Getting Down to Details: The Tangible Learning Design Framework

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Abstract: In this workshop session, we present the Tangible Learning Design Framework. The Framework has two parts: first, a taxonomy of five elements for thinking about the relationships between tangible features, interactions and learning; and second, a set of principles derived from cognitive, constructivist and social learning perspectives to guide the design of these elements. We will discuss examples from our tabletop research illustrating the use and usefulness of a subset of the principles.

The Tangible Learning Design Framework

The Tangible Learning Design Framework consists of a taxonomy of five elements for thinking about the relationships between tangible features, interactions and learning, and a set of principles to guide the design of these elements. The framework advances thinking about designing tangible user interfaces (TUIs) for learning in three ways (Antle & Wise, under review). First, the taxonomy provides a perspective on what aspects of TUI design are important to consider in learning contexts. Second, the principles characterize the dimensions of the design space in terms of learning theory at a level of specificity that can inform specific design choices. Third, by laying out the connections between TUI design choices and learning theory, we propose testable mechanisms of action by which TUI design is expected to affect learning. The dual payoff is a guide for thinking about how TUI design decisions can impact learning and a blueprint for research to develop empirical support for the proposed claims. We envision the design principles (Table 1) to be used: prescriptively by design practitioners to make theory-informed choices; generatively by researchers to develop TUI interaction-learning hypotheses; and educationally by students to better understand how and why TUIs can be designed to support learning.

Table 1: Summary of the Tangible Learning Design Framework principles

Elements 1 & 2: Physical & Digital Objects
1. Distribute information across modalities (e.g. visual, audio, haptic) to increase effective working memory capacity. 2. Integrate spatial sources of information across and within modalities to minimize extraneous cognitive load imposed to synthesize multiple inputs. 3. Use multiple presentation modes within a modality only when the additional representations complement or constrain interpretation and are familiar to the learner to add germane, not extraneous cognitive load. 4. Use concrete representations to support interpretation of abstract representations. 8. Design objects that allow for re-configuration to support adaptation of ideas. 14. Create configurations in which participants can monitor each other's activity and gaze to support the development of shared understandings. 15. Distribute roles, information and controls across the TUI learning environment to promote negotiation and collaboration
Element 3: Actions on Objects
9. Leverage primary schemata in input actions to promote usability and system learnability. 10. Use spatial separation, pausing system responses & learning activity design to support space for reflection. 16. Create constrained or co-dependent access points schemes to compel children to negotiate with each other.
Element 4:Informational Relations
5. Make mappings between physical and digital objects (both form and behavior) and meaning in the world coherent to reduce cognitive load and/or support automatic processing. 6. Use direct dynamic linking that is faded over time to support understanding of abstract representations. 11. Use embodied metaphor(s) in interaction mappings to support learning of abstract concepts. 12. Distribute parts of mental operations to actions on physical and/or digital objects to simplify and support developing mental skills. 17. Support the existence and comparison of multiple versions of representations across participants and time to support metacognitive activities.
Element 5: Learning Activity
7. Tell children what to do and how to do it to reduce extraneous cognitive load. 13. Create contextualized tasks that support children in forming and pursuing meaningful goals. See also principle 15 and 17 above which also apply to the design of the learning activity.

The Framework in Action

Below are three examples of existing research prototypes which demonstrate several of the Tangible Learning Design Framework principles.


Towards Utopia

1. Distribute information across modalities (e.g. visual, audio, haptic) to increase effective working memory capacity.

In the Towards Utopia system (a tangible user interface to a sustainable land use planning system), children use physical stamps labeled with land use images to make digital copies of those land use activities (left image) (Antle *et al.,* under review). Complementary information is provided through voice over narrative triggered by the stamps, providing readily accessible information about costs and benefits of each land use type. The information is distributed across modalities and each presentation mode (i.e., pictorial, voice) focuses on a different aspect of the domain.

Tangible Concept Mapping

12. Distribute parts of mental operations to actions on physical and/or digital objects to simplify and support developing mental skills.

In a tangible concept mapping application users can attach two graspable pucks to two digital "concept" objects and then connect concepts by connecting the male-female puck connectors (centre image) (Tanenbaum and Antle, 2008). Unlike mice, the design of the physical affordances of these tools ensures that dynamic bindings (the relationship between the two concepts) can be easily recalled and enacted.

Futura

10. Use spatial separation, pausing system responses & learning activity design to support space for reflection.

In Futura, a pervasive tabletop game, players try to support a growing population base with enough food, energy and shelter without seriously damaging the environment (Tanenbaum *et al.,* 2010). The tabletop supports a high level of multiplayer activity. Based on system activity, the system generates natural disasters which cause the game state to pause while the disaster plays out. The design of the learning activity can provide instructional guidance to support reflection during or immediately following the pause in game play (Wise & O'Neill, 2009).

15. Distribute roles, information and controls across the TUI learning environment to promote negotiation and collaboration.

In the tangible version of Futura, players are assigned different roles related to environmental preservation and development (Tanenbaum *et al.,* 2010). Each role is associated with a side of the table that gives the child access to unique (role-specific) digital and physical objects and controls (right image). To successfully play the game, children need to coordinate their actions in a coherent strategy; this requires them to negotiate and collaborate. The objects also serve as shared reference points to ground interaction and conversation (Wise *et al.,* 2009).

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