Gaze Awareness in Collaborative Problem Solving:
An Approach for Gaze Sensitive Interaction and Analysis

Philipp Schlieker-Steens, Dortmund University of Applied Sciences and Arts,
philipp.schlieker-steens@fh-dortmund.de
Christian Schlösser, Dortmund University of Applied Sciences and Arts, christian.schloesser@fh-dortmund.de
Andreas Harrer, Clausthal University of Technology, Germany, andreas.harrer@tu-clausthal.de
Andrea Kienle, Dortmund University of Applied Sciences and Arts, andrea.kienle@fh-dortmund.de

Abstract: This paper presents an approach to utilize eye-tracking technology for interaction and analyzing to understand complex collaborative competencies that are subsumed under the term learning to learn together (L2L2). Our analysis uses automated computation of gaze measures, domain activities, and qualitative manual coding to find differences between certain gaze visualizations. We present our results on an empirical lab study of a collaborative puzzle-solving activity in different conditions of gaze awareness between the collaboration partners.

Introduction
In today’s information society the requirements in the job, schools and university go beyond the mere acquisition of domain-related knowledge and skills. The term 21st century skills entails and stresses the importance of a wide variety of skills “needed to survive and thrive in a complex and connected world” (Trilling & Fadel, 2009). While we accept the importance of the standard skills promoted by more traditional systems, our work is motivated by the importance of moving beyond domain-specific skills and focusing on the collaborative competencies associated with group learning that today's complex, fast-paced environment demands (Scardamalia et al., 2011), i.e. a subset of 21st century skills that is especially relevant for CSCL research. In the Metafora project (http://www.metafora-project.org) we designed a pedagogical approach to encourage students to engage and learning those skills. This is subsumed under a frame we call “Learning to Learn Together” (L2L2) that focuses on the meta-level of how students learn from and with each other and includes interacting behaviors as follows: Distributed Leadership, Mutual Engagement, Help-seeking and -giving and Reflection of the group learning process (Dragon et al. 2013). Relevant for our study is the integration of eye-tracking as one input sensor. Studies in CSCL settings (Schneider & Pea, 2013) showed that providing awareness of the focal point of learning partners on the screen supports the coordination of learning partners within a group task and the development of a common understanding of the learning content. For our study we use the INKA-Suite (Kienle et al., 2013) that directly connects the eye-tracker’s gaze data stream and the CSCL system and identifies the areas of interest at runtime, regardless of size, shape and position. We will show how low-level gaze and operation information can be combined with high-level L2L2 category coding to get a richer picture of L2L2 in practice. And how different gaze visualizations infect those L2L2 behaviors.

Methods
The experiment consisted of collaborative puzzle where each participant used a separate computer. The puzzle is a collaborative adaptation of the turtle puzzle (see Fig. 1, left) which requires matching heads and bodies of turtles across 2 adjacent puzzle cards and that has been used in a similar way in CSCL studies before (e.g. Mühlenbrock & Hoppe, 1999). The turtle puzzle consisted of nine pieces and accepted just one valid solution, which was automatically detected by the system. As shown in Fig. 1, there were nine drop zones for solving the puzzle, as well as nine stack zones, which initially held the puzzle pieces. Every dyad had the same initial piece distribution. It was implemented as a “What-You-See-Is-What-I-See” real time web application, which transmitted every drag and drop. Conflicts like dragging the same piece or using the same drop zone was prevented by the system. Participants were assigned to a color, which was used to highlight drop zones and gaze indicators. It was also used by the experimenter to refer to participants via the collective voice chat.

Figure 1. Turtle puzzle game board (left) and gaze conditions (right)
In this experiment we used three conditions in a between-subjects design. Those conditions were divided by the support of gaze (see Fig. 2, right). The first group had no gaze support at all, the second group was supported by a mutual gaze cursor and the third group used a gaze enabled application, which highlighted the visible elements on the screen while fixating it without showing a gaze cursor.

Findings
In this study we used computational methods to derive gaze-related information. These automated methods have been complemented by extensive manual coding on a subset of the dyads that created a balanced spectrum of the different conditions and quickness of the solution (both quick success and maximum duration without success). The explicit coding of L2L2 behavior (four independent coders; code was established when coded by at least three analysts) and the parallel inspection of captured gaze properties and domain actions helped us to identify potential patterns at the different levels of observations that can guide the inspection of the full set of dyads. Mutual engagement is established in the different conditions in different ways. While the shared gaze in conditions gaze cursor and gaze awareness helps to create joint attention, this information is lacking in the no-gaze condition and has to be compensated by audible references or referential gestures within the tool. In the investigation of L2L2 behaviors in the dyads we coded manually, we detected a typical pattern of audio-gaze combination with an optional action taking place afterward in the two gaze conditions, while in the no-gaze we detected a typical voice-action-gaze pattern before joint attention was created (see Fig. 2). Similar characteristic patterns can be identified for Distributed leadership.

Discussion and conclusions
To conclude we utilized eye-tracking technology to investigate the presence of L2L2 behaviors in problem-solving activities. Our assumption that the sharing of gaze information can help to establish mutual engagement and distributed leadership was supported in our experiment. The analysis of our two different gaze conditions (i.e. replication of the gaze cursor vs. highlighting an area of interest as gaze awareness) brought a slight advantage of our awareness condition, yet no significant differences at this stage. We will have to explore in more depth if more complex learning scenarios will create clearer results. Useful for this analysis was the integrated and synchronized visualization of all relevant information inside the INKA-Suite.

References