The *Dynabook* Project:

An Engineering Approach To Research and Development of an Educational Innovation

Inverness Research

Executive Summary

Introduction

In 2003, Alan Schoenfeld and Hugh Burkhardt advocated for an engineering-based approach to research and development in education, and yet in the ten years since, relatively few examples have been put forward of work that manifests such an approach – when in fact, many would argue that it is even more relevant today. An engineering-based approach to innovation has long been more appropriate and effective than experimental design for producing tools and resources that education actually needs. Engineering-based approaches provide more understanding about how and why to design an innovation for particular contexts, whereas randomized controlled studies measure just a single causal factor with extraordinary certainty. Projects that over-rely on a single causal factor tend to be educationally ineffective and/or not sustainable in real-world contexts.

Through its work as external evaluators for the NSF-funded *Dynabook: A Digital Resource and Preservice Model for Developing TPCK* project, Inverness Research came to see, understand, and document this project as an exemplar of an educational innovation that integrated research, development, and practice, brought to fruition through an engineering approach.

Background

The *Dynabook: A Digital Resource and Preservice Model for Developing TPCK* project began as an effort to address a number of issues: the rising profile of/reliance on/promotion of digital textbooks as instructional resources, the opportunity to bring the Universal Design for Learning (UDL) framework into mathematics, and the need to effectively teach pre-service teachers how to address proportionality in middle school mathematics. To achieve this goal, the Dynabook project assembled a multidisciplinary team with expertise in these two frameworks, as well as in technology development: SRI International in Menlo Park, CA; CAST (the Center for Applied Special Technology) in Wakefield, MA; San Francisco and San Diego State Universities in California as organizational partners; and mathematicians, computer scientists, teacher educators, and learning scientists as individual partners. As the project got underway with its multi-disciplinary and multi-organizational team, it became clear they were engaging in iterative cycles of planning, research and development, cycles often associated with engineering-based approaches to research and development.

Engineering approach to research and development of an educational innovation.

Several theorists and practitioners have argued that educational research and development would be more useful to practitioners and to policymakers if it involved an engineering approach, which they also note is important in fields to which education is sometimes compared, such as medicine. They argue that educational research "would be more useful if its structure and organization were better linked to the practical needs of the education system" (Burkhardt & Schoenfeld, 2003). A fundamental question is: How does one refine ideas and materials so that they are robust across a wide range of contexts of implementation? To answer this, Burkhardt and Schoenfeld (2003) propose an adaptation of the "engineering approach" common to other applied fields. The engineering approach to research is concerned with "practical impact" and developing high quality solutions to practical problems (Burkhardt & Schoenfeld, 2003, p.5). It has been described as "the use of existing knowledge in experimental development to produce new or substantially improved materials, devices, products, and processes, including design and construction" (Higher Education Research Funding Council, 1999, p. 4). It is also conceived of as a practice that "combines imaginative design and empirical testing of the products and processes in development and in evaluation" (ibid). The engineering approach to research focuses on "the processes that link the development of good ideas and insights, the development of tools and structures for implementation, and the enabling of robust implementation in realistic practice" (ibid).

There is no one single model for "the" engineering approach to research and development but rather several different models involving four to ten basic steps such as design, develop, test and evaluate, and redesign, in an iterative cyclical manner. Outlined below is one useful model set forth by the Massachusetts Science and Technology/Engineering Curriculum and modified by the Center for Adaptive Optics (2007). In this paper, we describe each feature of the model, and then we describe how the Dynabook project exemplified each.

Features of the engineering approach

- Identifying the need or problem to be addressed
- Researching the need or problem to be addressed
- Developing possible solutions
- Selecting the best possible solution
- Constructing a prototype
- Testing and evaluating the solutions

- Communicating the solutions
- Redesigning (continual iterative cycles of research and development)

Identifying the need or problem to be addressed

The inter-organizational and inter-disciplinary Dynabook team had a shared understanding of the problem or challenge to be addressed: to develop an innovative technology-based resource incorporating the principles of Technological Pedagogical and Content Knowledge (TPACK) and Universal Design for Learning (UDL; Rose & Meyer, 2000). The Dynabook project was informed by the project leaders' awareness that digital textbooks were being developed and would become a booming industry within education. The project assembled a highly complementary team.

Researching the need or problem to be addressed

In "informed exploration" phases, the Dynabook project explicitly sought to interpret, within a specific context, learnings from the broader literature and team experience relating to TPACK, UDL, and specific needs of pre-service programs, and integrate these into the evolving Dynabook approach. These data led to scenarios of user needs, contents, design, and use models that were produced in the initial prototypes. In this way, in addition to UDL and TPACK, a focus on the additive to multiplicative learning progression (Lobato, Ellis, Charles and Zbiek, 2010) rose to prominence in the Dynabook approach, as did considerations of the "implied reader" (Weinberg & Wiesner, 2011) in mathematics texts.

Developing possible solutions

Dynabook researchers and project designers begin to imagine solutions that would address the problem or challenge. Some of these solutions are holistic; others only addressed part of the problem. Over the course of several design cycles, the Dynabook team iteratively produced more than five distinct and different prototypes of the resource, which were then tested in university settings and then further refined.

Selecting the best possible solutions

Dynabook's second design enactment phase set out to solve design problems suggested by teacher, partner, and advisor feedback, and formulated in terms of revision to the theory of operation. During "implementation research" (or "pilot") phases, augmentations and revisions of the technology, content, and planned lessons were completed and then employed over multiple class sessions on partner campuses. Qualitative and quantitative data collected during these sessions served the purpose of informing the next iterative design of the Dynabook content and software, as well as the in-class and out-of-class use-models, and the planned instructional activities within university classes themselves.

Constructing prototypes

Using the technology development expertise of CAST and SRI, both teams collaborated to build a Dynabook prototype, adapting an existing CAST platform. A revised prototype was the result of each design research phase; therefore, a series of prototypes evolved through the life of the project.

Testing and evaluating the solutions

The Dynabook use data came from classes conducted at the two partner universities. Because the Dynabook is an integrated development effort, with the technology and the content and the pedagogy evolving simultaneously, each pilot was different from the previous along all three dimensions. As a consequence, each data collection focused on an activity that was being tried out for the "first time:" a first time for a particular sequence of activities on either campus, a first time presenting the material and organizing the class, a first time for a new or redesigned feature, and even a first time for the data collection protocols. This approach is distinct from studying a well-established curriculum sequence and activities.

Communicating the solutions

For the Dynabook project, this step of communicating the solution(s) involved the project sharing and communicating about recent versions of the Dynabook resource and the associated research. In addition, a hallmark of the Dynabook project is the leaders' determined effort to collect and process feedback from a variety of sources – from the early conception of the project, through the prototyping and research phases, and through today. The extent to which and how the Dynabook project communicated their potential solutions and solicited feedback from different informants – including the university partners, the project's advisory board, the evaluators, a consultant network of teacher educators, and partners at other Cal State campuses – is in itself an innovation.

Redesigning (cycles of research and development)

Based on feedback gathered from multiple sources and through constantly revisiting design tensions and priorities, engineering projects continually iterate upon and improve their innovation. Further, each prototype must represent progress and advancement along multiple dimensions – it must be more complete, easier to use, and the value-added must be more evident and easier to access. Much of the Dynabook project's work that has been presented above continues to this day and will continue into the future. Even after five versions of the Dynabook resource, revisions were still being made in response to the feedback and input of different stakeholder groups. Dynabook is now poised to broaden its iterative design cycles to include new locations and contexts.

Summary of the Case

Many education design efforts are embedded within an experimental paradigm, where one takes a design, implements it, and tests its impact, gathering data on whether the design "worked" or "didn't work," with the user as an outcome rather than an input. While this approach can validate causal claims, it rarely provides insight into what exactly worked or didn't work, much less *why*. In contrast, early Dynabook research was in service of gathering insight into the needs of and value to the user, in order to continue to evolve simultaneously the conception and design of the product.

As the conception of the product became clearer, a shift from testing the concept to testing a prototype gradually occurred. Ironically, a premature effort to test an innovation "at scale" before its theory of operation is well-understood can undermine the quality of the innovation, thus reducing its chances of spreading and surviving. The slow and deliberate approach of the Dynabook project means it is more likely to have produced a robust innovation that will succeed in the real world and, perhaps, endure longer. To iterate on prototypes, the Dynabook project used a co-design approach. For this approach, the project brought together a multidisciplinary and multi-institutional team, implemented prototypes in real contexts, sought the feedback of multiple stakeholders through several design cycles, and *carefully considered that feedback*.

Conclusion

Through a collaborative approach that emphasized short-term cycles of design experiments (design, development, and testing), and heavily involved the perspectives of education practitioners, the Dynabook project has found a productive interaction or interplay between mathematics education and special education perspectives that encourages educators to listen to and consider carefully learners' mathematical thinking, along with a means for doing so.

Implications for the Future: Further Refinement and Dissemination

Sustaining the very same approach this paper has described, the Dynabook project is now primed to further its engineering-based approach by continuing to refining the resource, implementing it in different settings, and learning how it interacts with other systems. The engineering approach will continue; now it will be focused on engineering scale-up and broadening the reach of the project, focused on creating an improvement community around and growing the Dynabook resource itself. Rather than disseminating a final static product, the Dynabook project will be using an engineering-based approach in dissemination – the project will broaden the product's use and learn new lessons that will influence additional improvements, and the design, refinement, and dissemination will all be linked.