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A Radical Approach to Curriculum Design: Engaging Students Through Augmented Reality

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ABSTRACT

A contemporary challenge for education in STEM is the need to produce work-ready graduates for a fast-changing and technology-driven workplace. This study focuses on first-year undergraduate computing students who failed to engage with a traditional, didactic approach to teaching soft skills. A radical curriculum redesign implemented a new methodological integration of action research, mobile technology, and constructivist pedagogy. Students created interactive artefacts with an augmented reality app, on mobile devices, to promote and enhance teamwork and communication skills. Following an action research methodology, students develop soft skills as an emergent aspect of a blended approach to their professionally-inspired project work. This more authentic approach, using their own mobile devices, captured the imagination of students and directed attention to the significance of broader skills relevant to industry. Over the four-year study period, submissions rose from 66% to 93%, with student satisfaction significantly enhanced.

KEYWORDS

Action Research, Augmented Reality, Constructivist Pedagogy, Digital Creation, Mobile Learning, Soft-Skills, STEM Education

INTRODUCTION

The tensions between developing the technical skills of Science, Technology, Engineering and Maths (STEM) programmes at undergraduate level, with demands from industry for more rounded graduate entrants possessing soft skills, is a global issue. This has been highlighted by the OECD skills strategy (2019) with examples from government bodies in Australia *(Office of the Chief Scientist, 2016*), the EU (Caprile et al. 2015, European Round Table, 2018) and the ASEAN countries (Reeve 2016).

This study is based in the UK, where Government policy (QAA 2009, House of Lords 2015) and, more recently, the McKinsey report on the technological skills gap in the UK workforce (Bughin et al., 2018) demonstrate the importance for high-level digital and soft skills. A critical review of UK STEM degree provision and graduate employability recommended improving the work readiness of

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students by embedding the development of soft skills into degree programmes (Wakeham, 2016). Subsequent McKinsey Insight reports (2019, 2020, 2021, 2022) identify the continuing requirement for technical graduates ready for the workplace. The response from the accrediting bodies was to require personal development planning (PDP) as part of STEM curricula. The university in this study implemented personal development planning across all its programmes; with core skills of team working, communication, report writing, academic research, organisation and planning. For computing students, the requirement to pass the 'PDP' element was embedded within their compulsory first year design module. However, this approach was unsuccessful as fourteen percent of the student cohort failed to pass the PDP unit, leading to progression issues.

A review of the module metrics and student feedback identified that students were aware of the wider needs of developing softer skills for industry, however, these were viewed as peripheral to the core technical content of their degree. This review identified that the teaching was didactic, with assessment tasks peripheral to the learning outcomes, what Biggs (2003) refers to as an unaligned curriculum. A reconceptualisation of the delivery of the module was required, to bridge between the wider needs of industry and to engage the students with the whole of their curriculum. This paper reports on a four-year study, involving 411 students and 6 members of staff, and has University ethics approval.

The objectives of this paper are:

- to build theory and demonstrate the creative use of an innovative mobile technology integrated into a robust pedagogic framework
- to develop an action research methodology to provide the overarching conceptual framework for engaging students in the evolution of the curriculum
- share practice for the use of augmented reality for mobile learning

BACKGROUND

The work of Crompton and Burke (2018) in their systematic review of the use of mobile learning in higher education found the majority of studies focused on enhancing student achievement, with around three quarters of the studies framed within undergraduate provision. Just over 54% took part in formal settings, and more recent work (MacCallum and Parsons 2022) report on the affordances of mobile technologies for field work. Cochrane (2014), establishes a baseline for the use of mobile devices and points to the opportunities offered by the changes to institutional polices enabling student to 'Bring their own device' (BYOD); Clark et al. (2021) also found BOYD beneficial in fieldwork and supporting student learning. The trends on mobile learning were mapped by Lai (2020) who concluded in a study reviewing the 100 top cited papers that mobile learning places have changed from classrooms to real-world contexts. A bibliometric review of mobile learning by Sobral (2020), considers smartphones to be ubiquitous, with these devices being used across Higher Education to enable communication, access reading material and to enhance individual study.

Thus, the evidence base for effective learning through the 'blend' of formal and informal is well established. Work by Harron et al. (2019) points to the need for effective pedagogical practices around the use of this technology as a vital component for ongoing adoption. The use of augmentation for a museum field trip, with its formal/informal blend offers key steps for successful adoption. This research project is set within these broad themes of blending the formal/informal; the use of mobile devices for a real-world; authentic set of tasks; and a focus on solid pedagogical theory to underpin the design of student learning activities.

This work combines an action research approach (Norton, 2009) with the Vygotskian framework to technical student led innovation (Cook, 2010) to provide the theoretical base for applying augmented reality activities in classroom settings. For each year of the study, the action research principles of observation, reflection and participant contribution create the input for the next iteration and are used to inform the radical curriculum re-design process. From the outset we wanted a participative approach to the acquisition of soft skills. Careful scaffolding enabled students, unused to the responsibility and less able to articulate their requirements, to be active participants (Spinuzzi, 2005). The key debates that frame these approaches are set out below with a rational for selecting the augmented reality tool of choice. This is followed by the methodological framework and a summary of the data collected within each action research spiral.

Action Research as Method and Methodology

An action research methodology (Norton, 2009) was selected to frame the study, offering clear links between research and the improvement of practice. The evolutionary, reflective process of action research supports a sustainable, inclusive approach to curriculum development that aligns with the educational objectives of this study. Kemmis et al. (2014) characterise educational action research by spiraling circles of problem identification, systematic data collection and analysis, followed by reflection, data-driven action and problem redefinition. This framework was used, with systematic evaluation of student reflection (McNiff, 2013) to structure the research methodology. Students are involved as researchers and contributors to the content and delivery of the course.

The action research method has been shown to promote independent, autonomous learning in educational settings (Gibbs et al., 2017) and has provided successful outcomes for STEM students (Schiller et al 2018; Burrows and Borowczak, 2019; Barber et al., 2020). In this study the curriculum is developed through repeated action research spirals that contain the teaching activities and feed forward the findings from the delivery to refine the next version in an evolutionary cycle.

Pedagogic Theory: Augmented Contexts

Cook (2010) provides a detailed example and develops the 'Augmented Contexts for Development' theoretical context for autonomous learning, mediated by technology using mobile devices. The transformational nature of the learning is explained by extending Vygotsky's Zone of Proximal Development (Vygotsky, 1978), which shows how guidance affects the level of learning development through collaboration with 'more capable peers'. In this case, the role of the 'more capable peer' supporting individual development is provided by the affordances of the technology. Students learn problem solving and project skills by generalising from the specific examples provided by their work with augmented reality.

Augmented Contexts for Development is applied by mapping the six facets of the theory to the context and actions within the redesigned curriculum as follows:

1. **Physical environment**: the University campus and locality.
2. **Pedagogical plan**: embedding learning outcomes to deliver a more authentic curriculum.
3. **Tools for visualisation/augmentation**: Mobile augmented reality creation on student devices.
4. **Co-constructed temporal context for development**: Learning tasks implemented through student designed and constructed artefacts.
5. **Collaborative learners' interpersonal interactions using tools**: Independent creative group work facilitated through communication tools.
6. **Intrapersonal (internal) representations**: captured through reporting and reflection that enable learners to perceive the value of the activity.

Students work independently by researching content, managing project progress, communicating and organising meetings, recording progress and evidencing soft skills through a group presentation and a written report that includes individual reflection. Each of these tasks is explicitly aligned to demonstrate benefits for career goals and academic achievement. Face-to-face class time is used to share experiences and signpost useful material discovered by students and staff. Participant views are recorded and, along with the end of delivery review, provide reflective input to the curriculum development process.

The re-aligned curriculum evidences the soft skills being developed by this programme. Characterised as 'enabling' undergraduate skills, the focus is upon report writing, referencing, time management, team working, presenting, and library skills. The original PDP module assessed these but failed to introduce valuable higher-level skills such as the ability to frame and investigate a research question, a robust attitude to problem solving where setbacks can be seen as valuable inputs for future work, and the ability to marshal people and resources to achieve a goal through effective planning. Stewart, Wall and Marciniec (2016) point to the difficulties in measuring soft skills. To address these issues an interactive, team-based design was used, and the student experience captured through a questionnaire. The authentic task design reflects an industry brief in that it requires some technical skill acquisition; yet meets the 'learning by doing' approach to soft skill development advocated by Stewart et al. The approach undertaken by this study is supported by the recent findings of Succi and Canovi (2020), who stress the need for HEIs to guide students in accepting individual responsibility.

By evaluating the expression of soft skills, rather than the technical qualities of the artefact created, uninhibited experimentation and discovery is enabled. Thus, even a technical failure can enable the generation of good evidence of the assessed soft skills. This constructivist pedagogic approach generated input to the action research process and providing a platform for students to reflect on their learning, and to feed forward into curriculum development.

Educational Innovation with Augmented Reality

Augmented Reality is a term given for the ability to overlay a view of the real world with images, sounds and media, triggered by a predetermined image or location (Azuma, 1997). The augmented scene, combining the construct with reality, is watched through the camera of a smart phone or a dedicated headset. It is inherently interactive and situational, requiring a user to focus on a trigger at a specific location.

Augmented learning suits a social constructivist pedagogic framework, where the ability to create relationships between the real and virtual enables students to interact, visualise and construct their understanding of the learning materials (Sampaio & Almeida, 2016). Recent reviews show increasing use of this technology in education (Ibáñez & Delgado-Kloos, 2018; Holley & Hobbs, 2019).

Although primarily used as an engaging and interactive medium, augmented reality can also be used creatively, where students are authors rather than consumers of content. Phon, Ali and Halim (2014) emphasise the collaborative affordances for students and the motivational benefits of building applications through experimentation and play. Improvements in learning motivation, technical literacy and creativity were found by Wei et al. (2015), when students were tasked with creating their own content. In an extensive review Wang, et al. (2018) identified augmented reality as providing an excellent framework for '21st Century skills' highlighting areas of digital, media and communication.

Aurasma (2016) (later re-branded as HP-Reveal) was selected for this study for its free access, ease of use, and the ability to create applications from the mobile device. Aurasma calls these applications 'auras' that are complete, shareable, artificial reality artefacts that combine with a view of the real world though a trigger image or location. The tools for user-created content are simple but sufficient to use in a project designed to support learning rather than creating a sophisticated artefact.

Having an 'app' on their own device promotes a feeling of ownership and responsibility (Martín-Gutiérrez, et al., 2015). This is particularly important for active learning (Cook-Sather & Luz, 2015, Clark et al. 2021) where students take responsibility for acquiring the relevant knowledge. Being able to complete the development process on their own devices allows students to decide when, where and how they work together to complete the tasks.

Education technology tools often have a relatively short lifetime in the free public domain and HP-reveal has been discontinued. However, there are currently available alternatives such as that provide free tools for user designed augmented reality content creation, such as EyeJack (2022).

Additionally, there are more sophisticated authoring tools available through commercial suppliers (Holley and Hobbs 2019).

METHODOLOGICAL FRAMEWORK

The methodology for this study is illustrated in Figure 1. Action research provides the overarching conceptual framework and the guiding rules for evolving the curriculum. The pedagogic methodology, in this case augmented contexts for development (Cook 2010), provides the guidance for the development of a new curriculum. The course delivery data from the previous spiral informs these design choices. At this point external influences such as regulatory changes and university policy amendments can be included in the analysis. The new curriculum is then used to develop the syllabus that defines the generic requirements. These are then implemented within the context of the educational technology choices, in this case augmented reality, to frame the teaching activities.

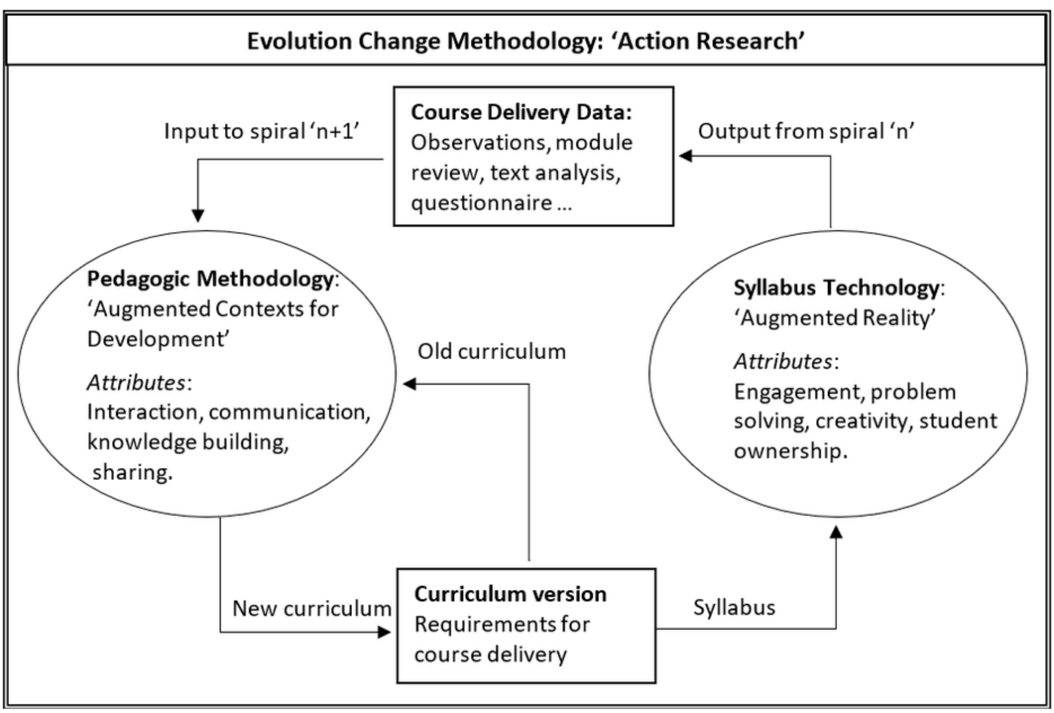
RESEARCH STRUCTURE AND DATA COLLECTION

The research structure is based on the action research spirals as outlined in Kemmis et al. (2014). Each spiral started with an overview of the module and a summary of the research project. Students were invited to make suggestions for changes that could be implemented for the current and future deliveries.

In all four spirals, as part of their assessment, students:

- gave presentations
- recorded their activities in a project blog.

Figure 1. Illustration of the conceptual framework and spiral evolution process



- wrote a reflective statement on their impressions of the learning activity.
- completed a 23-point questionnaire that asked for their experience in using the technology, the skills gained and their view of the project.

In the first spiral additional information was sought to gain greater insights to the student experience. Each student group was interviewed, and video recorded for 15 minutes. The interview questions encouraged students to talk about their experiences of the augmented reality project and they were asked if the module had helped them improve their confidence and skills. These video interviews were transcribed into text and used to inform the next spiral of the study.

Each spiral started with an overview of the module and a summary of the research project. Students were invited to make suggestions for changes that could be implemented for the current and future deliveries. At the end of the module, they were prompted to discuss their experiences and make recommendations for future changes that could be fed into the curriculum review process. As part of the more formal feedback process, students completed a questionnaire that tracked their attitudes, and the impact of each spiral on their learning.

The summary of the four annual action research spirals in table 1 shows the number of students in each semester of the PDP delivery and highlights the changes generated by the participants. The 'outcomes from the actions' shows the main effects of these contributions to learning in the module.

Findings are presented of four-action research spirals, named after the principal pedagogic outcomes - *'engagement', 'perspective', 'autonomy'* and *'dissemination'*.

Spiral 1 Engagement - The Augmented Library

Problem Identification, Systematic Data Collection and Analysis

The study was motivated by the anomalous submission pattern for the module assessments where 80% of students completed a challenging technical task but only 66% submitted the relatively easy PDP component. Informal discussions with staff and students and analysis of satisfaction survey comments identified a lack of student engagement and low perceptions of the soft skills curriculum. The focus group showed the cohort lacked awareness of the academic regulations and focused on other assessments that they could see were more directly related to the technical skills they sought to acquire.

The Augmented Library

Students were introduced to the Aurasma augmented reality creation app and self-forming groups asked to create an augmented reality 'aura' to illustrate a library service or book held in their subject

Table 1. Summary of the Action Research spirals

	Students	Key changes	Data collection and analysis	Outcome of actions
Spiral 1	78	Enhanced group interaction supported through augmented reality project	Questionnaire, reflective videos, unit data.	Improving submission and student satisfaction
Spiral 2	130	Sharing between groups – increasing awareness of the needs of others	Questionnaire, unit data, reflective writing.	Building confidence and competence.
Spiral 3	76	Independent research into technology –building autonomy and responsibility	Questionnaire, Unit data, analysis of reflective writing.	Embedding student contributions into the curriculum.
Spiral 4	75	Communication and dissemination of project activity – enhances self-evaluation and reflection.	Student interviews, Unit data, analysis reflective writing.	Enhancing teaching practice in a wider context

collection. An 'aura' is a complete, sharable artificial reality artefact that connects a trigger image with the media that is superimposed on the real-world scene. Students were encouraged to plan, script and storyboard a short video overlay for their aura, an activity that echoed core themes of software and game design. Weekly tutorials comprised feedback, discussion and the highlighting of supporting materials. Additional support was offered through email, a discussion board and comments posted on the student group blog sites. At the end of the development phase, groups gave a short presentation to the class to outline what they had done during the project. The PDP assessment evaluated activity recorded on their project blog, a group report of the project, a presentation and an individual reflective essay on their learning. Some of the topics created by students were:

- An aura triggered by the cover provides a weight-lifting animation for of a fitness book.
- An aura of mathematical calculations triggered by a book cover and an aura of a geometric diagram triggered by text on an inside page.
- Room number signs in a building triggering 'this way' arrows to the library.

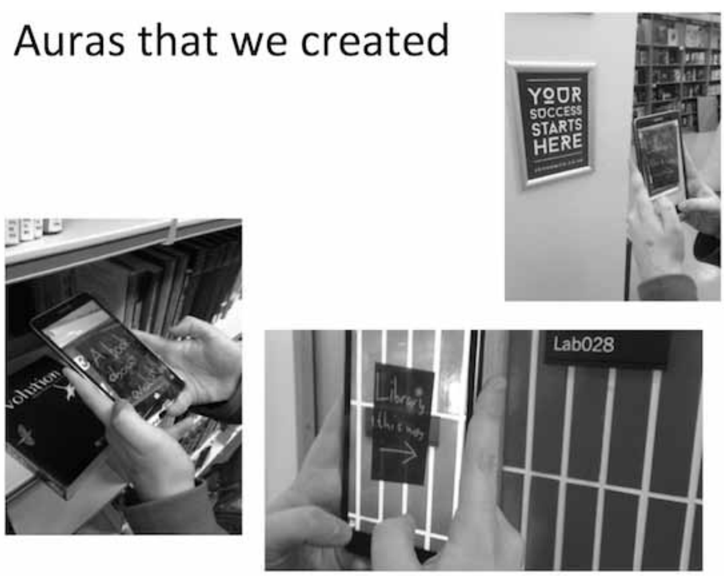
Reflection and Data-Driven Action

Examples of student output and more details on the scaffolding and process for this spiral are presented in Hobbs & Holley (2016a). From the interviews undertaken at the end of the first spiral, quotes were selected to illustrate soft skills in aspects of problem solving, communication skills and the appreciation of group work.

The first quote was representative of student feedback about the selected tool, and included to indicate the simplicity of students using their own mobile devices:

It's [Aurasma] very, very simple to use. It goes through everything that you need to know to create an aura.

Figure 2. Posting from student blog showing creation of auras using library notices as triggers with handheld devices showing the augmented overlay that direct users to the library



This quote indicates the students using a range of technologies, they are using Aurasma on their mobile phones, and moving across to a different technology to communicate:

The beauty of it was that we were able to email each other as it was a very technology-based thing.

The challenge of the task was a common theme, as is the pride with which these first-year students talk about their success in mastering the task – problem solving to create an aura and working in groups:

It's been challenging but we've overcome it.

The following extracts reflect the groupwork element of working together:

When I first came to university, I didn't know anybody. To be put into a group to meet people is quite nice.

By doing this PDP project I have felt a lot more comfortable working in a group and being with new team members.

The augmented reality project used technology to extend the learning context beyond the classroom and successfully engaged students in discovering library facilities for themselves. Aurasma made it easy for multiple authors to contribute and integrate their designs into a single project, even when working remotely. The creation of the aura develops teamwork, design and problem-solving skills and provides the context for presentation and report writing skills. The independent nature of the augmented reality project also helps develop resilience, time management and critical evaluation skills. The number and variety of communication and social networking technologies spontaneously used by students demonstrated independent problem solving.

The submission rate for the PDP element rose from 66% to 79%, which was better than the submission rate for the main part of the assessment (77%) but the team thought further improvements desirable. Analysis of the questionnaire feedback showed that students were able to cope with the technology and appreciated the project, with 80% having positive comments about the experience. 74% agreed that their group-working and communication skills had improved, with 75% reporting more confidence in referencing and writing. The four staff involved in classroom delivery were initially cautious but reported enjoying the more active and participatory teaching process.

In the review workshop students made recommendations for the next cycle:

- Increase challenge of the task – needing a more significant output.
- Increase co-operation between the groups – desire to know more about how others approached the problem
- Improve support for the task – including examples and extracts from project blogs to illustrate how students had solved problems.

Spiral 2: Perspective – Designing for Users

Problem Identification, Systematic Data Collection and Analysis

The improvement in results from the first spiral showed that the concept was working but comments from both the video interviews and the questionnaires showed that up to 50% of students thought there was room for improvement with the task and organisation of delivery. Staff also asked for clearer guidance on the technology and management of project-based work. The task was extended to make it a greater challenge that demanded more attention for planning, design and testing the application to better represent industry practice. The delivery was improved by incorporating the experiences from the previous students into a clearer, more reliable set of instructions. An important resource was the ability to use student work, and their feedback, as exemplars for the current cohort to see what was possible and spark their imaginations. To reinforce reflection and focus on designing for the end user, groups were asked to peer review their artefact with at least one other group. This change was motivated by the spontaneous sharing and discussion between groups developing applications in the previous spiral.

The Treasure Hunt

The readily understandable 'Treasure Hunt' was used as the theme for the augmented reality project. Examples of the student work are listed below and illustrated in Figure 3:

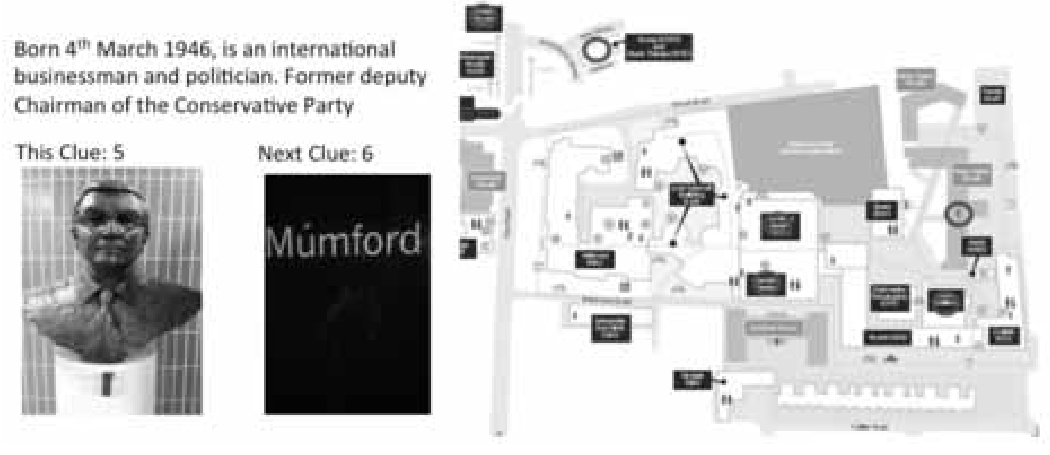
- 'Hunt the Word' - The students created a set of triggers, each one linked to a letter of the alphabet, to make a word.
- 'Locational Treasure Hunt' - Triggers were created in three areas, each one had a clue to the next and a series of passwords were used to confirm the user had completed the hunt.
- 'University Locations Treasure Hunt' – Based on a map of the university, six locations were given triggers with content aimed at helping students to navigate around the campus.

Reflection and Data-Driven Action

In comparison with the first spiral, the use of the Treasure Hunt game theme encouraged students to create more complete and usable applications. Students also had to use more of their own judgement to decide if they had met the brief, which gave them an introduction to critical evaluation. Students shared their knowledge of mobile apps and applied this to the group work activity, creating multiple, informal routes for communication to an even greater extent than the previous spiral. Here are examples illustrating reflection:

Taking part in this project helped me to improve time management and communication skills, developed deeper self-awareness sense and critical thinking skills.
During the project I gained experience on using various different applications and programs such as Moviemaker, Aurasma and Google Sites.

Figure 3. Statue used as a trigger to show the next clue (Mumford) as an overlay from a student treasure hunt augmented reality application, alongside campus map of trigger locations



More details on the scaffolding and delivery of the activity, along with student outputs, can be found in Hobbs and Holley (2016b). This delivery showed improvements in submission for the main technical element of the module (84%) and the soft skills PDP element (85%).

In the first cycle, 75% of the responses to the questionnaire agreed that they had improved in the soft skills of group work, communication, presentation, writing and referencing but the higher-level skills of research and planning only had a 60% positive response. In the second spiral, the implementation of the reflection from the first spiral to provide a more challenging task increased positive responses to an average of 79% in all the soft skill areas, including research and planning. The increased difficulty was reflected in by the question 'Was Aurasma Easy to use', which fell from 79% in the first spiral to 71% in the second spiral, but 'Did the AR project help my PDP' rose from 69% to 79%.

Spiral 3: 'Autonomy' – Student-led Content

Problem Identification, Systematic Data Collection and Analysis

The third spiral of the PDP delivery involved three seminar cohorts of 25 Computer Science students. With the experience and participant feedback from two previous spirals, more ambitious tasks were designed for the students. They were free to choose whatever they wanted, as long as it had an element of narrative to connect a number of Auras. Examples of the student work are listed below and illustrated in Figure 4.

- A Pacific Island treasure hunt – based on Pitcairn Island. Using Google Street View images of this island, landmarks were chosen for the short tour and used as triggers.
- A talking timetable – This group associated a short description of each event triggered by the description shown on the weekly timetable grid.
- A guide to the Department – A set of triggers based in the building of the department of Computing and Technology provided information about its facilities.

Reflection and Data-Driven Action

The student created augmented reality artefacts were freely available for others to download, enabling peer review and showcase activities. The variety of artefacts showed that students were able to adapt the assessment to suit their interests and that the task encouraged them to explore tools and technologies not directly covered by the curriculum. This cohort embraced digital literacy, with more groups using Skype, Google sites and Google docs, to enable all members of the group to contribute to discussions and document preparation. It was clear that, with briefings and exemplars from the previous cohort, students rapidly took control of their learning and sustained this outside the formal University systems. The following quotations show reflection on presenting, planning and communication as well as aspects of self-criticism over the acquisition of soft skills. These are exactly the skills that industry are seeking from their graduates; as evidenced by Bughin et al. (2018 op.cit)

In the future I would improve the quality of the presentation by adding pictures and splitting the text of the presentation up more so that the slides did not look so crowded.
Through this project, I learned to avoid over thinking assignments and thus, improve my confidence.
Our group used Discord for our meetings which meant we could discuss things even when I was not on campus but I think that Skype would have been easier for others

This spiral had the best submission rate with 91% for the PDP element, compared to the overall module submission rate of 88%. Questionnaire results and comments, gathered from the reflective writing posted by students to their group blog, showed an increase in the perceived value of the PDP activities, with over 82% agreeing or agreeing strongly that they felt the tasks had helped improve their soft skills.

The reflective narratives showed that students appreciated the ability to use their own devices, enabling work to be carried out when and where they desired. Students contributed to the reflective curriculum development by expanding the project to allow technologies other than augmented reality.

Spiral 4: Dissemination

Problem Identification, Systematic Data Collection and Analysis

The project was changed to incorporate participant feedback for increased autonomy. Students were asked to research, document and present an example application with instructional materials to showcase the use of freely available apps /web resources /communications technology in an educational or computing context.

Reflection and Data-Driven Action

Qualitatively, students carried out broader research and generated more questions and longer discussion during their presentations. More effort was taken by groups to disseminate the knowledge they had gained in building higher quality artefacts. The deeper engagement with the skills is illustrated with this quotation where a student shows they are aware of the development of other members in the group: which points to enhanced teamworking skills and development, once again, an industry skill gap (OECD 2019, op.cit):

Throughout the project I feel that the group had really started to develop their skills more within the roles that were given to them.

Topics included instructions on how to use an online software repository popular with professional developers, a cloud-based messaging system incorporating software development tools, a web development framework, a demonstration of machine learning, and augmented reality applications for linking information to references and to provide helpful hints when programming. The spiral end review recommended communication and team organisation as formally assessed elements. Participating staff identified greater engagement and attendance in the classes with more spontaneous student-led discussion. The leader of the sandwich year industry placement said, ‘These first-year students are showing more of the responsible independent behaviour I look for when matching students to placements at the end of the second year.’ The leader of the second-year research methods module reported ‘I don’t have to spend so much time on basic soft skills with the students from this cohort’.

Ongoing Impact

Two notable effects of the project were the impact on the continued use of the framework within the module and its use in other deliveries. The most recent delivery of the module, conducted by staff who were not part of the original research team, included student requests to give more emphasis on design and the project process. Previously un-assessed aspects such as the communication mechanisms, and team organisation were given credit in the mark scheme. Performance in these areas was always an implicit factor in assessment but now was explicitly rewarded which helped to highlight these important skills.

The framework was also successfully adapted from the 12-week semester delivery to a one-day project event for blended learning students. The Workplace Skills and Learning module is taken by first year Digital Technology Apprentice BSc students and starts with five days of intense teaching, either ‘face-to-face’, or more recently fully virtual. The rapid single day project was divided into periods for research, design, implementation, testing and group presentation. Virtual teams produced artefacts that used augmented reality to implement quizzes and virtual tours. The formal assessment for students included a report on their own learning development journey. Here, the majority of students reflected positively on the active learning augmented reality project embedded within the curricula.

RESULTS

To measure the effectiveness of the new curriculum, submission rates for the PDP were compared with the main assessment of the module. By focusing on a relative score, changes in cohort ability and other factors influencing the performance are normalised allowing different year groups to be compared. University quality assurance data and feedback from the unit student satisfaction survey highlighted concerns. This is represented here in the 'baseline' data that proceeded the interventions of this research.

The figures in Table 2 show the submission results for the submission results for the year before (baseline) and the four spirals of the Augmented Reality PDP project.

The baseline (the year before the study) shows that, while 80% of students completed the main assessment, only 66% completed their PDP, meaning that 14% needlessly failed the module. Spiral 1 shows an increase in the proportion submitting the PDP element over the baseline. This trajectory continues in Spiral 2 and is maintained in Spiral 3 and 4. The ratio between the submission of the main assessment and the PDP element is less than one in the baseline, and then consistently more than one in each spiral. This demonstrates that students are engaging and no longer failing due to non-submission of the PDP component. The cumulative improvement of 27% for the programme is derived directly from the recorded data. This relates to the whole cohort of students taking the module rather than a random selection from a statistically comparable population.

Included in this table is a key qualitative criterion obtained from the 23 point questionnaire, '*Agree that PDP tasks helped develop academic and employability skills*' and this shows a 16% increase, demonstrating an improvement in the perceived usefulness of the module to students.

Discussion

Over the period of the study, students progressing to the final year demonstrated improvements in report writing and referencing that were noted in comments from external examiners. While this cannot be completely attributed to the improved acquisition of soft skills in the PDP module, comments from staff teaching subsequent modules were themed, and broadly pointed to students being better prepared to cope with group work and academic report writing. Three key aspects that changed teaching practice were, firstly, the move to peer support, scaffolded both within and between groups. The second change noted by staff came through the changing blend of formal and informal delivery, with the classroom becoming a meeting room to share experiences, rather than a content delivery mechanism. The final aspect influencing change was the example of students contributing to learning materials and providing advice. This helped create an egalitarian atmosphere, even for

Table 2. Submission rates and response to questionnaire

Year	Cohort size	Main Assessment	PDP	Submission ratio	'Agree that PDP tasks helped my skills'
Baseline	55	80%	66%	0.8	-
Spiral 1	78	77%	79%	>1.0	69%
Spiral 2	130	84%	85%	>1.0	79%
Spiral 3	76	88%	91%	>1.0	82%
Spiral 4	75	89%	93%	>1.0	85%

those less prominent in the class. Teaching, learning and assessment are now constructively aligned, following Biggs (2003), as is evidenced by the increased submission rates and positive feedback.

The action learning spirals with their review design offered valuable feedback and challenged preconceptions, a key outcome of an action learning approach, as advocated by Kemmis (2014). The evolution of the framework and scaffolded content throughout the study supported students to produce more interesting and accomplished projects. Initial concerns about overloading students with learning new technology were unfounded as, in practice, the students were asking for task extensions and even more challenging activities. An analysis of the student reflections found they appreciated a clear framework; a representative comment was:

We were not sure what to do but once we realised what was needed, we were able to get going.

In their study on enhancing STEM equity programs with action research Barber et al. (2020) provide guidelines that include recommendations to explore processes rather than outcomes and to use an action research framework at the project onset. Findings showed the most informative data was collected through interviews and informal interactions with participants, which was then utilised to identify and justify changes to the curriculum. The action research spirals focused on the importance of enhancing soft skills, and each cohort could view previous reports, presentations and honest accounts of team working. The transparent action research process provided a platform for the student voice, enabling meaningful contributions to subsequent curriculum development and a practical example of the power of soft skills.

Despite the regulatory limitations for curriculum modification, action research facilitated student participation within the quality assured change management process. The different project themes, combined with the affordances of augmented reality, encouraged exploration of the world outside the classroom. More contemporary work in the area (Harron et al. 2019, MacCallum & Parsons 2022) advocate for stronger pre and post structured activities for fieldwork which offers a blend of physical and virtual reality. Spirals three and four demonstrated that alternative technologies could be used to provide the focus for the learning activity. Selecting technology by participants within the action research process offers further opportunities to develop responsibility and ownership, and prompts reflection, and work by Amhag (2020) offers greater insights as to how reflections and insights enhance the students experience, especially aligned to more vocational courses.

Over the four-year duration of the study, the success of the project can be seen in the submission rates for the PDP assessment improving from 66% to 93%; while maintaining the learning outcomes of the module. Qualitative data from questionnaires and student reflective writing showed and greater confidence in skills such as presentation, group work, project management and independent problem solving. Thus, the revised tasks with the student orientated focus and locus of control are starting to address the skills deficits outlined by employers and highlighted by the future thinking OECD report (2019).

CONCLUSION

In terms of the objectives of this paper, the framework outlined in this research contributes to building theory through the application of pedagogy (following Cook 2010), technology (augmented reality) and evolution (action research). A student centred and co-created process was initiated in the classroom (and more significantly, outside the classroom) that enabled variety and choice within an authentic, problem-solving context. This approach, outlined in the methodology, has shown to be robust and flexible in supporting improvements in learning outcomes for students. It offers a pedagogically underpinned pathway for teaching teams who are seeking authentic and innovative ways to engage their students and enhance attainment.

The objective of developing an action research methodology to inform the conceptual framework for engaging students in the evolution of the curriculum has been evidenced through four action learning spirals of the curricula. It has been adapted and implemented with the first cohort Digital Technology Apprentice BSc students, both face-to-face, and then as the Covid-19 pandemic hit, fully online. With the emphasis on the use of technology to support remotely located students outside of the classroom, it provides a good structure for online group work. This can be seen in the original student teams, using tools of their own choice to communicate (Trello/Discord) outside the formal classroom. As described in the fourth spiral, the classroom activities are easily transferred to an online platform. Class presentations can take the form of short video clips and/or webinar sessions without losing the practice of key skills and sharing student experiences.

The final objective of sharing mobile learning practice, via students' own devices, is demonstrated through the quality and variety of the materials developed. These provide a practical template for the use of augmented reality for drawing upon mobile learning for the development of softer skills, which are equally demanded by STEM industries and employers.

The flexible pedagogic framework, developed from constructivist principles, supported the student transition into Higher Education, and was the vehicle for changing attitudes to soft skills, for both staff and students. This met with the project aims of engaging students with their studies and enhancing their attainment through a well-managed process of evolutionary change. Informed by the student voice, the process improved the relevance and effectiveness of learning activities. This work has propelled change in the institution through the continuation of this model of curriculum development and the increasing use of reflective student input applied systematically in other modules and at course design level.

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