# Tangible-Based Assessment of Collaborative Problem Solving

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**Abstract.** Using Tangible User Interfaces (TUI) for assessing collaborative problems has only been marginally investigated in technology-based assessment. Our first empirical studies focused on light-weight performance measurements, usability, user experience, and gesture analysis to increase our understanding of how people interact with TUI in an assessment context. In this paper we present three of those studies: a windmill scenario where users can learn about the dynamics of energy generation using wind power; a traffic simulator educating the audience on the impacts of different traffic parameters on its fluidity; and a simple climate change scenario allowing children to comprehend the relation between their family's behaviour and its effect on $CO_2$ levels. The paper concludes each scenario by presenting assessment methodologies and observed learning outcome.

**Keywords:** Tangible User Interfaces, Technology-based Assessment, Complex Problem Solving, Collaborative Problem Solving.

## 1 Introduction

For the last few years, the term $21^{st}$ Century skill has shown up in scientific literature [1]. These skills include, for example, complex problem solving, creativity, critical thinking, learning to learn, and decision making [2]. A particular $21^{st}$ Century skill is complex problem solving which encompasses the ability to successfully deal with fuzzy and dynamically changing problems. Despite their importance, assessing these skills with existing technologies poses a challenge. Therefore, exploring new technologies, such as tangible user interfaces (TUI), may prove useful for discovering viable alternatives. TUI offer the possibility to assess collaborative scenarios due to their accessibility to groups. They also allow for using metaphors to imply functionality which can improve understanding and knowledge generation by tapping into the power of human cognition, especially visual cognition.

For each scenario we set up a tangible tabletop system based on the optical tracking framework reacTIVision[1], a toolkit for tangible multi-touch surfaces.

[1] http://reactivision.sourceforge.net/ (accessed April 14, 2014).

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The worktop has an interactive area of 75 x 120cm. Onto the table we project an image according to the scenario as shown in Figure 1 respectively Figure 2. In addition, for each scenario we create a set of tangible widgets, objects both physical and digital used to interact with the tangible table. The objects are tracked using a camera underneath the semi-translucent tabletop surface. Also located beneath the tabletop, a short throw projector provides real-time feedback as well as the initial scenario context images. The following short sections will elaborate briefly on each scenario before elaborating on the set-up for capturing user data and concluding.

## 2 Windmill Scenario

The windmill scenario allows exploring and understanding the relation of external variables on the production of electricity in a wind-powered turbine. Users can engage in the scenario by rotating tangibles on the surface to change input parameters. Input parameters such as wind speed or the number of blades are reflected in real time on output parameters such as rotor speed or electrical power output. Because all the tangibles can be moved freely on the table and exchanged, each participant gets a vote and hence collaboration and motivation was expected to be improved.

**Fig. 1.** Windmill scenario

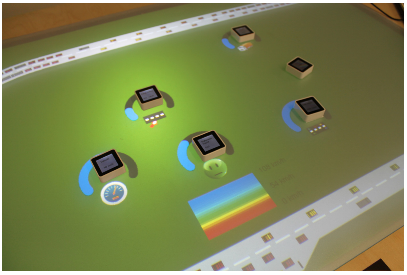

**Fig. 2.** Traffic Simulator

## 3 Traffic Simulator

The traffic simulator was adapted from an online traffic simulator of the Technische Universität Dresden's Institute for Transport & Economics. The original purpose as well as more information can be found in [3]. The adapted simulator has its interface revamped: all control elements are replaced by the functionality provided by tangibles. Akin to the Windmill simulator, feedback on the input dials is provided in real time but due to the nature of the simulated content, traffic reacts true to the laws of traffic dynamics: forming and dissipating traffic jams as given by the traffic dynamics influenced by the users. The simple scenario (Figure 2 lets users adjust the number of vehicles on the motorway and influx ramp as well as the average speed, and politeness of drivers.

## 4 Climate Change Scenario

The climate change scenario was build to allow children to understand the relations between causes of climate change and their effect. Special care was taken to expose causes that children of a young age (9 to 12) can relate to. The scenario builds upon the MicroDYN methodology of Greiff et al [4]. The TUI allows using widgets to ask questions to a group of test takers which each can vote on one of the proposed answers. Their votes are fed into a system of linear equations which gives feedback on the effect on climate change. In a second phase, test takers are able to freely manipulate parameters, that is, change votes on questions, to explore the climate model.

## 5 Experimental Set-up

During experiments, participant behaviour is monitored using video recording from multiple angles. Further, a researcher observes participants and takes notes of the solving strategies and arising usability issues. Afterwards, participants are asked to fill out two questionnaires. The first questionnaire aims to assess the knowledge of the participants gained during the exploration phase, the second consists of questions on the usability and user experience of the system.

The set-up has been tweaked during each experimentation such that for the Climate Change scenario, scheduled to run in 20 sessions in 2014 and 2015, participants will be video and audio recorded during the sessions. Using separate data channels, we prepare for our next iteration of the set-up where we intend to add more data sources and combine them using multi-modal fusion.

Results on a first set of studies using the Windmill scenario are presented in [5]. A detailed description of the Climate Change scenario, the MicroDYN methodology, as well as research questions and expected outcome can be found in [6].

## 6 Conclusion

Technology-based assessment has the potential to support educational innovation and development of $21^{st}$ century skills, such as, for example, complex problem solving, communication, team work, creativity and innovation [2]. The multi-dimensionality of TUI: the tabletop and physical objects, the projection and feedback, body language, and speech enable users to benefit from many inputs and learn naturally in a collaborative environment. While the system is not without its faults, mainly due to the spatial limitations of the tabletop, future iterations of the set-up will feature more feedback and information gathering dimensions and enable the use of multi-modal fusion to aggregate data into learning traces. This will in turn enable us to provide better feedback to encourage self-regulating behaviours.

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