The use of spherical learning XR-arenas based on an abstract symbolic environment in physics teaching

O Yavoruk

1 Independent Scholar, Russian Federation.
Email: yavoruk@gmail.com

Abstract. Augmented/Virtual Reality (AR/VR) teaching technologies are increasingly popular in physics classes. The AR/VR (united by the term Extended Reality or XR) makes the physics course more close and understandable for young people. In addition, an abstract symbolic environment inside XR spherical arenas is easy applicable for physics teaching. The paper describes elements of an AR/VR sphere, abstract and symbolic objects of a learning arena. It deals with some essential findings from the analysis of experimental XR-teaching, controversial and debatable issues. Methodology of the study involved practical using of XR-devices and XR-applications in order to find adequate teaching elements of XR-arenas and the survey of students’ opinions. Nowadays, XR hardware and software are becoming much more prevalent among students. Physics teachers can easily respond to this request due to the specifics of their professional activities. Both teachers and students are interested in the easy use of XR demonstrations, unusual techniques, and pretty staggering opportunities of virtuality.

1. Introduction
XR (Extended Reality) is a hypernym that incorporates and describes technologies and characteristics of VR (Virtual Reality), AR (Augmented Reality). This word encompasses a group of words: AR, VR, MR (mixed reality), etc. [1]

There are many XR technologies relevant to physics teaching [2-4]. The technical professional language (jargon) and communication style of programmers are not always understandable to the teachers’ community. It makes hard the teachers’ efforts to master a pretty attractive learning tool. The paper concerns the problem of the quick start for teachers beginning to use XR in physics classes. The level of physics, mathematics and computer sciences that mastered the school/college/university teacher is quite sufficient. An abstract symbolic environment of XR facilitates to the soft adaptation of teachers and students: the properties and features of virtuality becomes accustomed and natural. The XR device of acceptable price range, elementary computer and telephone skills are all they need.

Here we consider the version that can instantly become the widespread release due to the low cost, simplicity, reliability, and attractiveness. A physics teacher can start using similar XR technology right now, on the next lesson, even if he/she does not have a programmer qualification.

The paper is organized as follows: section 1 (Introduction) identifies a research problem, gives the brief and general information; section 2 (Spherical learning XR arena) lists the structural parts of a virtual sphere, components of the XR world, that can be used for physics teaching, and short rules of their applying; section 3 (Findings and discussion) describes all the discovered usefulness, effective tricks, and unexpected difficulties of teaching; furthermore section 4 (Students about learning inside
spherical XR arenas) focuses on the results of interviews and questionnaires; section 5 (Conclusion) summarizes and generalizes the research; section 6 (References) finalizes the paper.

2. Spherical learning XR arena

Learning XR arena (scene) is an apparent sphere that has an undetermined radius with the centre in the place of an observer (XR-learner). The student is surrounded by learning elements. All studied objects are projected onto the inner surface of the sphere. Due to the binocularity of AR/VR glasses and resizing objects, we can create the impression of a various remoteness of elements. The equipment of the arena can be changed by students and teachers according to the educational goals, learning progress, personal preferences.

The astronomical terminology, spherical geometry and trigonometry [5], the analogies with elements of the celestial sphere are simple, natural and clear to physics teachers. We can identify the direction of the view applying the following objects of the sphere: zenith, nadir, and equator/horizon. The point of the sphere located directly above the head is “zenith”, and the point diametrically opposite to it (under the feet) is “nadir”. Unlike the celestial sphere, zenith and nadir coincide with the poles, and the horizon in this model coincides with the equator. The horizontal (altitude-azimuth) and equatorial coordinate systems exactly match to each other (they are the same here).

The subject of the special agreement is the position of the North/South Pole (upper or lower points, zenith or nadir). I think that depends on the geographic location of the school (the northern or southern hemisphere of the Earth). In our paper we consider the top point as the North Pole, and the bottom as the South one.

For the initial moment of teaching the prime meridian is very important. This is a line of longitude, a large circle of the AR/VR sphere, passing through the poles of a virtual world (zenith and nadir), crossing the horizon at the starting point of teaching (first control point). This is the location of the first teaching XR element. Here the lesson begins. Visual XR objects are recommended to place along the horizon line. The most important and general information may be located near the poles of the arena.

We can fill it with symbols, signs, images, formulas, drawings, illustrations, figures. Here is no any limit distance, and our learning virtual universe goes to infinity. The journey through abstract symbolic environment is defined by education content, student's desires, teacher's instructions, and cognitive procedures. The movements of a person surveying an artificial virtual universe are simple and natural.

Practical teaching issues often necessitate depicting a sphere on a plane: the process of creating panoramic slides, the delivery of educational material when the teacher or his/her assistant is out of virtual reality. The latitude and longitude of the sphere transforms respectively to the horizontal and vertical lines. Mobile XR applications allow seeing a learning sphere from inside. The demonstrations of lessons are around the XR-learner, who begins to observe the learning arena from the starting point, indicated by teacher. Panoramic representations allow us to dispose and demonstrate the entire lecture in front of a student, delivering the general view from a height: the start and the end of the learning material, number of slides and their informative capacitance.

3. Findings and discussion

3.1. Why is it so simple?

Many teachers have known about AR/VR from the media, colleagues, and children. But they do not guess on the possibility to carry out a simple and quick start of AR/VR-applying in their everyday teaching practice.

What does a teacher need? This list involves: AR/VR glasses (1-20 dollars), a smartphone, a free mobile application, and open-source software to create pictures (optionally, because you may get ready-made slides). You insert a mobile phone into the AR/VR helmet, launch the application, come
into the learning XR arena and start to learn or explain a new lesson. Even if there is only one (belonging to the teacher) XR device, students can watch a spherical demonstration one by one, passing up the helmet to each other.

The transformation of a flat image (source) to a spherical one is quite uncomplicated. Any image, sign, table, text, picture, video can be placed on the internal surface of a sphere. A usual presentation may be easily turned into AR/VR by tools of an ordinary graphic editor. Filmstrips and slide films, which are well known to the old generation of teachers, can find a new life.

A panoramic perception of the world is natural for humans. Teaching strategies are traditionally oriented toward the concept of learning cycles facilitating opportunities for students to develop and practice their thinking skills [6]. The panoramic teaching AR/VR technologies have reliable biological, philosophical, psychological and pedagogical justifications. Numerous systems of the world were based necessarily on cycles, circles and spheres. The principles of a universal language by Bruno [7] are carried out by circular and cycle systems. The Bruno’s art of memory [8] develops the idea of a number intersecting wheels: a finite number of mnemonic images or icons can be accommodated on each of the single wheels for the creation of potentially infinite combinations. Note it is very close to the idea of teaching circular panoramas (cycloramas).

A blackboard (or chalkboard), whiteboard (or marker board), flip chart, poster, presentation slide on the screen, interactive whiteboard, demonstration table, teacher’s figure occupy a pretty small angular size. Every XR panoramic slide covers the entire solid angle: \(4\pi \approx 12.57\) steradians. The typical blackboard \((300 \times 150 \text{ cm})\) through the distance 5 m covers solid angle \(\Omega = S/R^2 = 0.18\) steradians (approximately 1.4% of the maximum). Of course, you need to use \(4\pi\) of virtual space rationally.

3.2. Teaching inside XR
A physicist and a physics teacher see and examine the same problem in different ways. A teacher sees that the problem should not only be solved, it should be explained for student: the origin (where it came from), methods for dealing with problems (how it can be solved), and methods of explanations for different students. The methodology of physics teaching (didactics of physics) answers the three questions: why to study/teach/learn physics, what to study/teach/learn, and how to study/teach/learn physics [9]. By the formulation of answers to these three questions, we form the theory and methodology for the educational use of panoramic slides, revealing as a concrete area of physics teaching. AR/VR-teaching is a very popular and controversial area for new intellectuals living and working with this cutting edge pedagogical technology. The role of fashion is important here in physics teaching, but this is an unexplored area of pedagogy with tremendous ramifications still awaiting its researchers. We need a mass educational culture of virtuality, the special technical educational realm, AR/VR mind-set, and all of these imply technological cheapness for the ease distribution of this technology in the pedagogical (students, teachers, parents) environment.

We engage teachers and students in applying virtual reality by:

- Stimulation of creating and using AR/VR slides;
- Transformation of traditional techniques to the AR/VR format;
- Preparation of a lecture given by teachers in an AR/VR helmet;
- Demonstrations for students wearing AR/VR devices;
- Creation of platforms for individual AR/VR teaching;
- Studies of persons who get exposed to AR/VR.

Teachers are encouraged to their XR-activities because only they can create effective practices. Physics teachers do this with pleasure. We can also use traditional teaching tools. Many simple teaching methods are also easily transferable to virtuality. Training in the spheres is more effective with final debriefing after XR-part of lessons: “What did we learn?”; “What was the hugely important stuff in this lesson?”; “Which way do we go?”

Areas of pedagogical research waiting for their discoverers are associated at least, but not limited to:
- Individual XR teaching;
- AR-Teacher’s Assistant;
- XR concept mapping;
- Flying drones, that allowed to travel easily on high;
- Multi-user XR environment;
- Online and distance XR lessons;
- Presence effects due to 360 cameras;
- Interface and controllers of XR Arenas managing.

A physics teacher can suggest to students on the XR-lessons:

- Panoramas of abstract reality;
- Panoramas based on natural images;
- Panoramic study of instruments and apparatus;
- Panoramas integrated into lecture courses, exercises and practical laboratories;
- Panoramas of introductions and conclusions to the lessons.

A mystery weirdness of virtual reality arouses human curiosity, increases an attractive power of the studied facts, concepts, laws and principles, theories, methods, etc. Here the student is alone with the objects of study, face to face with the whole Universe. However, putting on AR/VR device in physics classes, student immerses not into the world of Lewis Carroll, but into the world of physics and mathematics (not into AR/VR fantasy, but into the rigorous AR/VR model of the physical world). Panoramic demonstrational AR/VR capabilities enable us to visualize by different ways and for every student the zone of proximal development and the horizon of possibilities, as well as make it visible to the student.

Unfortunately, learning is uncomfortable [10]. This opinion is widespread in pedagogy [11]. Uncomfortable experiences are an irremovable part of learning. Breathtakingly vivid intersections of realities give a new opportunity to activate a learning process with simple and quick way. Substantially, models of AR/VR-teaching beyond boundaries of the classroom, comprised of the experience, unobtainable in usual reality and challenging situations, can engage students to strive a deeper mastering of physics concepts. “Humans think in stories rather than in facts, numbers or equations, and the simpler the story, the better” [12]. Each XR teaching panorama is assimilated much better if it is told as a story, and every slide has its own story. A simple set of facts, figures, and equations has no any didactic significance. Students inside virtual spheres are pretty interested in a bright and simple illustrated story told from beginning to end. The movements between panoramas, illustrating transitions from one part of the XR story to another, switch over and concentrate students' attention. There are descriptions of characteristics, principles and methods of virtual panoramic models [13].

3.3. Awkwardness of XR technologies

Teachers and students wearing XR devices can quickly get used to the weird poses and movements of their bodies outside virtuality. But there are more hard aspects: VR excludes us from reality, leads to isolation; AR combines two worlds. In both cases, the visual, emotional, intellectual pressure on the student increases significantly. Teacher may face students’ refusing. Moreover, the teacher is not recommended to insist on a forced immersion into virtuality.

There is a lot of awkwardness due to XR realizing:

- Diseases (visual disorders, nervous system, mental illnesses);
- Religious restrictions;
- Individual rejections and prejudices;
- Public condemnation (parents may have some objections).
In most cases students use technical devices and software with full responsibility for their actions, listen to the warnings and precautions: during experiments with the augmented or virtual reality students can receive moral suffering, insulted feelings, probable moral damages, possible seizures, abrasions, and bruises. However, this can happen as a result of any school physics experiment.

An intense or long use of the AR/VR device can lead to the students’ tiredness. For instance this may be due to the overload of video watching, audio listening, active gaming, special effects, and flashes. Dealing with the effects of fatigue and relevant recommendations can be found in many papers [14] [15]. Note that the fatigue from the video fragments was detected earlier, even before the AR/VR epoch [16] [17].

Teacher can apply short AR/VR demonstrations on-going from a few seconds to several minutes: students bring up glasses to their eyes, watch up the demonstration, then return down and keep on the lesson. This way suits perfectly for: frontal and individual observations; short lecture demonstrations; solving problems with visualization of the studied effect (phenomenon) in AR/VR; individual tips for students.

4. Students about learning inside spherical XR arenas

It’s interesting for teachers to know how students respond this technology, what they think about the possibilities of virtuality in physics teaching, how comfortable the technical devices of extended reality (extendiality) were. Russian high school students (the research period: 2019/2020 academic years) answered some simple questions after XR lessons.

Methodology involved next conditions: lessons were carried out in a typical physics classroom; there was no coercion for XR devices applying; students followed the teacher’s guidance instruction (including safety rules); the teacher’s assistant monitored for the safety in the physics classroom; the duration of the lesson was up to 20 minutes. My questions and students’ answers are listed here in Tables 1-5.

Table 1. What would you like to see in XR in physics classes? (25 students)

| Answers of students                                      | Number of students |
|----------------------------------------------------------|--------------------|
| (There were no any response options, students offered their own answers) |                    |
| a) Things, which cannot be seen through ordinary ways    | 15                 |
| b) Travels in space and time                             | 16                 |
| c) The internal structure of apparatuses in the process of their operating | 12                 |
| d) The essence of natural phenomena                       | 8                  |
| e) Games about physics                                   | 17                 |
| f) New ways of communications with other people (students and teacher) | 21                 |

Table 2. How do you think virtuality will change learning in the physics classes?

| Answers of students | Number of students |
|---------------------|--------------------|
| a) Completely       | 2                  |
| b) Partially        | 16                 |
| c) Nothing will be changed | 9                  |
| Total               | 27                 |
Table 3. Do you feel any discomfort on XR lessons?

| Answers of students | Number of students |
|---------------------|--------------------|
| a) Yes              | 3                  |
| b) No               | 15                 |
| c) Sometimes        | 9                  |
| **Total**           | **27**             |

Table 4. What are the reasons of a discomfort at the XR lecture? (27 students)

| Answers of students                                                                 | Number of students |
|-------------------------------------------------------------------------------------|--------------------|
| (There were no any response options, students offered their own answers)            |                    |
| a) Religious beliefs                                                               | 2                  |
| b) Hard and uncomfortable glasses (helmet)                                         | 11                 |
| c) My eyes get tired                                                              | 3                  |
| d) I'm afraid of loneliness inside virtuality                                     | 1                  |
| e) I cannot explain it                                                            | 6                  |
| f) Technophobia                                                                  | 1                  |
| g) I adapt easily. I do not feel discomfort                                       | 15                 |

Table 5. How do you think virtual reality will enhance learning in the physics classroom?

| Answers of students                  | Number of students |
|--------------------------------------|--------------------|
| a) It will get much better           | 8                  |
| b) It will get worse                 | 1                  |
| c) It doesn't depend on AR/VR        | 13                 |
| d) I do not know                     | 5                  |
| **Total**                            | **27**             |

According to the Table 1 a communication is the most preferred choice among high school students. And, of course, they like games, travels and unusual demonstrations. The leading opinion of students about radical changing due to XR can be characterized as the prudence (Table 2). This is a rather unexpected result for young people. On the second place we see the scepticism. Enthusiasts occupy last place. It is clear (from the Table 3) that students should not be forced to use XR technologies. It is important to know for teachers. They should prepare alternative ways to show demonstrations. Most students adapted easily to XR technologies (Table 4). But many of them felt uncomfortable due to the hard AR/VR helmet. Probably (Table 5), students see that the technical tools do not play a major role in the educational process.

5. Conclusion
Physics teaching inside XR spherical arenas based on an abstract symbolic environment leads to the increase of students’ interest to physics and activates the learning process. The opinions expressed by students substantiate the effectiveness of the discussed educational XR strategies.
The pivotal idea of this paper is the approbation of carrying out a simple and quick start of XR-applying in the everyday experience of physics teachers. However, after a quick start, teachers can encounter some challenges concerning the construction of the learning XR arena, the use in the learning process and the attitude of students to this kind of teaching technologies.

The simplicity of XR technologies in physics teaching is justified by the deep integration of an abstract symbolic environment to physics and to the professional education of teachers. Besides, a panoramic approach to the study of physics objects and phenomena is natural for humans and contributes to a better acquisition of educational materials. Here is described the ways of the teachers and students engagements to XR, pending didactic issues of XR learning environment, areas of further pedagogical XR researches.

In the near future, we are going to see how technology of augmented and virtual (extended) realities will become widely prevalent, much more accessible and even mandatory in the educational process.

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