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Abstract
The design of learning materials and researching their efficacy involves the application of both theoretical learning principles and ways of working or practices to move towards evidence based improvement. This paper abstracts 4 categories from our on-going work of educational technology research which we have found to be important in considering what constitutes a successful Technology-Enhanced Learning implementation. These considerations influence the likelihood or feasibility of the wider adoption a particular Technology-Enhanced Learning implementation in the longer term. We also discuss how these considerations relate to the scalability of the development.

Author Keywords
Technology-Enhanced Learning; Learning Analytics; Interdisciplinarity

ACM Classification Keywords
K.3.1 distance learning

Introduction
Educational technology has become big business. Forty years of research has delivered a wealth of working prototypes and accounts of their efficacy [7, 8]. In the multidisciplinary area of Technology-Enhanced Learning (TEL) the aim is to find practical solutions based on

Figure 1. The *virtuous circle* that links learning design with learning analytics (building on ideas discussed in [2]).

technology to educational problems. TEL consists of much more than a set of research-informed products that use technology under a belief in its efficacy or possibilities for enhancement. It is a complex system, which includes communities, technologies and practices that are informed by pedagogy (the theory and practice of teaching, learning and assessment) and an evidence base of research into its efficacy. Today we need to improve the process of moving from innovative prototypes arising from academic research to effective and sustainable products and practices. The *Beyond prototypes* report [8] describes the outcomes of an international research study designed to help us understand this transfer process. In tandem with this study we have brought out a consideration of the role of interdisciplinary working [6] in TEL and how teams working on research and development can be helped with this process. In this paper we will discuss 4 themes that we are exploring in our work in progress.

Interdisciplinarity

There is a growing recognition of the need for a cross discipline approach in solving complex research problems. In particular work in TEL seeks collaboration from the disciplines of learning, cognition, human computer interaction and computer understanding of the nature of learning, and whether or how it is changing. There has been a move towards interdisciplinarity in many areas but there are few studies of interdisciplinarity in TEL. The need for interdisciplinarity in TEL research is recognized in practical terms, e.g. working in teams on projects and the benefits these bring. Rarer are more complex cases such as the development of a Model of Game Motivation (MGM), explaining digital play motivation [3] by applying a multidisciplinary approach. In that case the choice of a mixed methods research design was reinforced by critical review of literature which revealed that a combination of evidence from multiple disciplines (psychology, sociology, technology) would contribute to a more comprehensive understanding of player motivation.

Learning design and learning analytics

Educational technology research has absorbed working methods from HCI such as participatory design, design-based research and socio-cultural approaches building on an evaluation model featuring context, interactions and outcomes [4]. Theories in use in educational technology influence principled decisions about the design of learning materials and the way we frame our research on learning. Work related to the design of materials has close links with the paradigm of design-based research. Learning design has emerged from the instructional design, computing and learning sciences communities [9] to provide both a way to study the range of actions involved in the specification of learning activities, and a means to represent the design of learning. It resonates (Figure 1) with a description of design-based research that captures the spirit of the endeavor of participatory design as iterative cycles of improvement [1]. As a process design-based research expects researchers to *'systemically adjust various aspects of the designed context so that each adjustment served as a type of experimentation that allowed the researchers to test and generate theory in naturalistic contexts'* [1, p4]. This way of working also can be used to aid design of TEL systems on a large scale, such as in The Open University where improvement cycles are supported by collection of data by educational technologists as Data Wranglers [2]. In this role they make sense of a range of data sources,

Beyond Prototypes [8]

Method: Existing critiques of TEL have focused on whether the innovations created in research and development projects have become embedded in educational practice going forward. In the *Beyond prototypes* investigation an expert analysis of TEL projects gives an in-depth examination of the processes of innovation.

Data: Case studies of projects were combined with systematic analysis of data collected from in-depth interviews with key figures from research and industry.

Key factors: Several factors are identified for the success of TEL projects: we highlight here *persistent intent* in working through successive projects and an understanding of the complexity of the infrastructure around TEL and the process of *bricolage*.

More information:
http://beyondprototypes.com

including demographic data from students, survey feedback data and activity data and information on the mode of delivery and the structure of courses and completion and pass rates. They produce reports that summarize important points and make recommendations, recognizing the importance of human sense-making to turn data into something which is actionable. In addition if patterns in the data can be identified which are highly predictive of learning outcomes, and especially if those patterns occur at particular points in a module, interventions and redesign of a module can be identified and planned. This model leads to connected research in learning design and in learning analytics, *"…the analysis and representation of data about learners in order to improve learning…"* [2.p683] Learning design makes explicit the process of planning and provides a means of describing underlying pedagogy. Learning analytics provides measures that help judge impact and motivate interventions that target improvements in aspects such as learner retention, satisfaction or attainment.

Persistent intent

The *Beyond prototypes* project (see Side Bar) reports as follows: "*Success in TEL is associated with 'persistent intent' – efforts by a group to develop inspirational ideas and turn them into products and practices over an extended period of time. … Teams of researchers need persistent intent in order to develop their work over time with a shared educational goal in mind. Many […] research projects may be aligned in order to work towards the same educational goal. Persistent intent motivates researchers to work closely with the communities that will be involved in implementation, developing a shared vision that is owned not only by the project team, but also by those who will take it forward once the research programme is complete and the development team has left. To carry out this work successfully, researchers need opportunities to develop the skills that will enable them to bridge the gaps between those different groups*." [8.p6] What this means in practice is that significant innovations are developed and embedded over periods of years rather than months, and changing teaching practices in a sustainable way is not a straightforward roll–out of a product. This contrasts with the perceived rapid change cycle in technology itself.

Bricolage

The *Beyond prototypes* project identifies how *"Successful TEL innovations, both in academia and in business, are developed by a process of bricolage [5] in which educational goals are achieved by bringing together pedagogic approaches, diverse technological elements, frameworks and social practices*.**"** [8, p7] TEL is a complex system. There is a need to consider communities which build up, technologies which become available and day to day learning and teaching practices that can be informed by theory or practice. "*The work involved in successful TEL innovation can be characterised as bricolage or tinkering. This productive and creative innovation process involves bringing together and adapting technologies and pedagogies, experimentation to generate further insights and a willingness to engage with local communities and practices*." [8, p6] The connection of bricolage to tinkering is illustrated by the term bricoleur [5]:*"Bricoleurs do not typically start a project and then consider which tools and materials will be required to achieve their goals. Rather, they review their available materials and tools and work out how to use them to achieve their goal or something close to their goal*

Above all, bricolage is rooted in engagement with the concrete properties of a situation and the available materials, rather than with an abstract model of how they will behave…." [8 p31]. Interviews conducted during the project revealed successful TEL innovators as …" *bricoleurs who achieve educational goals by bringing together diverse technological elements, frameworks and social practices*." [8, p32]. Viewing successful TEL innovation as a form of tinkering is a challenge to a researcher, interested in making planned adjustments to teaching activities that can then be evaluated for effectiveness. However the term captures the reality of a learning process in flux and subject to multiple influences. A key challenge for the researcher is the move from controlled experimentation for small groups in the laboratory setting to the investigation of large-scale naturalistic experiments 'in the wild'.

Work in progress

This work in progress involves refining the key factors influencing the success of TEL projects through case studies of successful TEL projects that examine the relationship between interdisciplinary working and progress and knowledge creation. A further intended outcomes is to develop a good practice guide for researchers new to interdisciplinary working. This approach, in combination with further case study work, is expected to extend the combined use of learning analytics with learning design to enhance designs and improve support for learner progress.

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