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Case Report

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Article

A Design-Based Research Approach to Developing Teacher-Student Co-Creation through Interactive E:Books

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Abstract: This paper outlines the evolution of a learning technology interface from a Beta version to launch with educators and its alignment to pedagogical theory, designed to maximise collaboration between teacher and student. It explores how the "co-creation" of curricula via textual sources that underpin teaching and learning can be enhanced through interactive e-books and outlines the challenges involved in this praxis. With a number of stakeholders involved in the live use of the platform (including teachers, students, HE educators, course instructors, curriculum designers and software developers), iterative feedback loops informed real-time design improvements to both the interface and theory. This collaboration utilised a design-based research (DBR) approach (Wang and Hannafin, 2005), which is outlined here as explanation of how the tool developed and how iterative feedback helped to reconsider the challenges educators face in implementing pedagogical innovation across differing contexts. We propose how speculative design (Lukens and DiSalvo, 2012) and Activity Theory (Engeström, 1987) workshops can methodologically enhance the planning and evaluation phases inherent to DBR approaches, which involve students to prepare for educators' innovation. Finally, we conclude with how educators can utilise these design principles using stratified approaches to help prepare organisational approaches for innovation.

Keywords: design innovation; co-creation; collaboration; interaction; speculative design; pedagogy; technology

1. Introduction

This paper charts the implementation of a Design-Based Research (Design-Based Research Collective, 2003) approach to a specific educational project. This approach to researching the introduction of technologies in situ of educational contexts can also be used to develop staff innovation in educational environments. In this paper, we discuss how the iterative approaches and multiple-stakeholder approaches that underpin DBR were used to attempt to develop co-creative pedagogical practices between teachers and students while using an interactive textbook interface called Nextbook. The paper tracks observations and questions that were raised by participants, the stages of technical and pedagogical implementation that were attempted, and subsequent changes that were made to both the interface and the teaching in order to procure 'co-creation'. We discuss the project's relative successes and offer a discussion as to how DBR could be used to develop and prepare for pedagogical and technical innovation on future projects. We propose that this highly collaborative approach to planning and evaluating can assist practitioners and professionals wishing to introduce a digital and theoretical innovation by focusing on insights generated from the iterative rounds of feedback from multiple stakeholders. We conceive that the iterative nature of DBR enables 'reflection-in-action' (Kennedy-Clark, 2015) that is in line with revised curriculum planning, where co-creation can be integrated.

2. Materials and Methods

The paper is based on the Erasmus+ funded Co-created Interactive Courseware (CiC) project, which began in 2019 and involved partners from Belgium, Portugal, Slovenia, and the UK. It was aimed at cooperation towards digital innovation and exchanging good practice in Higher Education with the technical development of a website, Nextbook (Nextbook.io), as the site of implementing co-creation. Co-creation itself is the collaborative development between different educational stakeholders, though principally these are teachers and students. In education, the value that is being developed in co-creation will depend on the particular educational setting, learning context, task, and potentially its assessment.

The CIC project initially undertook a scoping exercise on the pedagogical theories co-creation is founded upon to create firm foundations for the choices made throughout the project lifecycle (Smith, Scott and De Laet, 2023). Throughout, we used Ramaswamy & Ozcan's characterisation of co-creation as the "enactment of creation through interactions (2018, p196).

Examples of co-creation may be the design of particular curriculum content, i.e., through modifications made to core texts by teachers and students. Alternatively, if we take curriculum to mean the temporal structure of a course, then co-creation could be common agreement around when and how different parts of that course are accessed, i.e., via flipped, blended or spiral approaches. In either case (and more besides, given the breadth of meanings attributed to 'curriculum'), the focal point of co-creation can be characterised as consultation and co-operation explicitly involving students on decisions. This breadth of meanings may include traditional notions of curriculum, such as what is explicitly planned and thus 'received' in typically linear fashion (see, e.g., the 1949 Taylor and 1962 Taba models). Moving forward through curriculum design, Walker (1971), Stenhouse (1975) and Skilbeck (1976) separately proposed interactive or dynamic models, where there was a greater focus on situational analysis, exploring the needs of students first, with a wider range of ideas, theories and points of view in the design, with monitoring and feedback to evaluate the effectiveness of the curriculum design. These models focused largely on structure and sequence, rather than human capability and requirement or what has cultural and social value, including the 'hidden' curriculum that may exist at various levels and values represented as ideals (Marsh and Wills, 2007).

The relevance of 'curriculum' to co-creation may be aligned to modern, digital-based pedagogical models, such as rhizomatic learning (Cormier, 2008), which starts from a point of recognising that learning is not necessarily linear and does not necessarily have a start or entry point nor a clear finishing point or exit, in counterpoint to many traditional courses or taught modules. Cormier proposed the community *as* the curriculum as a central characteristic of rhizomatic learning, a community of users for whom learning is inherently social and who shape and define the curriculum in an unfolding manner. This is borne out by later writers, who speculate on the collective affordances of pedagogical collaboration to include problem-solving, decision-making, risk-taking and innovation (e.g., Bissola et al, 2017). Collaboration and the community is often held to lend itself to modern modes of learning, where online social networks and platforms reflect the importance of social connections.

Further key pedagogic ideas inherent in co-creation include Nonaka and Takeuchi's (1995) knowledge creation model, in which learning is seen as participatory and the knowledge and skills being learned/produced are not stable: not even defined or understood ahead of time; and the transformations undergone are literally learned as they are being created. One more key element is that learning is also seen as 'horizontal' (Bernstein, 1999), developed "through peer talk rather than from top-down 'delivery' methods, and is developed through boundary-crossing interactions (e.g. between two interacting activity systems, such as formal and informal learning methods, or theory-based and practical activities [see e.g. Akkerman & Bakker, 2011]), generally in socially-supported pathways" (Smith, 2017, p22).

Co-creation can take place in a variety of environments and formats, from face-to-face and blended to purely online settings. Here, it is proposed that there needs to be a Schelling point where educational activities converge as a locus. This is the role of Nextbook[1]. Simply, Nextbook is an online platform where resources such as textbooks can be shared, modified and enhanced by educators and students. Via Nextbook, students and teachers can work in collaboration with

theoretical texts by annotating and amending the textbook. This was the original premise for the CiC project, which involved a software developer from Belgium who launched Nextbook, and Higher Education academics from Slovenia, Portugal, the UK and Belgium.

Co-creation, Nextbook and Design Based Research (DBR)

The opportunity for launching a platform presented itself with challenges: the authors recognised early on that similar services were available and that this product needed a unique selling point, but also that in our own considerations we were able to potentially design in bespoke originality from the start, as informed by theory and practicality.

We saw an opportunity to take a Design-Based Research approach to recording the development of the platform in line with the project. Design-Based Research (DBR) is a methodological paradigm for researching technologies where implementation is situated in educational practice and is aimed at improving understanding of technological use in context (Tinoca et al, 2022). Unlike many research and inquiry approaches to technologies, it avoids undertaking perceptions of technologies as problem-solving; rather it takes an approach of 'reflection-in-action' (Clark, 2013). DBR recognises the implicit synergy between design, research and practice and has been applied to education through constructivist processes of discovery and exploration (Anderson and Shattuck, 2012). In essence, it is utilised as a bridge between theory and practice, bringing together empirical educational approaches and theoretical design, particularly of learning technologies and, more pertinently, technology-enhanced learning environments (Wang and Hannafin, 2005). Vitally, it integrates a number of stakeholders into the research process, from students through to teachers, technicians and learning technologists, since it acknowledges the multifarious nature of how technologies are used in situ by different actors. Its methodological approach utilises iterative cycles of feedback and review to improve products through different design stages, which might include both (or either) of qualitative and quantitative data, with Plomp stating that it is typically "cyclical in character: analysis, design, evaluation and revision activities are iterated" (2007, p13).

According to Reeves, DBR has three main principles:

- addressing complex problems in real contexts in collaboration with practitioners;
- integrating known and hypothetical design principles with technological advances to render plausible solutions to these complex problems; and,
- conducting rigorous and reflective inquiry to test and refine innovative learning environments as well as to define new design principles. (Reeves, 2006, p58)

With these sequential cycles of implementation and review, it is more accurate to consider it a series of approaches (Barab and Squire, 2004) that harness reflective and ongoing findings and configure these into the design; moreover, given the importance of pedagogical outcomes, these configured and iterative adaptations may be pedagogical, technical or both. The DBR approach can, then, be applied to the refinement of tools or artefacts for learning, but also to extend understandings of teaching and learning in different contexts. This can include designing innovations with technologies, but also re-thinking innovations in pedagogical strategy. However, "Importantly, design-based research goes beyond merely designing and testing particular interventions. Interventions embody specific theoretical claims about teaching and learning and reflect a commitment to understanding the relationships among theory, designed artefacts, and practice" (Design-Based Research Collective 2003, p6). Furthermore, it can be seen to confront theoretical issues and questions that arise, rather than merely refining educational practices (Collins & Bielaczyc, 2004).

In this instance, our central inquiry regarded the potential for implementing co-creation into different educational contexts as innovation centred around a collaborative digital interface that enabled interactivity with textbooks.

Firstly, however, according to DBR (Design Based Research Collective, 2003) a consideration must be also made of the problems that the technology and pedagogies are addressing. The problem ostensibly is the lack of interaction afforded to users through traditional textbooks, which, being static and insular, can prohibit social learning opportunities. While this perception or approach to teaching and learning is not necessarily a problem in itself, it puts students at a disadvantage where more

dynamic and richer resources and experiences exist and are being used, which is the case for interactive 'e-books', which "stimulate student motivation, engagement, and learning outcomes more than any other version of books when learning complex concepts" (Tlili et al., 2022, p2). Interaction has to be understood as a foundation of co-creation as a pedagogy and the basis of 'complex problems' that we seek to understand. The design principles, mentioned by Reeves above, may improve a product (such as the 'Nextbook' platform) through functionality by, for instance, creating more opportunities for interaction, which can be recognised and promoted through the iterations of a DBR project.

The stakeholders on CiC were from a variety of contexts, including engineering, foreign language and teacher education HE courses. Constant comparisons of use of Nextbook between these different disciplines were considered useful ways to support professional understanding of co-creation and to test design theory in education in practice (Reigeluth and Frick, 1999), in keeping with DBR approaches. As the formative research approach, it is this 'variant' of DBR, among others presented by Wang and Hannafin (2005), that we closest sought to implement. Our rich diversity of contexts afforded us constant comparisons drawing from prototype development through to end-users, since "with the involvement of both researchers and participants, emerging local issues can also be addressed in an efficient and timely manner. Consequently, the design may be better optimized given the constraints of the local setting and addressing participant concerns" (Wang and Hannafin, 2005, p9).

Kennedy-Clark (2013) reports three phases to a DBR project:

· A preliminary research stage, a needs and context analysis is undertaken, a review of the extant literature is conducted, and the researcher/s develops a conceptual or theoretical framework for the study

· During the second or prototyping phase, a number of iterations of the materials and/or approach are undertaken, with each iteration being a micro cycle (micro phase) of the research.

· The final stage is the assessment phase. The purpose of this phase is to conclude how the outcome of the investigation meets the pre-determined specifications of solving the problem (cf. Plomp, 2007). In this phase, recommendations for future work may be generated.

We sought early on to broaden use of Nextbook to as many different teaching and learning contexts, including subjects, sectors, age groups and levels, as possible. This was in order to generate feedback for the iterative cycles of design that are necessary to the stages of technology development. According to Wang and Hannafin, the characteristics of DBR are that it is essentially pragmatic, grounded, interactive, iterative and flexible, integrative and contextual (2005). This also aligns with the principles of DBR as involving participants closely, rather than treating end-users as research subjects (Anderson and Shattuck, 2012). Overall, we see a strong rationale in utilising DBR as an opportunity – particularly for teachers – to transcend performativity (Ball, 2003) and to potentially reconsider their work from a distance and prompted through a variety of lenses (Sachs, 2001), wherein the temporal landscape of work is tuned to a vivid present (Bailey and Madden, 2017). This appears to be borne out by Tinoco et al. (2022), who observed in their literature review analysis of DBR papers that a "positive impact of the methodology as it contributes to (a) the relationship with the context or to establishing relationships between the participants in the research, and (b) promote the constant articulation between theory and practice" (2022, p16).

Research problem

To reiterate, the project sought to improve student ownership of learning and promote learning as a more collaborative process raising peer-learning in a social-constructivist manner, where dialogue, collaborations and learning by doing are central to knowledge construction through interactions. Here, we promoted Nextbook as the locus of co-creation between teachers and students. As noted earlier, this paper essentially charts the DBR approach we implemented, the steps we took, the changes that were made and then discusses their relative successes and offers a discussion as to how this could be used on future projects.

Methods

According to Reimann (2011), an advantage of taking a DBR approach is the development of other theories alongside it. DBR as a methodological approach is related with pragmatism as an overarching paradigm (Karsten and van Zyl, 2023), which supports the research approach to exploring how interventions to normal practice influence professional thinking in various ways. Here, the intervention is the adaption of a new platform to teaching and learning and the attempt to introduce co-creation as a pedagogical mode. Crucial to the adoption of a DBR approach is the cyclical nature of implementation and evaluation, with stakeholders feeding back and reporting issues encountered or opportunities that could be realised through design tweaks. These came about through participant workshops where DBR was blended with other design-thinking theoretical approaches and the results of these are outlined later in this section, which followed cyclical evaluations of professional adoption of Nextbook in order to consider teacher and student feedback. It was important to extrapolate the issues and record with transparency those which could be acted upon and those which had further barriers, in order that we show how interventions have been revised – an issue raised by Zheng (2015) in his systematic literature review of DBR.

Design Workshops

Workshops were held at three different Higher Education locations (Belgium, Slovenia, Portugal), led by researchers on this project. At each workshop, a theoretical blend of problem-solving, design thinking and curriculum planning underpinned approaches to consider implementation of Nextbook and co-creation. Among attendees were:
- Engineering lecturers, Teacher educators and foreign language lecturers
- Nextbook software designers
- Student representatives
- Educational researchers
- University management
- Project officers

As stated, the workshops took on a blend of theoretical approaches to underpin the DBR principles. We used Activity Theory (AT) in order to identify the key elements of teachers' work, including: the community actors involved (e.g. students, technicians, teaching assistants), the object of activity, environments and the tools we use. We enhanced these classical elements of AT (Engeström, 1987) with a blend of another theoretical approach: that of Speculative Design (SD) (Auger, 2013) which was used to generate imaginative possibilities about the ways a new tool can be used. SD has been used in research (Ross, 2017) with participants postulating on the future scenario, an impact or potential direction something can take, particularly with emergent phenomena where the desired and undesired futures are contemplated (Jandrić and Hayes, 2021). Here, it was deployed for problem-finding (Scott, 2023), shown by Hoadley and Campos (2022) to be as important as problem-solving. This drew out participant views of the potential for the platform ('Nextbook'), the plausible consequences of the pedagogy ('co-creation'), as well as the barriers and boundaries to those. Prior to this, the workshops required practitioners to map the following in order to illuminate their professional contexts, including:
· the types of tools they normally use (e.g. textbooks, mobile phones, VLE/LMS, etc)
· some aspects of the core curriculum content that they teach
· any perceived or real boundaries around their teaching (e.g. rules, temporality, cultural barriers, etc.)
· the environments where teaching and learning take place
· the pedagogical approaches we use (including any beliefs or perceptions we have about what makes a good educational experience), and
· the assessment methods used on a course, module or single assignment.

Regular feedback was then drawn out in the project partnership meetings, as well as the workshops themselves, through Speculative Design activities such as the curriculum mapping and anticipated and obstacles. These responses, from an iterative cycle of sessions across eighteen months

and at different developmental stages of the project, form the data that helped us evaluate the implementation of the platform and pedagogy. They were collected by the project leads at each iteration and collated into the Results section that follows.

3. Results

Across the iterations of data collection, conducted as discussed above through problem-based learning, Speculative Design activities and sessions drawing on Activity Theory, we collated a raft of suggestions for, and identified issues with, the emergent platform. These ranged from vital recommendations proposed by educational staff (along the lines of "*if this isn't changed it's unusable*") to minor tweaks often suggested by staff and students in feedback sessions (suggested as *"we'd prefer it if"),* but we identified in all of these comments a desire to make the technology and the product maximally efficient and user-friendly for both teaching staff and for end-users. We have collated the suggestions into the themes we felt were emerging throughout the project lifecycle.

3.1. Technical limitations

- Delay in developer response to immediate issues and user needs
- Unsuitability of platform for particular modules and courses
- Messiness of archive materials
- High reliance on textual format for resources, unsuited to multimodal communication
- Lack of pedagogical fit with curricula (i.e. some courses are heavily instructional and dialogic approaches are seen as distractive or time-consuming)
- Limitations in teachers' pedagogical knowledge and capability of collaborative approaches

Although it is uncommon for educational staff to be involved in iterative design to shape the development of a Beta Prototype, this feedback is in accordance with the multiple stakeholder approach of DBR. It can be seen from their input that educators' perceptions are grounded in two ways: a student-as-user perspective and how the platform serves pedagogy. Both of these sets of perceptions are arguably beyond the remit of software developers and indicate the value of multiple stakeholders.

Table 1. Speculative Design workshop feedback.

Iteration responses leading to reconfiguration of the interface design, included the following list of issues identified with the platform and use,and the responses made over the project lifetime:

Requirements from end-users	Responses from project team and developer
Site needs to be secure and all user IDs need to be kept private	Users were able to identify one another once assigned to class groups, to make interaction easier, but users could use any ID they wished. Nextbook complies with hypertext transfer security protocols (HTTPS) and is encrypted and secure
Simple (non-technical) user manual needed, perhaps in video format	Series of short instructional videos created by Nextbook, and embedded on the site
Educators need the ability to upload their own materials directly, rather than waiting for the developer to approve	This permission was made available by the end of the project, following necessary changes to the code
Teachers need to be able to authenticate students' registration to use Nextbook: can this be automated, or do they have to wait for the developer to approve?	Authentication was manually approved by the developer at this Beta stage, since user numbers were relatively low. Users were invited to register by the teacher and invited to a secure space on the platform for their work.
Any element of text needs to be highlightable	Developer worked to ensure that any text could be highlighted, and commented on, by individuals

Students need to be able to respond to one another's comments: interaction cannot be solely restricted to teacher-student	Developer ensured that any comment posted opened a discussion tree for peer-to-peer commentary and dialogue
Need functionality for multiple document types to be uploaded to Nextbook	The developer enabled Excel and PDFs as acceptable formats
Fonts and interfaces should be adaptable to be more user-friendly for students with dyslexia	Users could control the font styles according to their individual choice
Rather than a single landing page, teachers and students should only see the documents on their specific course	Code altered to ensure students and teachers resources and activities were in their own encrypted pages
Comment boxes and discussion trees need to drop down when the cursor clicks on them, rather than being open by default (sometimes extensive and running over multiple pages)	Coding changed to allow this
Need the functionality for educators to embed images and/or video into the platform	Functionality added
Students' own videos/screencasts to be embedded into the platform	Although desirable, this functionality was not possible during the project lifetime
Dashboard learning analytics (LA) to be extended to teachers and course leaders	LA was a crucial element to the project, but although we provided a full commentary on desirable elements for a dashboard, due to the pandemic restrictions and a lack of staff time, this was never completed
Users to be able to individually export their contributions in order that these can be used for portfolios	Although desirable, this functionality was not possible during the project lifetime, unless users made screenshots of their contributions
Students to be able to upload their own documents rather than remaining a teacher-to-student process	Although desirable, this functionality was not possible during the project lifetime
Platform needs to be developed to improve small-screen, particularly Smartphone use and access (i.e., as an app).	Although desirable, this functionality was not possible during the project lifetime

Co-creation: technical challenges:

It became apparent that co-creation was not something that could easily be introduced to student groups without some reluctance and resistance on their part for it to be optimally realised. This was also in part due to limits among teachers' professional capacity and scope for innovation and risk, as well as limitations in the technology itself, which were identified in the SD phase of the workshop. However, it can be seen from the workshop analysis of the platform above, that educators bring a unique perspective to improving functionality and objectives for Nextbook framed on supporting students' needs (e.g. dyslexia, mobile access) and enhancing the co-creative pedagogical utility available. This can be particularly seen in some of the latter modifications listed, for example where students might be able to post their own resources, or export their contributions as demonstrative of their learning aptitude. Another technical element applicable to co-creation that was identified was the option for users to be able to edit the original text. Adapting and modifying resources are integral to co-creation, but an issue with this is that making one modification to a text may change it for all users and may not be a favourable change. This needs to be navigated, potentially by consensus among student groups. However, handled well, it means that successive groups of users will create bespoke socially-constructed understandings of the source material, leading to greater personal connection with the material, the learning and its ramifications for their education and professional careers.

The developer adapted the platform functionality so material could be viewed in several forms: users can revert to the original at any time, can elect to keep the adapted versions, and can also choose

to see just their own edits rather than the whole group's or cohort's. These options allow for multiple levels of engagement and co-creation. The educator can also switch between these views in order to keep track of the learning conversations, intervene to support, and make corrections if necessary.

There were technical limitations in terms of the logistical possibilities inherent to this project that made some features difficult (i.e. the expense involved in developing an Application version of the interface). However, one aspect that the educational staff in workshops felt would be an affordance that could enhance the co-creation properties of the interface were in the learning analytics dashboard. It was difficult to realise this in the lifetime of the project. Learning analytics have, as previously discussed, become commonplace in the design of educational technologies. We argue that they must be made transparent and available to students, particularly if the type of ownership that co-creation offers needs to be inculcated.

Table 2. Co-creation: pedagogical limitations experienced.

A list of pedagogical iterations based on student feedback were identified and plausible solutions considered, shown below:

Identified problems from user feedback	Potential solutions offered during DBR sessions
Students are often wary of sharing their own ideas or analyses of text, feeling that others who did less work would take advantage of their own efforts.	This could be circumvented by grouped work and task setting for different roles within the group.
The emphasis on learning as being situated around single literacy forms (text) and the challenge this represents to inclusion for students with dyslexia or visual impairments.	Developer to incorporate video and screen reader facilities.
Students need better direction of how to interact with the text, rather than it being left as a repository artefact.	Teachers should deploy a range of question types, signalling what should be focused on and providing adequate prompts to differentiate ability.
Lack of engagement with static text sources, especially with difficult concepts - students would rather have a teacher present	i) gamify interaction: create rewards/badges for engagement ii) create discussion groups to work on problem-solving tasks using the material iii) incorporation of video and screen reader facilities.
Best place for using Nextbook in a learning sequence: before lectures or after the face-to-face input?	Although this is entirely dependent on individual educators' needs and decisions, it was imagined as a 'flipped' approach to learning, allowing students to encounter and engage with crucial course elements before the taught sessions, allowing for greater discussion in lectures.

4. Discussion

Digital innovation tends to be driven by a need for change, based on either established problems or clear aspirations (or targets). Barriers must be identified, potentially through the curriculum mapping exercise undertaken in our design workshops.

Co-creation, as highly collaborative, needs careful preparation. Through the various DBR steps and feedback discussed here, we identify different levels of readiness for collaboration prior to co-creation being reified, with regards the professional and the student. In the first instance, we find that the ground for innovation needs to be well prepared with systematic problem-finding and identification of barriers. This has been the focus of this paper, with the iterative cycles of barriers, problems and issues drawn out from stakeholders and demonstrated throughout the paper. It's been shown how the manifestation of planning (for co-creation) will not necessarily result in its realisation as anticipated. This is in keeping with DBR according to Hoadley and Campos (2022) who recognise that enactment is different to theory, since participants in contexts have their own agency (such as withholding their own comments on a resource). There seems to be some flexibility and freedom in

handling DBR that supports ways to organise professional innovation. For instance, Hoadley and Campos, writing from a psychological perspective, argue it can underpin interventions that transform people, while Karsten and van Zyl base a recent paper (2022) on the premise that DBR can support students for HE.

Whatever the intent, interventions are inherent to DBR, as is theory building. But neither needs to be generalizable, since DBR approaches are malleable in design and reflect complex and messy realities. Reflection is a key part of the DBR process, so here we return to original speculations that co-creation and interaction can lead to rich knowledge creation.

We have drawn out the ways in which educators came together to speculate on anticipated problems and report on the intervention of a prototype platform and fledgling pedagogical theory. We conclude with proposals about how educators may better organise and be ready for innovation in future work, as according to this study (Kennedy-Clark, 2015).

Stratification of educator and student readiness innovation:

1. Identification of barriers at both organisation, personal and socio-political level; agreement on a distinct problem or issues to treat; consensus of intervention type and aspiration for success *(analytical protocol)*

2. Reflection on professional values including willingness for professional experimentation and risk and need for innovation; professional needs analysis; forecast of potential issues of implementation *(praxis: preparation for intervention)*

3. Agreement among stakeholders of theoretical understanding; targets and responsibilities; conveyance, rationale and application, indicators of success.

4. Student strata: theoretical understanding (rationale); student agency, intrapersonal praxis, interpersonal collaboration between student and teacher and student with student

Innovation that requires the buy-in of students (such as co-creation) necessitates preparation through explanation and discussion with them of the affordances of innovations. This is highlighted in the final stratification layer above. We propose that speculative design can be a mode of achieving this, by involving students more closely in the ground preparation for innovation through their speculation of the potential affordances derived from innovation. Future work in this area would focus on this fourth strata, by looking closely at interventions that directly involve   students and recording their own observations and experiences involved in preparing for innovation and how innovations are theorised, communicated for their involvement and applied.

5. Conclusions

The paper contributes to research around how Design-Based Research can be applied to help prepare for innovation in educational contexts, particularly with regards to the development and input of stakeholders to how an interface evolves in co-ordination with specific sought after pedagogical principles. It was constructive to be open to acknowledging the limitations of the project, in order to confront what value the technology had going forward, as well as to identify staff and student needs. The number of stakeholders in education and their input to innovation must be recognised. Using Activity Theory and Speculative Design, alongside the views of students themselves, was deemed imperative to prepare for the analytical protocol needed to introduce any technical interventions or innovation. DBR itself reached limitation with the theory-building stage, but as teacher educators we state that we were able to draw out some valuable lessons for better readiness, not only for co-creation but for more innovative educational environments.

Institutional Review Board Statement: Ethical clearance for the project was granted by the requisite body from each participating University as part of their project agreement, and ensuing decisions were discussed as to their ethicality throughout the process by the project's own ethics panel. All subjects gave their informed consent for

inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki and several decisions were made to ensure that the research was conducted in an ethically sound way.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data related to the findings in this paper are held securely with the corresponding authors and may be shared by request at the email institutions provided.

Conflicts of Interest: The authors declare no conflict of interest.

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