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A Rationale to Form a Community to Develop Free Online Simulations that improve Access to Higher Education Science and Engineering Courses for Students in Low-Income Countries

Abstract

A number of inspirational educational leaders, such as Brian Mulligan (2022) of The Atlantic Technological University (ATU), have long since advocated for ways to reduce the cost of online Higher Education courses in order to improve access to students from low-income countries. This paper argues that, while cost may be the major barrier to access, education systems in low-income countries may not provide students with the necessary skills to pass entry requirements to, or succeed in, such courses – particularly in regard to subjects such as Science and Engineering.

The specific focus of this paper is to provide a rationale to create a community of online simulation developers, with the intent of improving the skills of students in their ability to make abstract connections. Abstract connections are necessary for students to make predictions based on hypothetical situations. This, in turn, enables students to succeed in tasks that require understanding consequences, generalizing learning to new situations and relating cause to effect – all essential to success in Engineering and Science courses.

With the ubiquitous nature of smartphone technology, it is the author's belief that effective online simulations can now be developed and distributed relatively efficiently, which could support the development of abstraction within students whose education may be lacking in this area.

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Keywords

Abstraction Science Engineering

1 Introduction

1.1 Scope of this paper

The Remote Labs initiative at the ATU, Sligo, in Ireland, has been looking into ways of developing content for delivering its practical work in an online setting during the Covid-19 pandemic, and beyond. The basis of this paper is to develop a rationale for scaling up this work, using a global community of developers, with the aim of producing freely available resources to improve access to higher education Engineering and Science courses.

1.2 Background

Between 2016 and 2019, I worked with a group of international secondary school students on a project in a remote village in Mozambique. This was a long-term ongoing community project. The latest task was to build a Community Centre, where the villagers could gather to discuss their business. For decades, this function had taken place under a large mahogany tree, but the villagers felt that a modern brick-built alternative would be more appropriate for the present-day. In order to document the history of the project, the students hoped to learn about the discussions that had previously taken place under the tree. They asked one simple question the village elders, “If the tree could talk, what would it say?” The response was unanimous, “Don’t be silly, trees can’t talk.”

2 Abstraction

2.1 Taking the hypothetical seriously

Further discussion with the elders suggested that this was more than just a misunderstanding of the question or a problem with translation. What the villagers lacked was the ability to make an abstract link between the tree as an inanimate object, and the tree eavesdropping during village debate, in an anthropomorphized form. They were unable to hypothesize based on this abstraction. Flynn (2013) refers to this as not being able to “take the hypothetical seriously". His studies on IQ testing suggest that western education systems have changed significantly during the course of the 20th Century to facilitate a more abstract way of thinking. The question of what the tree would say highlighted a disconnect between the rurally-educated villagers, and the internationally-educated students, many of whom shared the same ethnic background as the villagers.

According to Duke University ("The FASD Student & Learning Issues", 2016), a student who has "difficulty with abstract and conceptual thinking" can exhibit a number of characteristics that may not have caused them a problem prior to the 20th Century, but that are detrimental in today's complex interconnected society. These include not understanding consequences; not being able to generalize learning to new situations; not relating cause to effect; an inability to determine similarities and differences between events; difficulty with money and time, poor social skills; and problems interpreting verbal information.

As Cherry (2010) explains, Piaget, in his theory of the four stages of mental development, found that the ability to abstract and form reasoned hypothetical arguments develops in children aged around 12 and up. However, Blake and Pope (2008) reason, using Vygotsky's theories, that in order to move cognitive development forward, students need to be in the "Zone of Proximal Development" (ZPD). This requires the modeling of new (increasingly complex) concepts by a "more capable person, such as teacher or peer". Abstraction, therefore, as a high-order cognitive function, requires both physical development, and exposure. If it is not seen, it is not learned.

Although Flynn (2013) notes the importance of subjects like history and geography in contributing to the political strength of hypothetical debate, he points to advances in science education as being pivotal in developing the ability, in students, to hypothesize based on abstractions. Millar (2004) suggests more specifically that "practical work in teaching and learning of science content is to help students make links between…the domain of objects and observable properties and events on the one hand, and the domain of ideas on the other". In other words, practical work in science education helps to form a bridge between the concrete and the abstract.

Based on this, it would seem that a well-constructed program of practical science should expose students to a range of links between the concrete and the abstract, thereby modeling the process of abstraction, and supporting student cognitive development in this area.

2.2 Abstraction in Physics

Just performing practical work itself is not enough, however. It needs to be meaningful practical work. In the domain of Physics, for example, there are often two levels of abstraction.

The first level of abstraction in Physics is the simplification of the real-world problem, and the second is the conversion of that simplified problem into a mathematical model. Take, for example, a soldier pulling a tyre up a hill, or a speed skier racing down a ski slope. As they stand, these scenarios are too complex to investigate practically in a secondary school classroom, so teachers simplify them into an abstract representation – a trolley on an inclined plane ("Investigating motion on a sloping surface", 2021) where, no doubt, friction, and air resistance are ignored. The simplified physical model can then be analyzed and a mathematical relationship determined that is consistent with Newton's Laws of Motion – an abstract mathematical model of the abstract trolley on an inclined plane.

To present the abstraction of a trolley on an inclined plane directly to a student assumes that they have some ability to relate what they are seeing to something concrete in the real world. If the student is then presented with an exam question based on a different real-life example, they are expected to first realize that this is simply a manifestation of an abstract trolley on an inclined plane, before they can then take their second abstract leap and apply Newton's Laws of Motion. The student who can do this successfully under exam conditions is allowed to study the subject further at a higher level (subject to being able to afford the fees). However, without being able to make the first abstract leap, the student will almost certainly fail at the second hurdle. Abstraction in Physics, therefore, is the key to problem-solving, which is a prerequisite for most Higher Education Science and Engineering courses.

2.3 Education without abstraction

Mozambique is a country still recovering from a brutal 16-year civil war that ended as recently as 1992. One report ("Education in Mozambique", 2021) showed that less than 7 percent of potentially eligible young Mozambicans complete secondary school, of which there are only 82. Even those few Mozambicans who complete their state secondary education are unlikely to do so with the use of a well-resourced science laboratory.

The problem is not confined to Mozambique, however. In 1964, the Malawi government commissioned UNESCO to develop a post-colonial primary science curriculum (Dzama, 2006). This was introduced in 1966 and aimed to provide students at the secondary school level who were “endowed with enquiring minds; pupils who were prepared to ask questions and who are not always ready to accept answers”. This was a far cry from the previous British missionary education system to which the country had been subjected for many years, yet it was discarded by the Malawi government in 1972 as the political elite wanted to produce citizens who would obey without asking questions. These “modern methods” in education were abandoned, and the system that was introduced still prevails today.

When teaching in an international school in Thailand in 2014, I worked with a group of students who wanted to reach out to a local, under-resourced, secondary school to offer practical science classes to their students. Once per week, the local students would visit our expansive private campus, where our students would create stimulating and engaging practical activities in our well-resourced science laboratories. Within a month the Thai ministry of education stepped in and canceled the project. The local students were not spending enough time in their classrooms “learning science”. They even had their holiday canceled so that they could make up for the lost time.

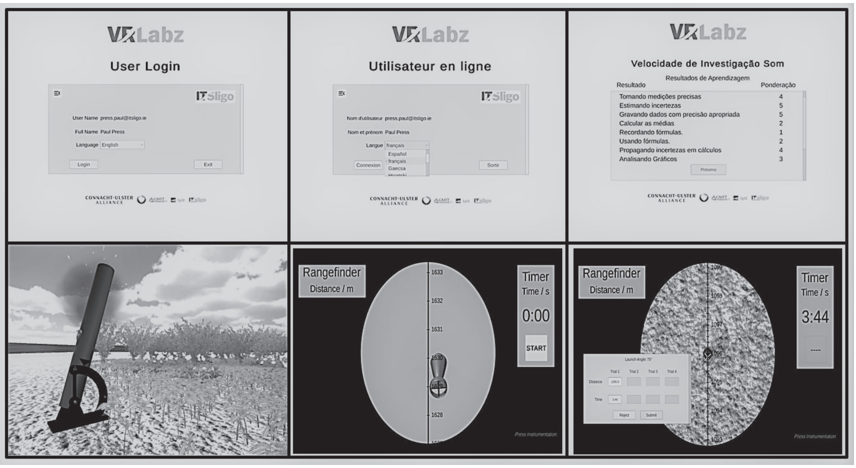
These are just a few specific examples, based on my own teaching experiences, but it is likely that there are many more places around the World where the trees can’t speak. Populations where consequences of actions are not being understood, where effect is not being linked to causing, and where similarities and differences between events are not being recognized.

2.4 Smartphone solutions

It is unlikely that we will change the views of the political elite or provide science teachers and equipment to every remote village school across the globe. However, the answer to the problem might lie in that same village in Mozambique, where each week hundreds of people sit down to watch their local pastor deliver a sermon. With Covid-19 guidelines in place, these sermons are being delivered remotely, and people are watching through social media platforms on their smartphones. GSMA (“The mobile economy”, 2021) expects that by 2025, 31% of Sub-Saharan Africans will have internet-capable phones. That means, if someone doesn’t own one, they will likely know someone who does.

To make the trees speak, we need to produce freely available authentic scientific-practical experiences, grounded in the real world but linked to the abstract, that can be conducted on a smartphone, by anyone, in any language.

There are many laboratory simulations and videos available online (Press, 2021a), but experience suggests that most of those that are freely available require the student to understand an already abstract view of an experiment. One of the leading developers in this area is the University of Colorado, with the PhET range of simulations. These have revolutionized teaching using simulations within secondary schools and higher education institutions, but even they rarely present a realistic real-world experience. There are an increasing number of Virtual Reality (VR) simulations available, which can provide this context but, even if they are free, they require the use of additional equipment (e.g. VR goggles), which can make them inaccessible to people from low-income countries.



User Login

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Velocidade de Investigação Som

Resultados de Aprendizagem

Resultado	Ponderação
Tomando medições precisas	4
Estimando incertezas	5
Gravando dados com precisão apropriada	5
Calcular as médias	2
Recordando fórmulas.	1
Usando fórmulas.	2
Propagando incertezas em cálculos	4
Analisando Gráficos	3

Figure 1: Screenshots from Speed of Sound (Press, 2021)

The ATU, Sligo, has been investigating the use of the game engine, Unity, to design and develop a prototype of suitable practical work, starting with an investigation into the Speed of Sound (Press, 2021b). The strengths of this simulation are that it is grounded in a real-world context, web-based, and therefore freely available, provides feedback on performance when completed, and is multilingual. The hope is that mass production of realistic simulations, of this kind, could help students to make links between real-world phenomena and the abstract scientific concepts that underpin them – thus developing their general skills of abstraction.

2.5 Further studies

Research is needed into the efficacy of simulations in developing an ability to form abstractions. The simulation above is still in a proof-of-concept stage and requires further development to produce a smartphone-compatible version, as well as context-sensitive support, perhaps using Artificial Intelligence to maintain students within their ZPD. Developing this further would require a community of developers with the necessary skills. However, this simple example demonstrates that simulations of this type can be easily produced, and this may provide a solution to the problem of providing contextualized practical experiences for students to model abstraction, irrespective of their geographical, linguistic, and financial barriers.

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