Journal of the Foundation Year Network, Volume 5 (2022), pp. 79-87

Combining Blended Learning with Role Play in an Online Simulation of the Bletchley Park Enigma Codebreakers in WWII

ADAM J. WOOTTON and JEFF T. NEAT
Keele University

The foundation year programme at this English university prepares Mathematics and Computer Science students for their degree with a range of different subject-specific modules. One of these (Logic, Codes and Cryptography) introduces students to the concepts of mathematical logic, set theory, permutations and cryptography. Our approach delivers what might typically be a complex and dry topic by instead immersing students in an online role play simulation. By using discrete online videos, research notes, national archive records, and online applications, students follow the path of a WWII Enigma machine encoded message from the point of its creation through to the application of cryptographical techniques at Bletchley Park and analysis into ULTRA Intelligence. These resources are linked together with formative and summative assessment using the LearningPool e-learning platform and MS Forms, combining blended learning with role play. As the module progresses, skills are developed by placing the students in the position of operators at various stages of the decryption process, such as interceptors, traffic analysts and hut 6 crib identifiers. The onus is placed on the students to develop their understanding with the support of scaffolded learning. This self-direction is encouraged by the blended learning approach: LearningPool synthesises new content with existing online resources, such as Enigma simulators and living history. As such, students are encouraged to explore and discover more complex resources for themselves, fostering deeper learning and helping students to hone the study skills that they will use throughout their studies and beyond.

Introduction

Students on the Foundation Year at this university who intend to progress to study Mathematics, Computer Science or Data Science study a number of subject-specific modules, each of which employs a different approach to delivery and assessment. For Computer Scientists, the fundamentals of computing and programming are covered in the first semester module, *Foundations*

of Computational Theory and Programming, while *Advancing Programming* and *Advancing Computing: Client-Led Collaborative Design* push the students' technical and creative ability in the second semester. Mathematicians, meanwhile, work towards Further Maths A-Level equivalent content in *Foundations of Mathematical Methods* and *Advancing Mathematical Methods*. Both study *Foundations of Academic and Personal Skills for Computer Scientists and Mathematicians* in the first semester before going on to study *Advancing Applied Maths and Computing: Making Decisions* and the module discussed here, *Advancing Applied Maths and Computing: Logic, Codes and Cryptography* (henceforth referred to as *LCC*). The content delivered in LCC is challenging, covering topics such as permutations, set notation and ciphers. The full list of topics is as follows:

- Set notation
- Permutations
- Combinations
- Code breaking
- Caesar shift cipher
- Simple substitution ciphers
- Book substitution ciphers
- Rail fence cipher
- Affine cipher
- Vigenère cipher
- Mathematical logic

Given the breadth and complexity of these topics, it was decided that the delivery of the module should be radically different from the others. While the other modules in the Mathematics and Computing FY employed more traditional lecture/problem class approaches or project-based learning methods, students on *LCC* were immersed in a Bletchley Park-based role play that took them through the entire process of decrypting Enigma-encoded messages during the Second World War.

Implicit and Role Play Learning

At the heart of this idea were a few key concepts: blended learning, implicit learning and role play learning.

The concept of blended learning is not a new one. For example, Bonk and Graham (2012) identify discussions of blended learning dating back to 2001. In the same work, the authors define blended learning as '[combining] face-to-face instruction with computer-mediated instruction'. The goal of blended learning in this context is to provide a learner-centred experience that encourages active learning. This is closely linked to Bruner's (1961) ideas of learning through discovery, as the students will be encouraged to work through the online resources at their own pace, individually progressing through each step of the Bletchley Park codebreaking process.

Role play learning is rooted in the idea of implicit learning, where reflective imitation is used instead of deliberate learning of concepts. At the simplest level, implicit learning occurs when a learner acquires knowledge without being aware that they are learning (Frensch and Runger 2003). In this module, students were placed in a range of different situations in order to apply and develop the mathematical skills that they obtain (Russell and Shepherd 2010). This is strongly linked with Kolb's idea of an experiential learning cycle (Kolb 1984), as the roles give students concrete experiences through all the other stages of the cycle, to active experimentation.

A combination of blended learning and role play has been used in a number of past studies. For example, Dracup (2008) developed a five-week online activity followed by face-to-face role play as part of a Change Management MBA programme, while Schnurr, de Santo and Craig (2013) found that blended learning and role play complemented each other well in teaching about global environmental governance. The combination has also been used successfully in such diverse fields as Law (Ruyters *et al*. 2011), Social Work, Language Studies (Lee and Chong 2007) and Midwifery (Sidebotham *et al*. 2014), albeit with varying levels of emphasis placed on the face-to-face and online elements. Of particular relevance for the work discussed here is the past incorporation of this approach in teaching Mathematics for Engineering students (Albano 2006).

Motivation and Structure of Paper

The goal of this paper is to present the structure of *LCC* and the theoretical research underpinning it. While we give some very brief examples of module performance and student response, our main intention is to demonstrate how a role play-based module can be structured, the tools that we used to do so and some reflections on the future of the module.

The remainder of this paper is structured as follows. Firstly, an outline of the module is given, considering the content, learning technology, delivery and assessment, along with a field trip. Some brief results are then presented. The paper then gives some reflections on the future of the module and short concluding remarks.

Outline of Advancing Applied Maths and Computing: Logic, Codes and Cryptography

Once the idea of using role play learning had been established, the module was then constructed. The core module content was augmented with Enigma codebreaking material and materials for blended learning were created using the LearningPool platform. This section details the different elements of *LCC*.

Student Internship

An important principle behind *LCC* was that much of the work developing and curating the platform would be done by student interns. These were to be former FY students who were studying Mathematics or Computing and were keen to develop their own work-related skills. This was mutually beneficial. For the student, it meant that they were able to take paid work within the University over the summer while picking up a variety of technical skills, enhancing their understanding of how students learn and getting a flavour of the world of academia. For the FY, it meant that the module had an in-built feedback loop, where the experiences of former students directly fed into and shaped the future of the module. As a student who had recently studied the module, they would have a unique perspective on how it could be moulded to allow for more effective learning.

Content: Codebreaking at Bletchley Park

Over the course of the semester, the students were taken through the full pathway of an Enigma-encoded message in the Second World War, from the original transmission of the message to ULTRA intelligence. The stages covered in this process were:

1. 'Somewhere in Germany': how to set up an Enigma machine and structure an encrypted message.
2. 'Y-Station – RAF Cheadle': where and how messages were intercepted, including the capture of Morse-code transmissions.
3. 'Bletchley Park': the development of the Government Codes and Cipher School and the house and grounds at Bletchley Park during the Second World War.
4. 'Hut 6 – Traffic Analysis': Gordon Welchman's traffic analysis, gleaning information from unbroken messages by examining their external characteristics.
5. 'Hut 6 – Finding a crib': taking a ciphertext message and matching it to a plaintext phrase (crib).
6. 'Hut 6 – Creating a menu from a crib': deriving a crib menu and bombe menu from the crib determined in the previous step.
7. 'Hut 11': the bombe menu from the previous step is used to inform the selection of rotors and initial settings on the bombe machine.
8. 'Back to Hut 6 – Deciphering the message': use of the checking machines and type X machines to decipher the message.
9. 'Hut 3 – Translation and ULTRA Intelligence': the German plaintext message is translated to English and analysed for new information.

Over the course of the module, students were put in the position of a person working at each one of these stages, starting with an Enigma operator during 'Somewhere in Germany' to a Hut 3 analyst determining the value of a deciphered message.

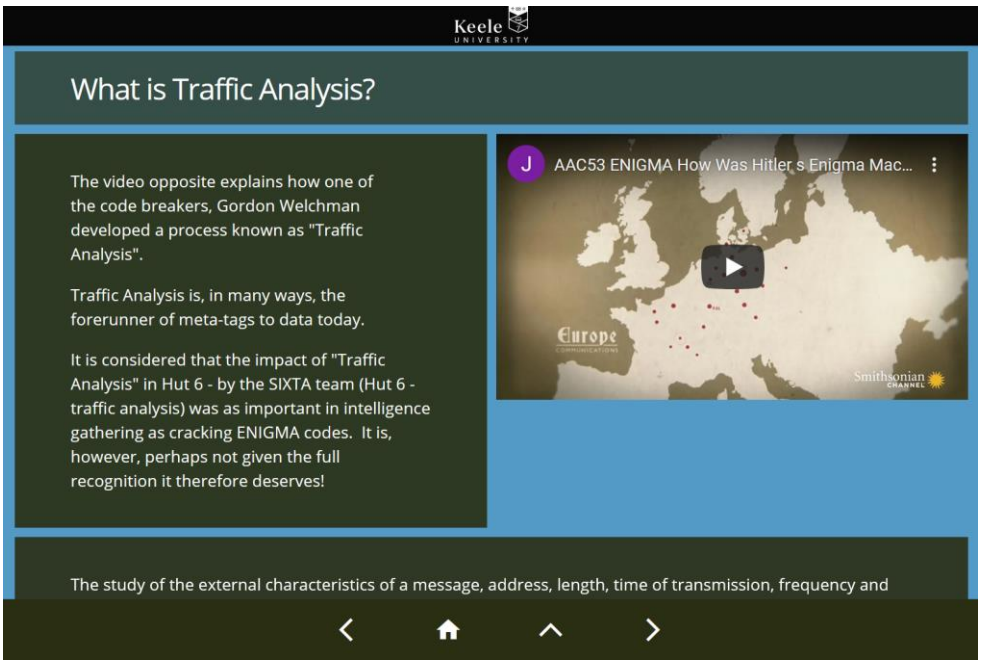

Figure 1: An example of a LearningPool Adapt page combining a pre-existing external resource with original content.

LearningPool and 'Blended Fusion'

The blended learning approach was underpinned by use of LearningPool's Adapt Builder (LearningPool 2020) as a means of collating a wide variety of learning resources.

The Adapt Builder is an e-learning package that allows for the creation of interactive online courses that can be stored as SCORM files. This meant that they could easily be embedded within the University's existing learning platform, the KLE, which is based on Blackboard. The chief advantage of using Adapt is that it gives a straightforward way to develop a simple, responsive and organized 'one stop' repository of content, exercises and external resources. It also includes an engagement monitoring system that can be used by both students and staff to monitor progress. For this module, a single SCORM file was created and embedded in the KLE. LearningPool has not been used for asynchronous learning in Higher Education beyond its use for continuing professional development courses for staff and its use by the authors in a separate module on the Foundation Year (Wootton and Neat 2022).

Since Adapt provides a platform for the combination of lecturer-developed and external material into one seamless resource, a guiding principle for this module was that it would incorporate pre-existing open access materials, such as Enigma simulators, alongside original material. This would be used to create a meaningful narrative and orient the students towards the learning objectives. Figure 1 shows how an externally-produced video could be linked with contextual information. Other resources, such as quizzes, interactive images and podcasts were all embedded within the course.

Delivery

The LearningPool content was designed to enable blended delivery. As such, it was supported with three in-situ taught sessions. The first of these directly related to the LearningPool resource and acted as an impetus session for the students, preparing them for the challenges of that week's content. Students were introduced to the core ideas of that week's topic and expectations on the use of the LearningPool content for that week were set out.

The other two sessions were more conventional and were designed to support students with their understanding of the underlying theoretical concepts. Following the principles of scaffolding, students were provided with gapped notes for these sessions. Gapped notes set out all of the content to be taught in a session but with strategically placed gaps where students are expected to note down information or engage with example problems, and have been cited by Bridgeman (2012) as an example of how deeper learning can be fostered by giving students written tasks. Additionally, students were given the opportunity to break out into study groups and work collaboratively on formative problems.

Assessment

Two forms of assessment were used in *LCC*: a portfolio and a problem sheet. The portfolio consisted of eight elements, each one corresponding to a different topic and to be completed on a weekly basis. The nature of the element varied depending on the topic. For example, the first element tasked the student with answering multiple choice and short response questions to test their comprehension of the initial outline of the Enigma machine. The 'Somewhere in Germany' task had the student setting up an Enigma machine based on given daily settings and then encoding a message. By the end of the portfolio, the students received an encrypted message in morse code, derived a crib and a bombe menu, and acted on the intelligence gleaned by deciphering and translating the encrypted message. This assessment ensured that the students were fully immersed in the role play learning and touched on principles of authentic

assessment as the students performed real-world tasks that demonstrated a meaningful application of knowledge and skills (Mueller 2005).

While the portfolio tested the students' understanding within the context of the role play, the problem sheet assessed the students' pure theoretical understanding of the core concepts. Over the course of a range of questions, students were expected to demonstrate their knowledge of topics such as permutations and logic in more abstract scenarios. This combination of authentic and 'traditional' assessment allowed students to show both the knowledge and skills that they had picked up over the course of the module (Mueller 2018).

Field Trip

The Easter vacation at this university usually cuts into the middle of Semester Two, creating the space for a curriculum-enriching field trip to the Bletchley Park site. There, students were able to visit the mansion and huts where the codebreakers worked, engaging with real lived experiences through a series of exhibits. From there, the trip went on to the adjacent National Museum of Computing, which houses a fully working bombe machine alongside other equipment discussed in the module. This allowed students to see how the simulators that they had been using for the module corresponded to real-world equipment. The museum also gave students a window beyond the timeframe of the module, as the museum charted the development of the computer beyond bombe. For example, the museum also houses a fully working replica colossus machine, widely regarded as the first modern digital, electronic and programmable computer and originally constructed to crack the Lorenz cipher. This also provides a link with the history of Computer Science topics covered in Semester One.

One advantage of this field trip is that giving the students new experiences in a museum can contribute to the evolution of their identity (Rounds 2006), something that may prove vital at their critical point of transition to Higher Education. Furthermore, the field trip can help to foster a sense of curiosity in the subject, potentially enhancing engagement in future years.

Outcomes

The module has proved popular with students and has seen both good engagement and good performance. The average module marks of 64% in 2020-21 and 51% in 2021-22 matched well with the average for the FY as a whole. Student feedback on the module was also positive, with examples including:

"I really enjoyed the field trip that connected the theory and practical aspects together"

"When I was studying this topic I was excited to visit Bletchley Park. Practically I experienced the Enigma and bombe machine, so that's helped me to understand more about that. This was an unforgettable experience for me."

"It was actually fun roleplay approach with historical background. I felt motivated and interested in the subject."

The Future: Beyond Bletchley?

The blended fusion approach comes with an additional benefit: it is relatively straightforward to adapt and extend once the framework has been put into place. This offers a great deal of flexibility when considering the module's potential future development.

For example, the LearningPool SCORM file is portable and can be integrated into a range of different platforms. This opens up the possibility of doing further development with external collaborators from both the commercial and academic spheres. The content can be copied and tweaked to meet another university's needs or adapted to suit an external provider.

Similarly, it is relatively straightforward to augment or extend the existing content with additional resources, or to create a similar package for a different topic. *LCC* is exclusively concerned with Enigma and bombe, but there are other case studies that students could be immersed in. Students could be given the opportunity to consider the more complex Lorenz cipher and Tommy Flowers's colossus. A module could be developed that focuses more on the longitudinal history of Computer Science, dipping into particular case studies over the decades and introducing students to core Computer Science techniques.

A further development on that theme could even be using the principles outlined here to develop a module that propagates through the different levels of university study in Mathematics or Computer Science, as the study of the early years of computing kickstarts study of its continued development. The work on Enigma and bombe could form the basis of a foundation year module, while a level four module could be constructed around Lorenz and colossus. Modules that track the further development of the computer could then take place in levels five and six, building on the skills already laid down at level four.

Concluding Remarks

In this paper, we presented an approach to teaching a foundation year Mathematics and Computer Science module that delivered key mathematical skills to students by immersing them in a Bletchley Park-based role play scenario. This was done through the use of a blended fusion model that used an online learning platform to curate, integrate and develop resources to create a seamless narrative through the different stages of the Enigma decoding process. This work could potentially provide a model for future efforts in blended learning, focusing on building resources in a professionally authored e-learning package.

Acknowledgments

We acknowledge support from Keele University in providing funding via the Teaching Innovation Project 'Combining blended learning with role play in an online simulation of the Bletchley Park Enigma codebreakers in WW2'.

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About the Authors

Adam Wootton is the Director of Education and a lecturer in Mathematics, Computing and Physics for the Keele University Foundation Year. He has a particular interest in innovation through technology in the Foundation Year. He can be contacted at a.j.wootton@keele.ac.uk.

Jeff Neat is the Head of Foundation Year Mathematics and Computing at Keele University and has vast experience of both Further and Higher Education, having been at Keele for the last seven years and Stoke-on-Trent Sixth Form College for the 27 years prior. He is a strong believer in the role and benefit a foundation year can offer in supporting students to fully achieve their potential.

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