact that such a method develops both general competencies of communication, collaboration, problem solving, creativity, critical thinking but also those specific to science and ICT.

Our article presents how science digital comics can be integrated into pre-university Physics education, both through formal and non-formal activities, and investigates the participating students' and preservice science teacher's attitudes towards this method that is less used in Romania.

2. Digital Comics and science education

2.1 Teaching science with narratives and comics

Writing, talking and reading about science are desirable goals of scientific literacy (Ritchie, Tomas & Tones, 2011), written texts being currently one of the main sources of information (Falk, Storksdieck, & Dierking, 2007). Narrative texts are not generally specific to the learning of Physics (Norris, Guilbert, Smith, Hakimelahi, & Phillips, 2005), but in the

context of a population less and less interested in scientific information itself, used with brief, often emotional impact information, such an approach is becoming popular especially in that segment of the school population who does not declare itself interested in exact science disciplines.

However, stories in their traditional form are no longer suited to the generation of native digital students who are used to using Internet-based multimedia communication, Youtube, WhatsApp, or Instagram, and having difficulty reading and understanding long texts (Kivunja, 2014). The development of ICT has led, on the one hand, to switching from printed texts to digital ones, e-books, articles, virtual libraries, but also, on the other hand, to a variety of environments where text can be combined with visual elements into websites, blogs, electronic presentations, videos, animations or comics.

In USA, Japan or Western Europe, comics are one of the most popular media for adolescents because they make reading enjoyable and comprehensible (Weitkamp, & Burnet, 2007). If these comics are done through specific applications, then they are called digital comics.

Digital comics are stories narrated by static images, in fixed sequences, created, viewed and sometimes stored by specific applications (Dittmar, 2012), a multimodal textual-visual form of literature (Cook, 2017) with elements like panels, speech bubbles and text boxes.

There are recent studies that have shown that although there is no difference in the aspects of knowledge and attitude between learning by reading a comic or a classic text, the results of emotional perceptions imply that science comics have the potential to develop people's ongoing interest and enjoyment for learning science (Lin & Lin, 2016). By combining narrative, ICT and visual art, and having a multimodal nature, digital comics present a real potential to increase readers' engagement and facilitate learning (Eilam & Poyas, 2010; Farah, Syamsul & Norshuhada, 2014). Other advantages of using comics in science education have been synthesized by Trnova et al. (2013) as follows: great motivating potential, short concise texts, putting subject matters into meaningful contexts, visualization of issues, identifying and removing misconceptions, interdisciplinary approach, support of constructivist teaching approach, etc. Among the possible identified hindrances in the successful use of the method were inappropriate choice of content, shortening the text can lead to ambiguous and scientifically inaccurate statements (Trnova, Trna & Vacek, 2013).

It is worth noting that digital comics are considered feasible for students at different ages and skills (Farah, Syamsul & Norshuhada, 2014, Keogh & Naylor, 1999; Spiegel, McQuillan, Halpin, Matuk & Diamond,

2013; Koutníková, 2017) being beneficial for students with no prior knowledge of the subject (Farinella, 2018).

From the perspective of science teachers, digital comics are a viable alternative for them to incorporate creativity and emotional content into their teaching (Khalid, Meerah & Halim, 2010), and can help humanize science, making it more accessible to students, regardless of their competence and availability in learning science (Farinella, 2018; Craciun & Bunoiu, 2015).

Digital comics can be used both in formal and non-formal or informal learning activities (Rowlands, et al., 2008; Scott, 2015). In the following, we present the different types of comics currently available, their characteristics and dedicate applications that can be used to develop them.

2.2 More about Digital science comics (types, characteristics and dedicate applications)

The term 'comics' is generally used as an umbrella term for a variety of products ranging from classic comics printed in magazines and newspapers, to long-format graphics, books, sometimes even digital cartoons. There are comic stripes, comic books, graphic novels and one-panel cartoons.

If these comics have science themes, then they have the generic name of science comics. Depending on their purpose, Tatalovici (2009) identified two types of science comics, those created for entertainment or science fiction and those devoted to science education. The purpose of these science comics is to facilitate scientific literacy and to make scientific information accessible to both the public and students in formal and non-formal activities.

There are various types of classic comics with great global influence, manga being, for example, one of the most popular forms of Japanese publication in this category. In the case of science comics, there are specific one-panel cartoons that can be used either to convey a simple idea (Tatalovic, 2009), or to introduce a certain concept, called concept cartoons (Keogh & Naylor, 1999). The one panel cartoon category also includes Sciencetoons (Srivastava, 2002), which also have a humorous tendency and which are generally caricatures accompanied by a relevant explanation of the depicted scientific topic / phenomenon. The science comics spectrum has been expanded since the online science education platforms began to give them various possibilities of interactivity, so they now include animated cartoons, motion comics and hyper-comics (Farah, Syamsul & Norshuhada, 2014).

Nevertheless, as Farinella (2018) mentions, it is more important to identify the common characteristics of comics, regardless of the form of the comics, and in this sense, they include visual - persuasion, narratives, humor, emotional and cognitive engagement.

Digital science comics can be created, viewed, and sometimes stored using online or offline digital applications. There are many applications that may be used for free to create digital science comics. We would like to mention some of them that were presented to the students and preservice teachers in order to carry out the formal or non-formal learning activities (which we will discuss later):

- **Make Beliefs Comix** (<http://www.makebeliefscomix.com/>) - an online comic creator suitable for children to create simple comics and does not require an account.

- **Witty Comics!** (www.wittycomics.com/) - an intuitive application which allows the development of comics depicting the dialogue between two characters.

- **ToonDoo** (<http://www.toondoo.com/>) - an online application which allows users to choose from a large variety of characters, object and scenes to create original comics.

- **Pixton** (<https://www.pixton.com/>) - an online application which allows users to create, share, combine and publish comics, offering predefined templates, instant translations, as well as the possibility of combining existing comics.

- **Comic Strip It!** (app on Google Play)

We note that all of these applications are easy to use, and can be used by secondary school students in their learning activities in school.

Given the wide variety of comics, the educational benefits identified in the various studies above, the great motivating potential and the many free and easy to use dedicated applications, we found that this method can be used in formal and non-formal design for preservice science teachers, from UVT.

2.3. Formal and non-formal activities based on digital comics in UVT.

1. Digital comics in formal activities.

Combining important elements such as narrative, ICT and visual art, digital comics are effective pedagogical tools (Scott, 2015) and can be used in various teaching sequences to capture attention, to facilitate discussion on science topics, to effectively recall prior knowledge, to facilitate the

differentiation of scientific concepts, or for conceptual development (Dalacosta, Kamariotaki-Paparrigopoulou, Palyvos & Spyrellis, 2009).

Comics can be used for knowledge acquisition, assessment, and experimental activities to facilitate experimental data, data processing, or identifying concepts underlying experiments or evaluations (Affeldt, Meinhardt & Eilks, 2018).

Preservice science teachers participating in our study had the opportunity, in the Teaching Physics course, to design different learning activities, folded on Gagne's teaching steps (Gagne & Leslie, 1997) and involving several types of comics and various specific applications. They have created digital comics to introduce the topic to be studied during the lesson, to explain a given phenomenon, to identify and correct pupils' misconceptions, for evaluation or as part of experimental activity charts. A detailed description of these activities can be found in Craciun and Bunoiu (2017) together with some examples of digital science comics made by preservice science teachers.

These comics were actually used in simulated didactic activities at Teaching Physics seminars as part of the theoretical training of teaching in pedagogical practice. Taking into account that preservice teachers have carried out a small number of effective teaching hours in pedagogical practice, which depended greatly on teachers' willingness to try unconventional teaching methods, we decided jointly that the students should actually use digital comics in non-formal activities, usually conducted in the same schools.

II. Digital comics through non-formal activities conducted by UVT

To this end, the "Physics - A Story in Images" yearly project editions were organized annually during the preservice teacher training program offered by UVT through the Teacher Training Department and promoted "through and for" science education, focusing on the interactions between the scientific and the cultural / artistic environment.

The activities carried out during the 5 years of nonformal teaching activities, 2014-2018, aimed at communicating the concepts and phenomena studied in the above mentioned disciplines, as well as topical themes from the top fields of science, in a visual and creative way, using annotated images, comics, digital stories and concept drawings, made with the help of specific free online applications. The activities were designed, organized and evaluated with the help of preservice teachers from UVT, being supported by the Timisoara Branch of the "Romanian Physics Society".

The objectives of the successive project editions were generally the same, for the period covered by our study, 2015-2017, being the following:

OB 1. Increasing pupils' interest in Science by carrying out activities specific to the art and humanities.

OB 2. Training pupils and preservice science teachers in developing their capacity to deliver the scientific message in the real and virtual environment.

OB 3. Using new technologies to promote science education.

For the preservice science teachers enrolled at UVT, it was a complex activity aimed at designing, managing, evaluating and disseminating non-formal learning based on digital comics.

These formal and non-formal activities carried out by preservice teachers from UVT have been the basis of our study, the ultimate goal being to introduce digital comics into the formal teaching activities of science teachers in our area of influence, e.g. Timis County.

3. Methodology

3.1 Description of the study. Research questions

The context in which our study is conducted has been presented above, and the solution that we have proposed, starting from the existing situation in science education in general and the Romanian one in particular, is the use of digital science comics as a teaching method both to develop competencies related to science and ICT, communication, problem solving, creativity, critical thinking, but also to increase students' motivation and interest in learning sciences.

This study targets two distinct populations, secondary school students and teachers, in our case preservice science teachers.

In the case of the secondary school students, we want to investigate how they are willing to use new methods and technologies in learning, and whether the various non-formal digital comics activities can influence their attitude to science learning, targeting the various Physics fields studied in school

In the case of the preservice science teachers, we are primarily interested in them actually using digital science comics in designing teaching-learning-assessment activities and carrying out teaching activities based on them. Based on these experiences, we wanted to see the attitude of these preservice science teachers towards digital comics integration in science learning and communication, and whether there is a desire to use this method in the future. Finally yet importantly, having in mind that they had

the opportunity to carry out with students an activity based on digital comics, we were interested in how they perceived this activity from the students' interest in methods, topics, types of activities, compared to the classical practices they have carried out in pedagogical practice.

In this sense, the pedagogical practice activities were completed during the period 2014-2018 with the non-formal activities of the yearly editions of the project "Physics- A Story in Images", the activities taking place in the pedagogical practice application schools in Timisoara and Timis County.

Hence, the research questions that underlaid our study were the following:

Q1. What is the attitude of future science teachers towards digital science comics and their integration into the teaching activities they were / will be involved in the future?

Q2. What is the attitude / interest of students towards using modern methods based on visuals and especially digital comics in didactic activities and how does this interest depend on various factors (such as gender, age, competencies, school environment)?

3.2 Participants

Each academic year, at UVT, between 4-8 preservice science teachers graduate the psycho-pedagogical training program, of whom 3-5 preservice science teachers participated in the yearly editions of the project "Physics - A Story in Images". Participating secondary school students are mainly from the application schools for pedagogical practice, but also from the rural schools.

Our study, conducted between 2015-2017, involved 16 preservice science teachers (87.5% female and 12.5% male), and 145 students (53.1% girls and 46.9% boys). During this period, students in the 6th to 8th grades from 6 schools from Timisoara and Timis county participated in our study. The distribution of students based on schools and grades is shown in Figure 1.

Figure 1. Distribution of students participating in the study based on schools and grades.

3.3. Materials and Instruments

In the case of preservice teachers, the study involved the application of an in-house questionnaire (CH1), both before and after the didactic activities, which was completed with a focus group at the end of the activity. The CH1 questionnaire consists of 15 items (5-point Likert scale), structured on 2 subsets:

- **ICT/specific comics apps in preservice teacher training** (Q1. The use of ICT can positively influence teaching-learning-evaluation activities in Physics; Q2. Digital cartoons are a useful / viable method in learning science; Q3. You can integrate ICT and digital cartoons into your teaching; Q4. You can communicate laws / concepts / physical phenomena through digital comics; Q5. You have been trained to use ICT-based methods in teaching Physics), and

- **Digital Comics in science teaching** (Q1. can influence students' attitudes toward learning science; Q2. increase students' engagement and motivation in science learning; Q3. lead to changing students' preconceptions; Q4. represent an effective method for teaching-learning-evaluating Physics; Q5. facilitate lifelong learning; Q6. develop higher order skills; Q7. develop creativity and students' imagination; Q8. develop communication skills and cooperation between students teachers; Q9. provide an opportunity to make connections with real life; Q10. deliver an effective feedback).

A third section required respondents to put in order of importance (1-least important and 5 most important) 5 obstacles and 5 opportunities that aimed at integrating digital comics into science teaching as follows:

• **5 obstacles** (ob1. Students can be attracted more by the characters used than the theme approached, diverting from the main purpose; ob2. Digital comics represent a time-consuming method, for both teachers and students; ob3. Comics can lead to a fragmentary approach of proposed topics, being ineffective in explaining phenomena / laws / concepts; ob4. Lack of adequate ICT training and specific software for science teachers; and ob5. Lessons learned by teachers in adapting teaching and learning methods to integrate modern learning and visualization technology); and

• **5 opportunities** (op1. It increases the accessibility of scientific content and creates a creative learning environment; op2. Stimulates and motivates students to learn abstract concepts from real-world situations; op3. Communication of scientific content; op4. Digital comics can be used in various stages of the lesson, both for teaching/learning and for evaluation and op5. By highlighting some essential issues, they determine an environment conducive to discussion / exploration and argumentation).

The focus group was composed of 8 of the preservice science teachers participating throughout the study, the questions targeting feedback about the work done, the science comics as a teaching method, the technical and pedagogical difficulties encountered in the development and integration of digital comics, the preservice teachers' motivation, the benefits of integrating such visual and ICT-based teaching methods, etc.

A post-test and a quasi-experimental design without a control group was used to investigate the perception of secondary school students on the usefulness of digital comics in their science education and ICT integration in learning activities. For this purpose, we used an in-house questionnaire (CH2) with 14 items (11 based on 4-point Likert scales and 2 open ended), structured on 5 subsets: **Attitude towards technology integration in class** (at_teh), **ICT Competences** (comp_ICT), **Attitude towards Comics** (at_com), **Comics integration into student's own activities** (int_com), **Global feedback on activity** (fb). The 2 open ended questions aimed at feedback on all the didactic activities of students (fa) and the areas of interest (fs).

3.4 Activity description.

Preservice science teachers were acquainted with and created their first digital science comics in the year preceding the effective non-formal activities at the Teaching Physics course, and the CH1 questionnaire was first applied then.

In the following academic year, after a period of formal activities in pedagogical practice, preservice science teachers participated in the non-

formal activities carried out within the editions of the project "Physics - A Story in Images", organized by the Teachers Training Department of UVT as part of their psycho-pedagogical training.

Within the editions of the project, between 2015-2017, each year, 4 distinct activities took place:

A1. Designing comics and preparation of non-formal teaching activities by preservice science teachers. Preservice science teachers have prepared a series of digital science comics on various topics inspired by the lives of scientists, breakthroughs in scientific fields, research-specific methods, science and technology history, basic concepts in science, phenomena studied in secondary school, etc. Various specific applications (MakeBeliefsComix, Pixton, ToonDoo, etc.) were used to accomplish them.

A2. Digital Comics Workshops for Students. Preservice science teachers participated in a series of presentations (based on their own digital science comics) in secondary schools and high-schools in Timișoara and Timiș County, followed by discussions on topical subjects in science and the necessity of scientific literacy for any graduate of compulsory education, in order to be competitive in today's society. They were involved in both administrative and presentation activities. These workshops were meant to be a creative and exciting way of presenting the sciences in general and Physics in particular, having as their main purposes the training of preservice teachers to carry out non-formal teaching activity, motivating students to study science and presenting active teaching methods, based on ICT. Students were briefly presented the applications used for digital comic strips and created short strips themselves on topics found following wordsearch activities on Physics topics. Students had access to the edited comics catalogs, providing them with tutorials in Romanian for all applications used in the activities. The questionnaire CH2 was applied to all of the participating students after the completion of the activity.

A3. Comic Contest addressed to all participants in the project, involving both students and preservice science teachers. Following the interactive activities performed by preservice science teachers, participants from pre-university education level were invited to draw their own comics based on how important science breakthroughs can change everyday life, with a digital creativity contest being organized. Preservice science teachers from UVT evaluated the students' digital science comics based on a regulation made by them.

A4. Dissemination activities in the virtual environment (digital panels) and real environment (exhibitions) in the schools involved. All of the science comics made in the workshops and the competition were

posted on a digital panel (Padlet) accessible to any student, preservice / in-service science teacher or parent. After printing, the award-winning digital science comics were exhibited in a space offered by the Faculty of Physics of UVT, in a thematic poster exhibition "Physics - A Story in Images", as well as in most of the participating schools. Upon completion of these activities, the involved preservice science teachers completed CH1 again and reflected on the activities of digital science comics throughout the training program within a focus group.

4. Results and discussions

The data obtained by applying the two questionnaires were analyzed using qualitative and quantitative methods. Quantitative analyses included descriptive statistics, tests and reliability analyses. Likert-scale items were initially scored and subsequently exported into the Statistical Package for the Social Sciences (SPSS) where means and standard deviations were calculated for each subset component as a whole.

In the case of preservice teachers

Scores on each of the subset component were computed for each preservice science teacher, before the non-formal activities (pre measure) and at the end of the non-formal activities (post measure).

Table 1. Preservice science teacher descriptive statistic

<i>Subset</i>	<i>N</i>	<i>M</i>	<i>SD</i>	<i>Values</i>
ICT/specific comics apps in preservice teacher training	32	3.29	.66	1 – 5 (1 strongly disagree- 5 strongly agree)
Digital Comics in science teaching	32	3.68	.74	

Where N = number of participants; M = mean; SD = standard deviation.

To test for the significance of the gain score (post measure-pre measure), a repeated measures t-test was conducted on each of the subset components. As seen in Table 2 there is a significant gain ($p < 0.05$) on the two components. The effect size denotes the increase in the mean score in standard deviation units, and the values obtained indicates a large increase.

Table 2. T-test and reliability analyses for the two components

<i>Subset</i>	<i>Pre-meas.</i> <i>(N=16)</i>	<i>Post-meas.</i>	<i>dif.</i>	<i>t</i>	<i>P</i>	<i>d</i>
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	<i>(N=16)</i>							
	<i>m</i>	<i>SD</i>	<i>m</i>	<i>SD</i>				
ICT/specific comics apps in preservice teacher training	2.86	.47	3.71	.54	.85	12.23	.000	3.15
Digital Comics in science teaching	3.43	.65	3.93	.77	.50	6.59	.000	1.77

Where N = number of participants; M = mean; SD = standard deviation
dif. = mean difference; P = P sig (2-tailed); d = effect size.

This result shows that preservice teachers believe that both modern ICT-based teaching methods and digital comics can be used in science teaching, and their degree of confidence is increasing as a result of the activities actually carried out, which is in line with specialized literature stating that the effective ICT use in training programs favors the use of these applications in teaching (Collis & Jung 2003; Haydn, 2014).

Statistical analysis of each item shows that for the first subset (ICT/specific comics apps in preservice teacher training), there is a significant increase for all items Q1-Q5, the highest effect being obtained in the case of item Q1 - 'The use of ICT can positively influence teaching-learning-evaluation activities in Physics - which shows the preservice science teachers' confidence, after their activities, that this method can be used in science teaching. In the case of the second subset (Digital Comics in science teaching), a significant increase was identified for 8 of the 10 items. The two items that did not show a significant increase in activity are Q6 (develop higher order skills) and Q7 (develop creativity and students' imagination) can be explained by the fact that preservice teachers were still enrolled in the teacher training program and had little experience with students, while higher order skills or creativity, aimed at students, were still quite abstract notions for them. It is noteworthy that the largest increase was noticeable for item Q1 (digital comics can influence student attitudes towards learning science), followed by Q2 (increase student engagement and motivation in science learning), showing that digital comics according their opinion can change students' attitudes towards science and science classes, increasing their interest and motivation for learning.

Obstacles and opportunities in the integration of digital science comics in teaching physics identified by preservice teachers are presented in Fig. 2 (the horizontal axis shows the scores given for each obstacle / opportunity, the vertical axis shows the number of preservice teachers who opted for that score).

To rank preservice science teachers choices, we calculated a weighted average for each obstacle or opportunity. This is how we found that the main obstacle to the integration of digital comics into science teaching (in general) is ob4 (Lack of adequate ICT training and specific software for science teachers) (4.06) followed by ob2 (Digital comics is a time-consuming method for both teachers and students) (3.63) and ob5 (Limiting teachers' knowledge of adaptation of teaching-learning methods for the integration of modern learning and visualization technology) (3.06). These answers express a factual situation in the Romanian science education, where, despite the various training courses offered to teachers, this knowledge remains only in the theoretical sphere, with few practical activities being actually realized, which decreases teachers' confidence in their own use of modern teaching methods based on ICT.

Figure 2. Obstacles and opportunities identified

The main identified opportunities were in decreasing order op2 (Stimulates and motivates students to learn abstract concepts from real-world situations) (4.19), op1 (It increases the accessibility of scientific content and creates a creative learning environment) (4) and op3 (Diversifies the options of communicating the scientific content) (2.81). All of these answers show the positive attitude of preservice science teachers towards digital comics and their integration into science education and the use of this ICT-based method in their future teaching career. It also notes their confidence that digital comics can motivate students to learn science and can be a bridge between science education and the real word.

Analyzing their own professional development in the focus group, the preservice science teachers pointed out that, following the activities carried out during the project, they developed skills to create digital comics to transmit concrete scientific information adapted to the students' age, to

design teaching activities based on digital comics / cartoons to identify misconceptions or to teach a scientific concept / law / phenomenon, depending on the level of the students they will teach, to use and critically assess activities based on web based comics to stimulate and motivate students, as well as to teach creatively and student centered.

In the case of students

In the case of the questionnaire CH2 applied to the secondary school students, scores on each of the subsets were computed for each student at the end of the non-formal activities. These results are shown in Table 3.

Table 3.

<i>Subsets</i>	<i>N</i>	<i>Mean</i>	<i>SD</i>	<i>Values</i>
Sc_at_teh	145	3.68	.71	From 1 to 4 (1strongly disagree- 4 strongly agree)
Sc_at_com		3.43	.73	
Sc_int_com		3.36	.90	
Sc_comp_ICT		3.33	.84	
Sc_fb		3.52	.64	

It is noticed that students have a good perception of their ICT skills, a positive attitude towards digital comics, and their integration into teaching-learning-assessment activities in sciences, being a bit less confident in their ability to achieve and present digital science comics, which is explicable, considering that before the project started most of them did not know anything about the applications dedicated to creating a science comic, or about digital comics in general.

Next, the different correlations between the components of the questionnaire and the grade of the participants, the gender or the environment of the school (rural / urban) were analyzed (table 4). We have identified the first positive correlation showing that a positive Attitude towards Comics (sc_at_com) leads to the desire to integrate them into their own activities (sc_int_com) and to a positive global feedback (sc_fb). Also we observed a second positive correlation in that ICT Competencies (sc_comp_ICT) leads to a positive Attitude towards Technology Integration in class (Sc_at_teh). In addition, a negative correlation between grade and sc_Int_com and sc_fb was observed, which means that the higher the grade of the student the less interested the student is in comics integration and the lower is his given feedback. In the latter case, the result obtained was

influenced by the fact that the project activities were carried out on mixed groups of students, grades 6-8, the topics and activities actually being performed were originally designed for younger students (6th grade).

This result strengthens our belief that the method can be viable for any age but needs to be adapted to the age and training of students, which can be achieved through formal education (by age groups).

Table 4. Subsets and Grade Correlations

			<i>sc_int_com</i>	<i>sc_comp_IC T</i>	<i>sc_fb</i>	<i>class</i>
Spearman's rho	<i>sc_at_tech</i>	Corr. Coeff.		.266**		
		P Sig. (2-tailed)		.001		
	<i>sc_at_com</i>	Corr. Coeff.	.300**		.353**	
		P Sig. (2-tailed)	.000		.000	
	<i>sc_int_com</i>	Corr. Coeff.			.443**	-
		P Sig. (2-tailed)			.000	.000
	<i>sc_fb</i>	Corr. Coeff.				-
		P Sig. (2-tailed)				.250**

**. Correlation is significant at the 0.01 level (2-tailed)

Analyzing how the gender and the environment (rural / urban) of the school of origin influenced the received feedback, we found that there were significant differences in global feedback between boys and girls, Sig. (2-tailed) = .008 for *sc_fb* (the girls were more willing to make digital comics and participate in the proposed teaching activities) and significant differences in Comics integration Sig. (2-tailed) = .004 for *sc_int_com* (rural students wanted to integrate comics more than those in the urban environment), ICT competences Sig. (2-tailed) = .000 for *sc_comp_IC T* (urban students felt that they have higher ICT skills than rural students), and almost significant differences in attitude towards technology integration in class Sig. (2-tailed) = .056 for *sc_at_tech* (urban students had a more positive attitude toward integrating technology in their class).

Analyzing these results, we can observe that the degree of confidence in using ICT in their own activities influences the attitude towards the integration of ICT-based didactic methods in class, but does not influence the desire to integrate digital comics, which justifies us to assert that this method could be applied successfully, regardless of the students' ICT skills.

The responses to the 2 open ended items led to the following results:

- The topics of interest identified by the participating students were: Mechanics/Gravitation 29.6%, Heat and thermal phenomena 23.2%, Electricity 20%, Optics 16%, Astronomy 9.6% and Simple machines 1.6%.

- Students were interested in the following types of activities: digital comics 53.7%, followed by activity sheets (puzzle and word search) 22.4%, poster and drawings 15.7% and preservice teachers oral presentations 8.2%.

Finally, we noticed that over 50% of participating students considered digital comics to be a teaching method to use in science classes.

5. Conclusions

This exploratory study aimed at identifying the attitudes of secondary school students and preservice science teachers from UVT towards the use of digital science comics as a visual, ICT-based method of communicating and learning science, highlighting aspects that can be taken into consideration in the future for an effective integration of this method in the schools in Timis county and the dissemination of this method at national level.

In the case of students we observed a positive attitude towards the use of comics in teaching and learning science and personal life. We also observed that there are no gender differences in attitude towards comics and ICT integration in science education, but the interest in integrating comics decreases with the age / grade of the students. It is also noticeable that rural students have been more eager to integrate comics, even though they feel they have lower digital literacy skills than urban students.

In the case of preservice science teachers, we observed that they strongly believe that digital comics can be used effectively in learning and communicating science. They also expressed their desire to integrate digital comics and concept cartoons in their future teaching activities and considered that using comics and/or other creative teaching methods can motivate students in learning physics.

All these results make us affirm that digital science comics could be used as a student centered and ICT based science teaching method, in Romanian science education, at different ages, to develop communication and ICT skills and can be a viable alternative for science teachers to incorporate content and creativity in their teaching and to develop students' 21st century skills.

There are also limitations to our study, such as the lack of a control group or a pre-measure for students' attitude (application of CH2 before the activity), or the self-reported results of preservice teachers. Nevertheless, we still believe the use of digital comics in Romanian science education can be a

viable method for non-formal education, it can be implemented in formal education, and finally yet importantly, it can be one of the factors that will increase the motivation and interest of students in learning exact sciences.

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