Conceptual Models for Malleable Educational Tools

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ABSTRACT
Developing regions currently face a shortage of educational tools and resources because they have not traditionally been perceived to be viable markets. We propose flexible educational tools as a solution and argue that these tools should be designed with compact but powerful underlying conceptual models. We then present the conceptual model in Boxer to illustrate some relevant principles in the design of these models, and conclude by raising some open questions that warrant closer examination.

INTRODUCTION
Lin and Hatano [6] argue that educational tools ought to be designed for flexibility so that users could readily adapt them to new situations and newly conceived uses. This statement is consistent with the shortage of appropriate educational tools for developing regions, which is partly due to the perception by many developers of educational content and software that emerging economies are not viable markets.

Implementing educational tools for developing regions is not a far-fetched idea. For instance, the Azim Premji Foundation [1] has established telecenters in the over 400 schools in the states of Karnataka and Andhra Pradesh in rural India, where low-income students can visit to use educational software on shared computers. Furthermore, to address the above provisioning problem (i.e. the under-supply of educational tools), the Foundation has underwritten the costs of software development.

The idea of flexible educational tools is particularly appealing because low-income communities will not need to bear the massive costs of developing these tools. Instead, end-user communities will only need to cover the costs of adapting existing tools to meet their local needs, conditions, cultural values and educational practices, as well as new conceived uses that were unanticipated by the original designers of these tools.

CONCEPTUAL MODELS
More importantly, while Lin and Hatano [6] advocate the benefits of flexible tools, they also point out the downsides of flexibility. For instance, by virtue of their flexibility, such tools are easy to use in ways that do not achieve educational purposes, particularly when teachers are not necessarily well-qualified, which is the situation in many developing regions.

Our position is that when developing appropriable educational tools with underserved communities, designers should not strive for flexibility at the level of tool usage. This is because we believe that it is necessary to design these tools with prescribed practices of use in mind, such that these practices play the role of the "absent (expert) teacher" by scaffolding the learner-user's activities. Hence, we argue that designers should instead strive for tools that are *malleable* at the level of their underlying conceptual models.

By conceptual model, we refer to the model of a system that its designers invent to provide an accurate, consistent and complete representation of the system, such that this model could be taught to its users to explain how the system works [7]. While users may form, through their use of the system, mental models of the system that do not correspond directly to the underlying conceptual models, experiments with a stack calculator have shown that teaching users the underlying conceptual model have enabled them to solve novel problems using the calculator more effectively as compared to the control group [5].

BOXER
As such, we believe that the key to having educational tools that can be readily appropriated by its end-user community lies in designing compact but expressive conceptual models for them. Compact models are essential because their simplicity greatly facilitate the users in learning them.

diSessa describes the Boxer programming environment and some experiences with children in educational settings over a two-decade period to illustrate how such a conceptual model could look like [2, 3]. More importantly, diSessa shows how children and teachers were capable of understanding the model to the extent that they c.

diSessa envisions how an open toolset facilitated by systems like Boxer will facilitate the emergence of a community of tool-builders and tool-sharers. Fostering capacity building in tool appropriation and creation in a learning community will empower users of educational tools to take more responsibility towards meeting their learning needs.

Some of the principles reflected in the design of Boxer's conceptual model include:

- *Textuality*, i.e. text is a powerful and expressive medium.
- *Abstract spatial metaphor*, in which the generality of "boxes" and their containment/hierarchical property can be easily understood across multiple contexts.
- *Computational structure*, i.e. every structure in Boxer can be either computed on or computes, or both.
- *Logical structure* (i.e. systematicity, order and consistency) to how operations change the system state.
- *Visibility* of underlying state and how they change in response to operations. Visibility includes exceptions in how inconsistencies appear to the user. For example, files appear to the user as black-colored boxes.
- *Interactivity,* i.e. the user can change the values of underlying state variables and observe how they affect the tool's operation.
- *Learning trajectory*, i.e. some familiar functionality and initial use helps the user understand the system and its conceptual model. The user can subsequently use the system for more useful tasks. To some extent, learning is aided by visibility and interactivity in the conceptual mode.

OPEN QUESTIONS

Boxer was designed to facilitate mathematics and science education, and has been shown to have some successes in this direction. But it is not clear if the elegant conceptual model built into Boxer would make it a suitable end-user programming toolbelt that will enable communities of students and teachers to create new and appropriate existing educational tools for literacy education. We believe that to some extent, the benefits from being able to read and write (either in English or one's native language) outweighs the importance of a background in mathematics and science.

In the process of exploring the relevance of Boxer for literacy education, and the lessons that it provides for the design of conceptual models that facilitate malleable, appropriable systems, the following open questions need to be investigated:

- Can designers create and impose a system's conceptual model onto users? Or should designers to work with users to iterate on the conceptual model, so as to devise a more intuitive model?
- How is learning about the system and its conceptual model contextualized in the users' needs and activities?
- How do user communities discover, in the above process of learning, highly valued uses for existing and new educational tools?
- Are existing models of open source initiatives in educational technology such as SchoolForge [8] and Eduforge [4] appropriate means of organizing and regulating the production processes of flexible educational tools?

Some degree of participatory design was carried out in the development of Boxer, in which the initial conceptual model was invented by designers but underwent several rounds of iterative design with end-users. Due to the technical constraints involved, it was believed that while collaboration was valuable, the designers nevertheless had to assume more responsibility for the design. We plan to adopt a similar approach through a design workshop in a rural primary school in India during the summer of 2005.

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