On the effectiveness of an interleaved curriculum in increasing exposure of secondary school pupils to astronomy and astrophysics

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Abstract*— Despite the publics continued fascination with astronomy and space, the numbers of students who spend at least 50% of their higher education time studying astronomy based topics has fallen since 2010, and the overall number of first-year students studying over 50% astronomy topics is under 1000. Astronomy is a unique vehicle in engaging students in science, covering the very small and the very large scale questions in equal measure. The lack of astronomy within the current physics curriculum, and the relatively low number of centres offering GCSE Astronomy as an option means that many students will only study one topic of astronomy through their entire secondary education. Interleaving is a method of teaching whereby core topics are taught several times through the thread of separate contexts. This paper proposes the introduction of astronomy into the physics GCSE curriculum as a vehicle to deliver varying topics from radiation to waves. This would increase students' exposure to astronomy through their secondary education, and allow more students to experience astronomy in much more depth.

I. Introduction

Astronomy and astrophysics have always been subjects that capture the imagination of the general public. From the earliest cave paintings of the Pleiades open cluster over 16'000 years ago, to 15% of the global population tuning in to watch the 1969 Apollo 11 landings, human beings have been predisposed to wanting to learn about what lies beyond our atmosphere. Despite this wide reaching fascination with the subject, the headcount of students spending at least 50% of their education time on Astronomy related topics has fallen since 2010 [1], despite headcounts on physics courses increasing over the same period, and the total numbers of undergraduate first year students studying at least 50% astronomy is well below 1000 [1].

Currently, Astronomy is available to students between 13-18 years of age in 3 possible ways. There are 2 optional methods of gaining knowledge of astronomy in the A-Level Physics optional module, and the Edexcel GCSE Astronomy course. The optional A-Level module is, however, only taught in the final term of year 13, when students have already made university choices, and they must have already decided they wish to study physics at A-Level. The Edexcel GCSE Astronomy allows students to study the subject earlier in life, however, it is currently offered by very few centres. Only 1293 students entered into the 2019 GCSE Astronomy exam, out of over 500'000 students who took GCSEs in June 2019 [2]. Despite the fact that all students taking GCSE science will experience some astronomy in their physics classes, this is usually in the form of one single topic, and includes a very narrow section of content with very specific learning outcomes which are solely relevant to learning a small number of basic facts about astronomy, such as the Solar System, and the life of a star.

Whilst astronomy continues to show itself as a hugely dynamic, inspiring, and broad topic within science, its uses in education tend to be very narrow and only taught over a short period of time. As a consequence of this, students will receive only a very basic education in a very small section of astronomy and space during their life in secondary and further education, unless they already show great interest in the subject and find a school or external centre offering either the GCSE or A-Level options in Astronomy.

II. Theory

Interleaving has been a recent research phenomenon in education that has increasingly shown promise. Studies in 2008 showing improvement in mathematical skills over a 3 month period [3] and another study showing improvements in subject knowledge in 2008 [4] have been widely cited as evidence in favour of this method. It involves the weaving of skills and concepts throughout themes across a longer time period, with repetition in different contexts and has shown promise in overcoming one of teaching's biggest problems, long term recall. The use of interleaving in a curriculum not

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only allows for contextual teaching, with more real-world application of knowledge to draw on and context to 'hang' knowledge from, but also to ensure skills and concepts are practiced on multiple occasions and in different ways, building a deeper knowledge of the topics at hand.

This method of teaching is already prevalent in other subjects at Key Stage 4 and in further education. For example, English departments across the world teach skills such as analysing texts and identifying literary devices through the threads of books and novels. These create a storyline for students to follow and gives a more realistic context than simply teaching the pure concept. The use of a storyline to ensure concepts are consigned to long-term memory rather than forgotten quickly is long established in educational research[5]. It allows the mind to use this story and create a connection with the meaning of the concept[5].

III. Methodology

The current physics curriculum in year 9 taught by the author includes topics such as waves, heat transfer, energy stores and astronomy. It was proposed that, in order to invigorate and rejuvenate the year 9 physics course, the year could be split into two 'themed' terms. The first of these terms would be titled 'Astronomy'. This term will offer a significant portion of the topics covered in the previous year 9 curriculum, but threaded through the context of astronomy.

The topics of waves, radiation, heat transfer, motion and gravity will all be taught through a broader astronomical context. This aims to enable the students to receive the same level of knowledge in GCSE specification topics, while giving them a far more in-depth experience of astronomical concepts such as black holes, stellar structure and human spaceflight that are not discussed in the standard GCSE physics curriculum [6].

A good example of this is the teaching of the electromagnetic spectrum and waves through the context of astronomical observations, including explanations of the uses of different wavelengths in astronomy and how these can give us different information about objects we observe. This gives students a more in-depth understanding of astronomical techniques, scientific method and more importantly, makes it easier for students to see what the concepts mean in a real-life, scientific scenario. This is echoed in another example used in the new curriculum, with a greater description of how gravity gives rise to structure in the universe, from very small to very large scales, showing students the inspiring concept of the immense scale of the universe, whilst enabling them to see an important application of the effects of gravity on our universe.

This use of a themed term also lends itself to including an increase in project-based learning. For example, students will spend a week at the end of the Autumn term across all 3 sciences working on a presentation of their design for a base on another planet or moon, including aspects of the topics that were threaded through the term. This project-based group work has also been shown to improve engagement for female students, who have been found by studies to generally prefer group work and work which rewards effort rather than simply the quality of answers [7]. This is an important step in improving the well-documented gender imbalance within physics, and this curriculum aspires to enhance sense of creativity involved with the interleaved curriculum, providing greater engagement for female students than the traditional formulaic topic-fact-equation style of teaching in physics.

The effects of this new curriculum will be tested by three methods. Firstly, there will be observations conducted throughout both the physics department and the science department in general with a specific focus on both quantity and quality of student engagement. In addition, the end of term test results for each given themed term will be compared with previous years' topic tests, and the end of year test will be compared with previous years' averages, in order to see if the students have improved their subject knowledge of the necessary content. Finally, in the long term, there will be data taken on the number of students studying A-Level Physics and physics in higher education, and how the numbers compare between students who have taken the new and old curricula respectively.

The new curriculum aspires to improve engagement within the classroom, and as a consequence improve students' subject knowledge and test results. In the long term it is hoped that this will translate into an increased uptake of students in both A-Level Physics, and even physics and astronomy-based courses in their higher education pursuits.

IV. Conclusion

The physics curriculum in Key Stage 4 has been updated so as to thread the traditional GCSE topics through the context of in-depth astronomical concepts. It is predicted that this could improve students' engagement with the inspiring nature of astronomy and space science, alongside improving students' knowledge by threading the traditional topics through varying contexts and applying the knowledge in different scientific situations.

This will be initially brought in with an autumn term theme entitled 'Astronomy', including the topics of 'Stellar structure', 'Origins of the Universe' and 'Human Spaceflight'.

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