3D Curriculum

Dominic Oakes[1], Teri Birch[2], Sofya Lyakhova[1]

[1]Swansea University, [2]Wrexham Glyndŵr University

We have presented previously on 'Connections: Deepening A-level Mathematics through curriculum design and support. How best to develop and research?' (BSRLM November 2017) and 'Bringing a connected curriculum to life'. (BSRLM March 2019) These sessions looked at creating various representations of connections in the WJEC A-level curriculum, culminating in creating a 3D environment using the Unreal Game Engine. Developing the 3D Curriculum is a first step in our research, which aims to investigate firstly whether and how teachers of A-level Mathematics could use the 3D Curriculum to inform their short- and long-term teaching plans and secondly whether students will find it valuable in developing their mathematical understanding.

connected curriculum, depth and understanding, virtual environment

Outline of the problem

In 2015, the Welsh examination board (WJEC) introduced new specifications for A-level Mathematics and Further Mathematics. The Further Mathematics Support Programme in Wales (FMSPW) worked with a group of teachers in Wales to construct a scheme of work to support understanding of the new specifications. The idea behind this scheme of work was that it would help teachers to teach mathematics rather than teaching how to pass the examination, focusing on building connections and developing deep conceptual knowledge.

Following this we offered Continuing Professional Development (CPD) about our SoW in December across North Wales. At these events many teachers said that their biggest problem was lack of time to deliver the specifications in a connected, deep way. We have been researching the Flipped Classroom Approach (Oakes, Davies, Joubert, & Lyakhova, 2018), (Joubert, Oakes, & Lyakhova, 2018) as a possible part solution to this problem.

Simultaneously, we have been looking at developing the MindMap that we created (see below) into a tool that makes teaching with connection easier. This has led to a working prototype for embedding resources into a virtual environment that will allow teachers and students to travel through the curriculum following connections between areas of mathematics.

We are interested in whether and how this resource can lead to more connected teaching and learning.

Connection and Curriculum Representation research

Making connections in mathematics is crucial. The Cambridge Mathematics Framework recognises this by having as one of its three guiding principles "connectivity: making important connections explicit in a consistent way will help these connections to be referenced more easily, including those which may span

multiple areas or otherwise tend to escape attention in existing curricula." (2018). It also talks of "Schematic understanding is such that the learner has a sense of how mathematical actions, processes and objects are connected. Such understanding leads to the learner developing a mental image of mathematical connectivity." (2015).

In textbook based teaching, there is a danger of the "…rapid, superficial coverage of a large number of topics each year." (Engelmann, Carnine, & Steely, 1991) Research-based mathematics curricula reveal various shared characteristics, including, "maintaining close connections between tasks and children's mathematical thinking" (Clements & Sarama, 2004).

In recent years there has been a growing discussion about visualisation of the curriculum to make it more connected and interactive for teachers and students. There have been prototype ideas aimed at universities (Siirtola, Raiha, & Surakka, 2013). There was a curriculum-based application called CurricVis which was a work in progress. It used nodes for topics connected to other nodes to show sub-topics in a graphical form. Its purpose was to show the flow of the curriculum in a graphical display (Gestwicki, 2008).

These attempts have not considered using a gaming engine and are still presented in the form of a graph which is not viable considering the size of a connected GCSE to A-level Mathematics to A-level Further Mathematics. The idea of presenting the curriculum in a 3D format has been looked at but was still not broken down enough to be usable by teachers. It uses a package called X3D (Extensible 3D Graphics) (Sommaruga & Catenazzi, 2007).

Game engines, such as Unreal, are already being used to create 3D environments and hence virtual tours (Fritsch & Kada, 2004).

What we did

The work towards a 3D curriculum started with building connections (or more strictly possible dependencies) into the original planning for the scheme of work. Writers were required to identify necessary and dependent topics for each sub-topic. For example, for de Moivre's Theorem we have Figure 1:

Prior knowledge: include syllabus code if relevant (+ connection)	Learning objectives (by the end of the unit students should be able to …)	list of further topics in the syllabus dependent on the currect topic: include syllabus code if relevant (+ connection)
M2.1.6a Exponentials (exponential function) FM2.1.1 (Proof by induction) FM2.1.2 (Basic complex Numbers) FM2.1.4b Sums of Series (sums of series)	Understand De Moivre's theorem, including the proof for positive integers Know and use the exponential form for complex numbers Converting trig functions of multiple angles into powers of trig functions and vice versa. Find the nth roots for reiΘ and draw the polygon on an Argand diagram Use the complex roots of unity in geometric problems	FM2.4.7a Hyperbolic functions (relationship with trig functions) FM2.4.8b 2nd order Differential equations (trig & exponential relationship)

Figure 1: Topic dependencies

From this we then constructed a MindMap showing all of these dependencies. Figure 3 show the whole MindMap. It is only readable when printed on a minimum size of A0 paper. Figure 2 shows a section of it.

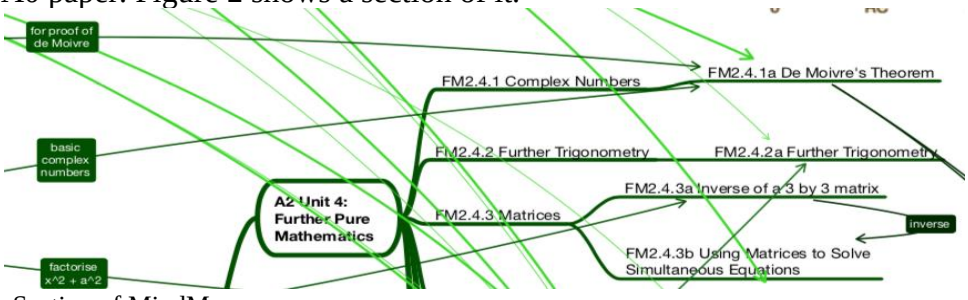

Figure 2: Section of MindMap

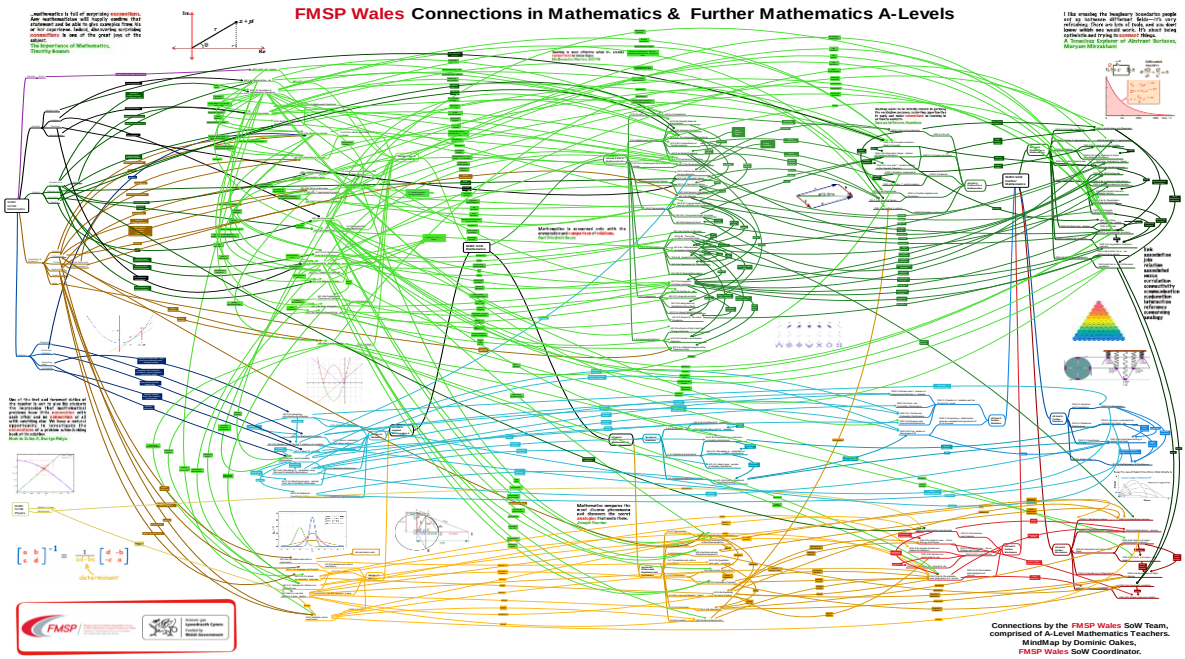

Figure 3: FMSPW: GCSE to Further Mathematics MindMap

The MindMap is useful in demonstrating to students and teachers how interconnected Mathematics is. It is perhaps of limited use in curriculum study or planning owing to its size and complexity. Until recently, it was not 'clickable' but a software update (MindNode on Mac OS) means that this functionality may has been introduced and we are looking at whether we can now derive a useful tool from it.

Another possibility, which we discussed with Cambridge Mathematics who are working with it, was to use Neo4j software for mapping. This is a promising idea but would require a large investment in software development to attain the functionality we want.

Our next step was to look at using a gaming engine to develop a usable 3D curriculum. The brief was to: design and develop a mapping tool in the Unreal game engine that will enable A-level teachers to map the curriculum; test and analyse the visualisation tool for A-level teachers; provide a complete set of documentation and user-guides; consider how the visualization tool could be built upon to offer teachers a fully functioning educational tool.

We decided to focus on a small section of the Statistics specification to develop a 'proof of concept' within the Unreal gaming engine. Figure 4 shows the area we have worked on.

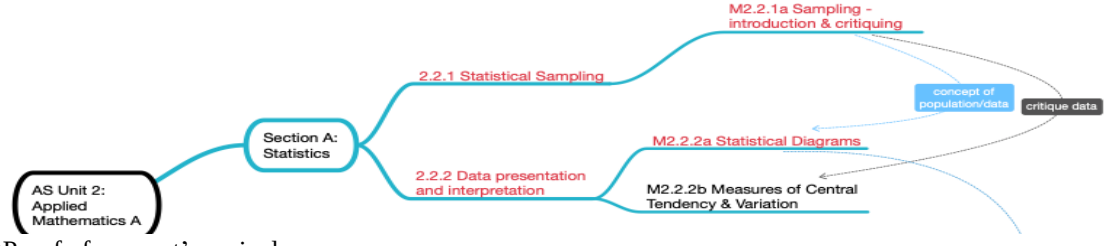

Figure 4: 'Proof of concept' curriculum area

We now have a prototype which we can move around in, with video resources embedded and other resources, including hyperlinks accessible from inside topic rooms (see Figure 5)

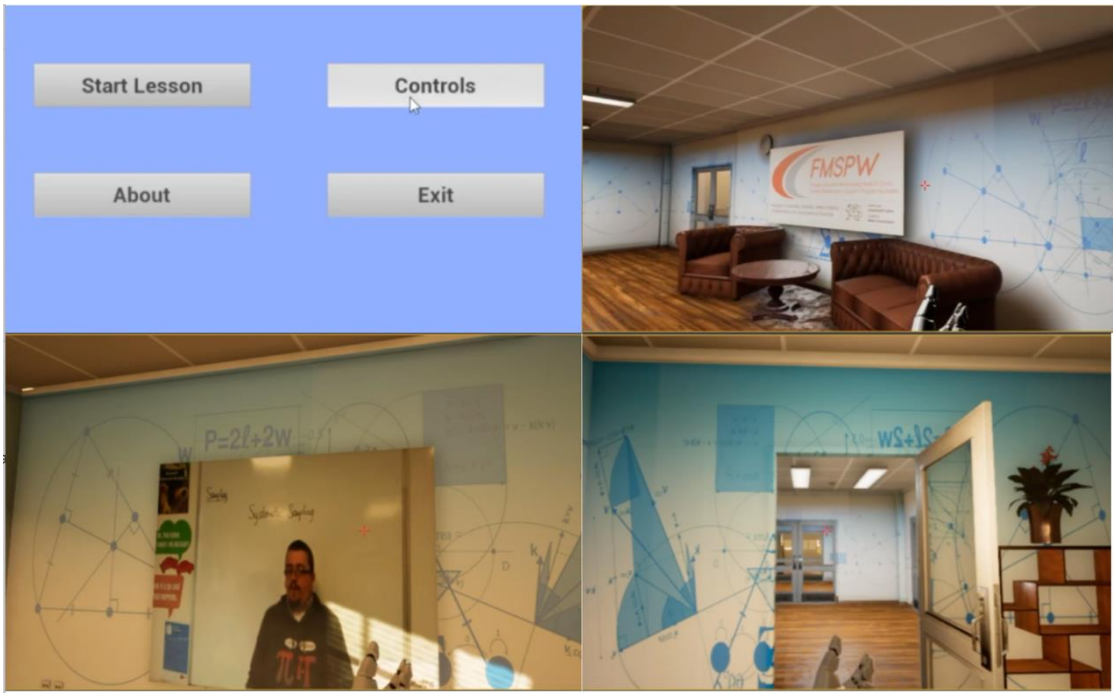

Figure 5: c/w from top left: starting menu; foyer; navigation example; embedded videos

Next steps in development will include embedding other resources directly into rooms and introducing teleport links to related topics using the connections from the MindMap.

Findings

Our findings are limited to the reaction of delegates at our BSRLM presentation and at the FMSPW Conference on Innovation and Creativity in Mathematics Teaching (July 2019). Essentially there was excitement at the prospect of developing this resource being developed so we shall persevere.

There was a lively discussion regarding the potential of our 3D curriculum. Ideas for us to ponder included: whether a different setting (e.g., a space station) would increase its attractiveness to students; the potential for generalisation (our tool is, at present, specific to the WJEC Specifications); and aspects of functionality.

Conclusion

Our session at the BSRLM Conference was intended to look for answers to the following questions. Can our Gamed Scheme of Work lead to: a) rich connections & depth in Mathematics being understood & discovered by teachers? b) promoting a less linear, more connected approach to Programmes of Study in A-level Mathematics? c) rich connections & depth in Mathematics being understood & discovered by students?

By developing the 3D Curriculum in the Unreal gaming engine further, we hope to be in a position to investigate these questions with students and teachers.

References

Clements, D.H. & Sarama, J. (2004). Learning trajectories in mathematics education. *Mathematical Thinking and Learning, 6(2),* 81-82.

Engelmann, S., Carnine, D., & Steely, D. G. (1991). Making connections in mathematics. *Journal of Learning Disabilities*, *24*(5), 292–303. doi: 10.1177/002221949102400506

Fritsch, D., & Kada, M. (2004). Visualisation using game engines. *Archiwum ISPRS 35,B5*, 621-625

Gestwicki, P. (2008). Work in progress - curriculum visualization. *Proceedings - Frontiers in Education Conference, FIE*. doi: 10.1109/FIE.2008.4720392

Joubert, M., Oakes, D., & Lyakhova, S. (2019). An in-depth look at students' experiences of, and thoughts about, 'flipped classrooms' in mathematics. *Proceedings of British Society for Research into Learning Mathematics, 39*(1). Retrieved from: http://www.bsrlm.org.uk/wp-content/uploads/2019/07/BSRLM-CP-39-1-05.pdf

Cambridge Mathematics. (2015). Cambridge Mathematics Framework, Draft 1, Retrieved from: https://www.cambridgemaths.org/Images/cambridge-mathematics-framework.pdf (accessed February 2018, updated March 2018, no longer available)

Cambridge Mathematics. (2018). An Update on the Cambridge Mathematics Framework, Retrieved from: https://www.cambridgemaths.org/Images/cambridge-mathematics-framework.pdf

Oakes, D., Davies, A., Joubert, M., & Lyakhova, S. (2018). Exploring teachers' and students' responses to the use of a flipped classroom teaching approach in mathematics. *Proceedings of British Society for Research into Learning Mathematics, 38*(3). Retrieved from: http://www.bsrlm.org.uk/wp-content/uploads/2019/02/BSRLM-CP-38-3-14.pdf

Siirtola, H., Raiha, K. J., & Surakka, V. (2013). Interactive curriculum visualization. *Proceedings of the International Conference on Information Visualisation*. doi: 10.1109/IV.2013.13

Sommaruga, L., & Catenazzi, N. (2007). Curriculum visualization in 3D. *Proceedings of the twelfth international conference on 3D web technology* doi: 10.1145/1229390.1229423