Writeup

Target audience

The target audience is high school students (16-18 years old) who successfully took classes in math and physics and are interested to see how science works in real life. We expect students to know some basic physics facts such as Newton's laws, thermodynamics laws etc., and have the knowledge of basic geometry. At the same time, we do not expect them to know anything beyond basic physics facts and beginner level geometry.

Object under consideration

In this tool for online learning, we are aiming to design a video lesson that helps students to understand how a GPS operates. GPS is a system that people use in real life and hence understanding of some fundamental principles is useful, as it can help to avoid some common misconception.

Level of technical understanding

GPS is a very complex system and to get a full understanding of its mechanism one must have very specific knowledge (i.e. special and general relativity). Hence, we decided to abstract out many technical details (such atomic clock synchronisation, time dilation correction) and concentrate on explaining the main concepts essential to understanding of the GPS at the level of high school student with math and physics background. While this understanding is not full, it enables student to use GPS technology consciously and judge about its limitations.

Learning objectives

At the end of a video lesson, students should be able to understand and articulate the fundamental principles of GPS:

- computation of distance between device and satellite radio messages
- positioning on map given distances to several satellites

and limitations of the system:

- the inability of many devices such mobile phones and smart watches to communicate their location to the rest of the world without internet connection

Instructional approach

We want learners to see the deeper structure of the system and shift from "satellite tell me where I am" understanding to more structured way of reasoning about the technology. Hence, instead of giving the concept to student, we walk them through it, using the guided discovery (in particular, invent-then-tell). The main benefit of this technique for our lesson is deeper understanding of a concepts that stand behind the GPS system. A possible limitation is that in video lesson it might be hard to correct all the hypothesis students can come up with, as we can not predict all of them beforehand, so we expect that the effectiveness to be reduced as compared to a classroom setup. Of the same flavour, there will be no interaction between students and this again can reduce the effectiveness of the technique. Finally, there is also a general drawback of invent-then-tell that says that students are get used to tell-and-practice and have a better feeling of progress it T&P is used. That said, we believe that the guided discovery still remains our best option as the main benefit of this technique (deeper understanding of concepts) is well-aligned with our goal.

Interaction
Throughout the video students are asked to answer some questions that require discovery of the main concepts behind GPS. Given that the principles of GPS are quite involved, we do not ask students the question “how does GPS work”. Instead, we partition the mechanism in two main parts (distance measuring and positioning) and further partition these parts into a bunch of sufficiently simple questions so students are able to answer them. Each question is a multiple choice question and we provide feedback according to the selected option. By doing so, we scaffold guided discovery for learners as we show them the correct way to reason about the complex system, still leaving enough freedom for discovery.

Common misconception
In addition to the fact that most of people have very vague understanding of the GPS, many people believe that GPS enable devices to not only compute their locations, but also allows to communicate their location to the rest of the world. After guiding students through the concept of GPS, we ask them the related question and explain why this misconception is false.

Feedback
Corrective feedback is out workhorse for this lesson. Corrective feedback is known to is known to increase attention to task details which is what we want as our goal is to tell students what really matters (what are the concepts behind GPS). Corrective feedback might have some limitations in out case. Indeed, if some student consistently answers questions wrong, then the feedback she receives is always negative. If increase of efforts does not help students to improve their performance, they may shift their attention to self and stop paying attention to task. While this is an issue, we know a way to mitigate it. Potentially we could track the accuracy of student’s answers and introduce some measure of efforts (for example time spent on task or whether student uses pen and paper to solve them) and try to carefully implement mindset in case we see that increase of efforts does not improve performance. However, this task is difficult from both technical and conceptual perspectives so we leave it for the future work.

Augmenting mental processes
First, we use channeling to help students understand the concepts of GPS. Indeed, to ease the understanding, we reduce the dimensionality of the world from 3D to 2D. While the concepts we want students to understand work both in 2D and in 3D, the reasoning in 3D is much easier as one can make corresponding plots and more generally because human brain is more comfortable with 2D geometry. Next, we use furthering in a following way: we first guide students through the understanding of distance measurement (first and the most important concept) and then use distance measurement as a subroutine for positioning (second concept)

Challenging and Straightforward parts
The choice of instructional approach was straightforward as guided discovery exactly fits our needs (achieve deep understanding of concepts). The choice of the object and audience was also easy. Creating the questions such that they are sufficiently easy to be answered by students but still not trivial so they lead to discovery was the most challenging part and required a lot of work.

What we want to improve
In addition to what we said above (see Feedback section), we would like to improve our video by adding better visualisation (especially for 3D case) and animation. As an idea, it would be great to design a computer program that models some basic physical laws and would allow students to test their hypothesis.