

# Exploring collaboration during mathematics problem solving in the classroom with multiple mobile eye tracking

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# Collaboration during problem solving

- During collaborative problem solving we wish to observe:
  - states of affect during problem solving session
  - Behavior during significant events in the problem solving session

# MathTrack main study

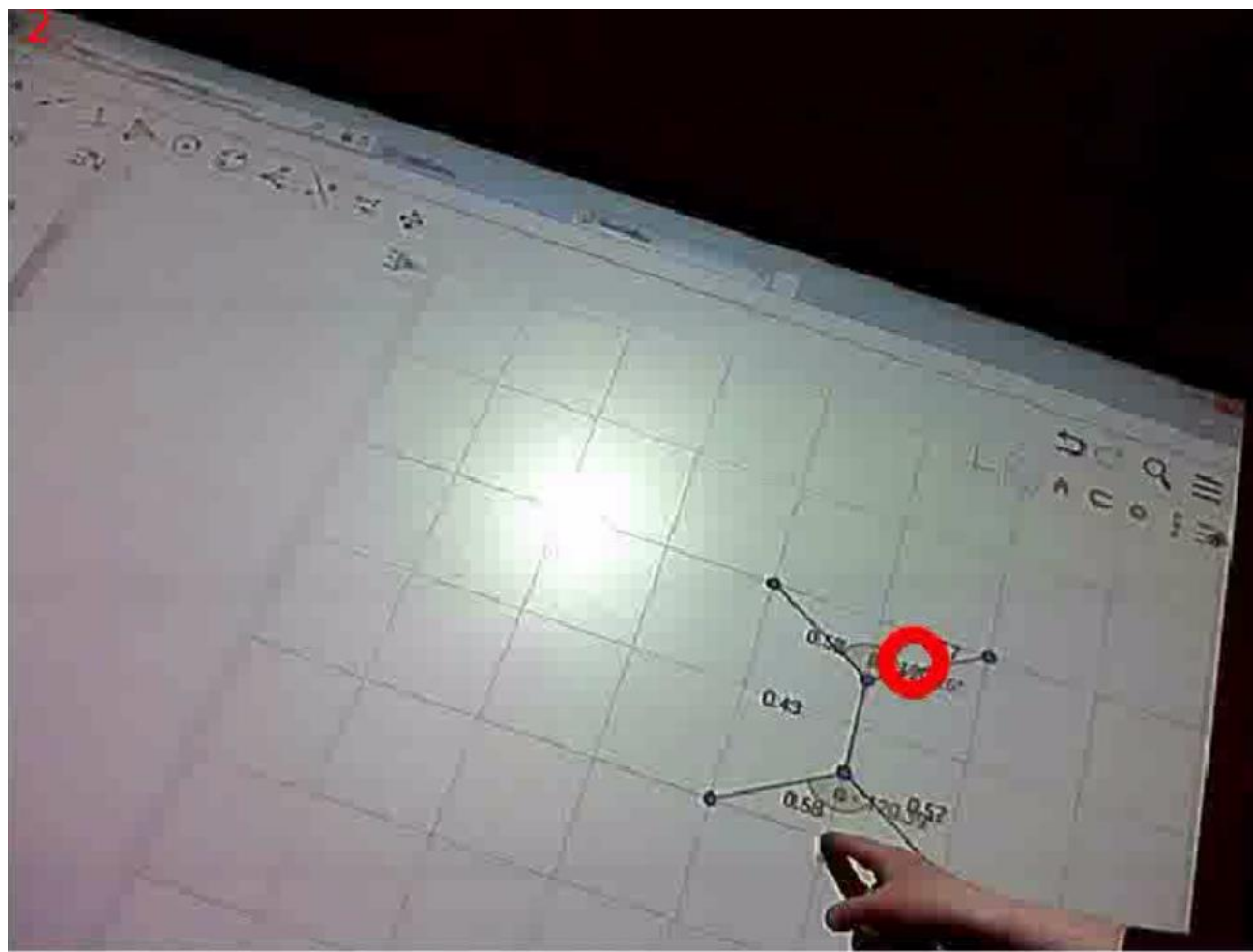
- Faculty of Educational Sciences, University of Helsinki
- Four-year project 2016-2020
- Funded by Academy of Finland

# Methods – mobile gaze tracking, video and other recordings



- Students wear a mobile gaze tracking device
- The gaze tracking device consists of a glass frame equipped with mini cameras which produce a video scene and keep track of the direction that the eyes are pointing at (3D-eye model gaze detection)
- The gaze tracking glasses are connected with three cords to a laptop carried in a backpack.
- The glass frame is 3D-printed, all components are standard off-the-shelf, and the instructions and software are published
  - Do it yourself!

Example of what the output looks like



# The experiment and its setup

- We explore student collaborative behavior and gaze with mobile eye tracking in a problem solving session during a regular lesson
- Three students and the teacher are wearing mobile eye trackers
- Two additional cameras record the students, the teacher, and the classroom
- Audio is recorded from all subjects
- Scribble is recorded with smart pens
- Computer activity is recorded via screen capture
- Post lesson stimulated recall interviews take place with gaze videos as stimulus

# The problem and working mode

- An open ended problem is posed: how to most effectively join four cities lying in the corners of a square, with cable, or pipes
- The teacher is instructed not to provide any information leading to the solution of the problem, and to encourage students to look for better solutions as they come up with some
- Students work first alone, then in pairs, then as a group of four. In stage 3 students are encouraged to walk around and see what other groups of students have been able to produce

# Research questions - 1

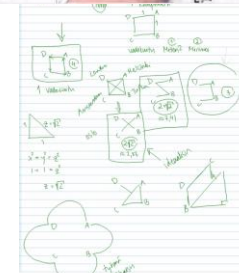
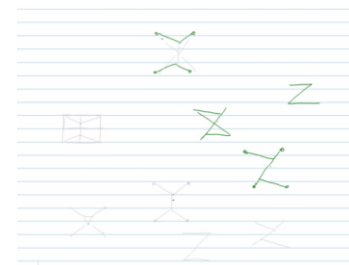
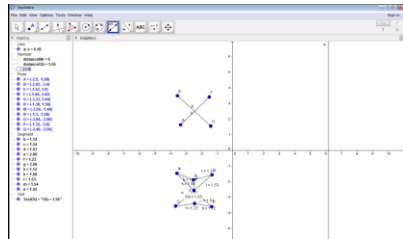
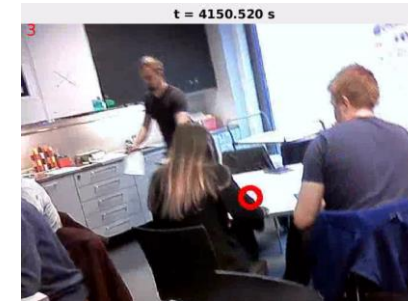
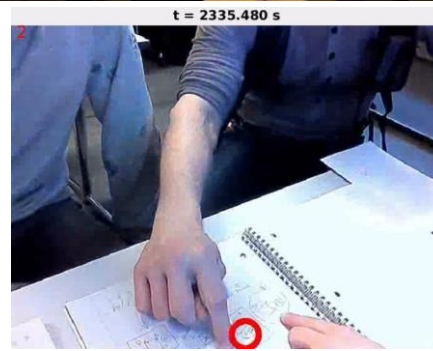
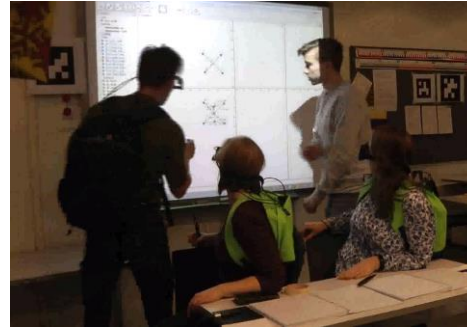
- We are interested in finding out patterns of collaboration, and the outcomes of shared attention requests at different points of the problem solving session, and if possible, identify problem solving strategies (note, there may be more than one – different experiments may reveal different strategies)
- We are interested in verifying qualitative observations of joint attention quantitatively, and use these quantitative measures to identify working strategies – how, in time, students work together or independently, and when working independently, on what they will work at what time (same idea, different ideas)



# Research questions - 2

- Furthermore, we are interested in observing gaze patterns at specific important events during the problem solving session, such as the “aha” moments when the better solutions are found

# Data: 9 synchronized videos + 4 stimulated recall interviews + questionnaire



Vuorot: 100 oppituntia, 50 oppituntia, 50 oppituntia

Oppituntin sisältö	1	2	3	4	5
Olla luovutettu	1	2	3	4	5
Olla luovutettu oppimalla	1	2	3	4	5
Oppimalla luovutettu	1	2	3	4	5
Tuottoa luovutettiin	1	2	3	4	5
Kokonaan luovutettiin	1	2	3	4	5

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# Methods - Analysis

- The gaze durations in the tracking videos are hand coded (frame by frame – videos are previously synched with universal time stamp).
- The phenomena that can be identified in gaze tracking videos is analyzed with verbal information at hand, and reanalyzed with information gained from stimulated recall interviews obtained with gaze tracking information right after the lesson, as well as from the video recordings and other data collected.

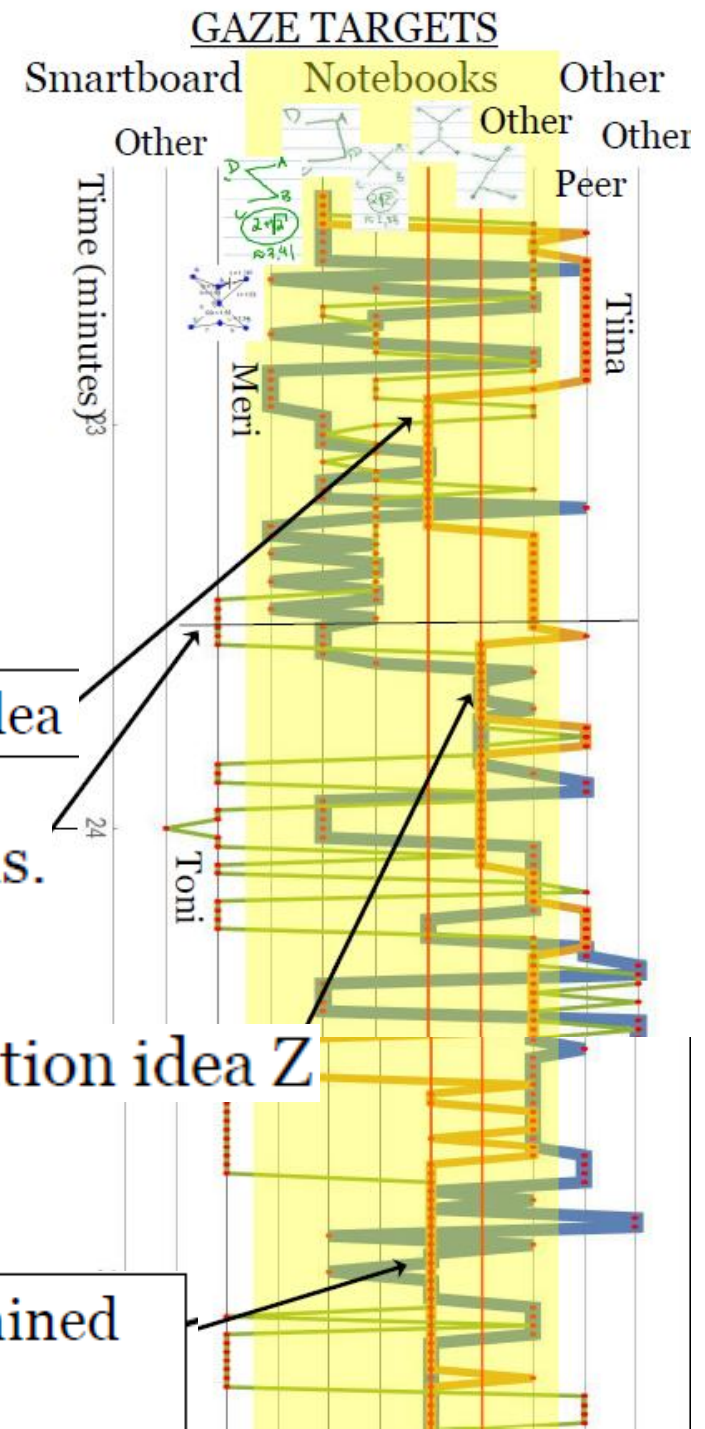
# Methods - Analysis – quantitative

- We look at gaze durations. The onset of a gaze duration in any of the three gaze videos is a synchronization point. There are 543 sync points in about 5-6 minutes of simultaneous gaze videos.
- Longest common sequence analysis (LCS – explained ahead) applied to running windows (3 pairs) of 25 sync points (about 10 seconds) is used to find moments of shared attention of the three students – the length of the window is obtained empirically to remove noise without eliminating important detail.
- Quantitative estimate of pairwise AOI overlap is given by the LCS length in a moving window of 25 sync points (15 sec). This estimate is obtained for each sync point. Pairwise estimates are averaged to get an overall overlap estimate. This average is compared with LCS lengths of randomly generated data, which provide a baseline measure of overlap.

# LCS explained

- At each synch point a window 25 synch points long; example with a window having 11 synch points:
- {a, b, r, a, c, a, d, a, b, r, a}
- {b, a, r, d, a, a, d, d, r, r, a}.
- {b, r, a, d, r, a} – length 6 is a measure of overlap
- Character set of size 5: a, b, c, d, r
- Compare data overlap with random overlap mean (here we would generate pairs of sequences of length 11 using 5 characters thousands of times, compute the LCS of each pair, and take the average of the LCS measures to obtain a baseline measure.
- Data overlap (blue) is compared to overlap between randomly generated data (red) with same set of characters
- Pairwise overlap measure is averaged to get overlap for 3 or more individuals.

A visualization graph of synchronized gaze locations of three students on aggregated areas of interest, with significant moments identified



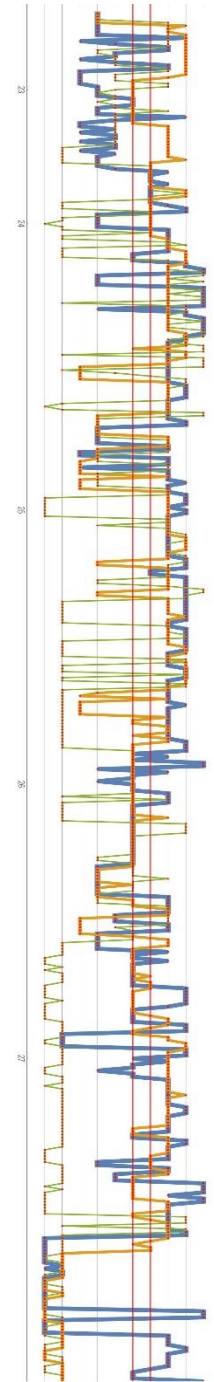
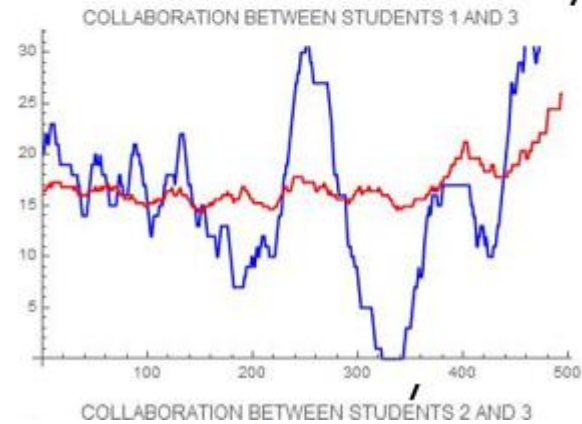
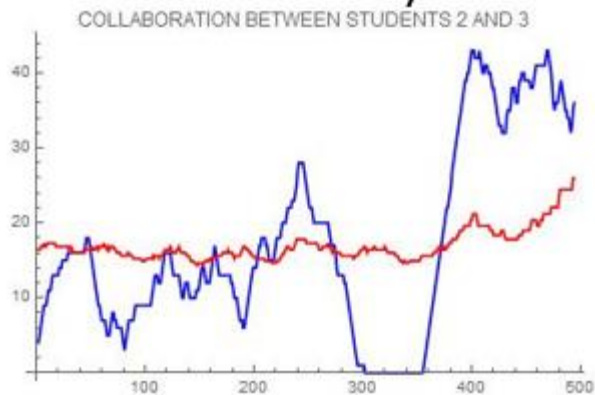
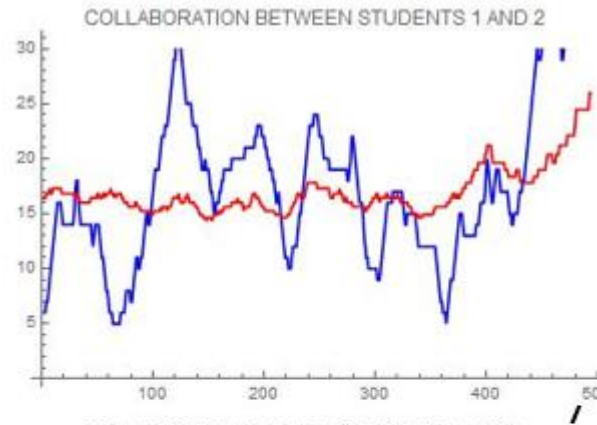
Tiina creating the right idea

All students focusing on different ideas.

All students focusing on Tiina's solution idea Z

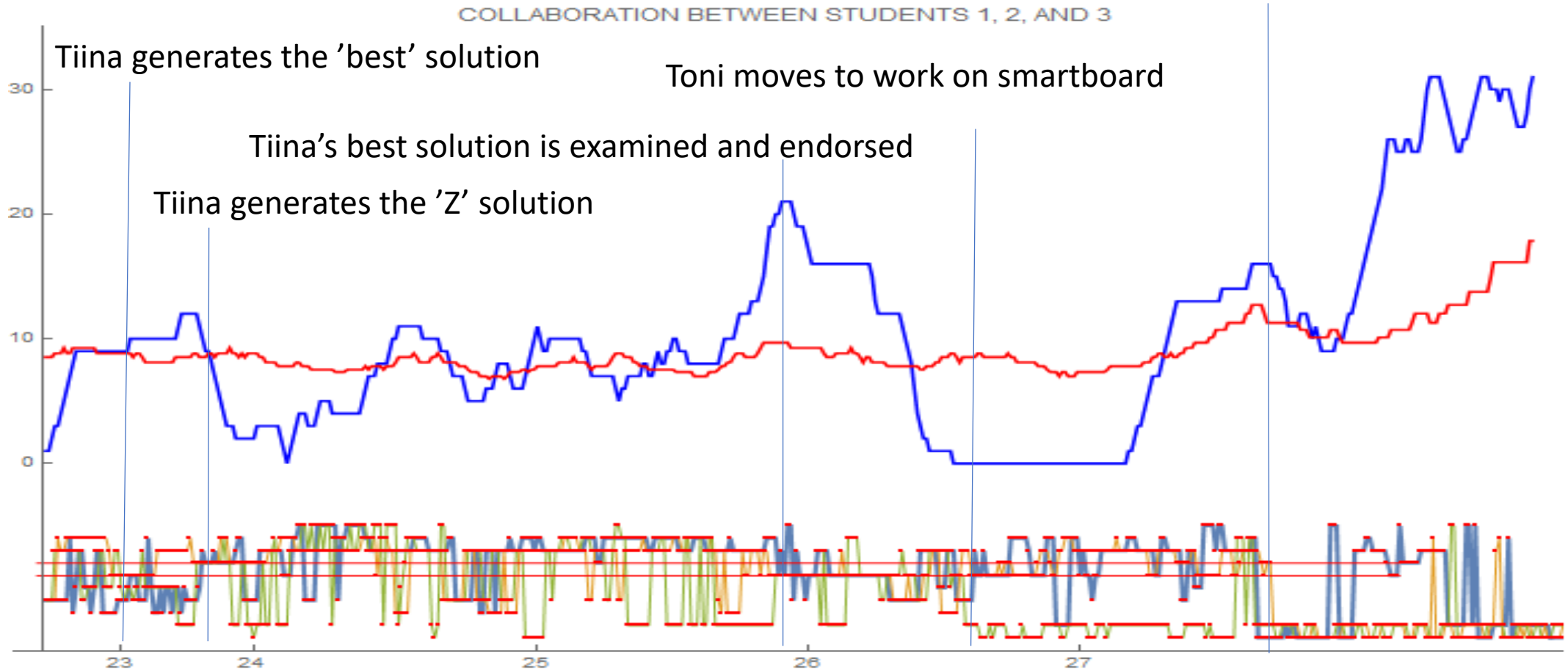
Tiina's solution idea (see Figure 2) is examined and endorsed

Three pairwise collaboration patterns (blue) vs. baseline (red), and a visualization of synchronized gaze locations of three students on aggregated AOI's to the right



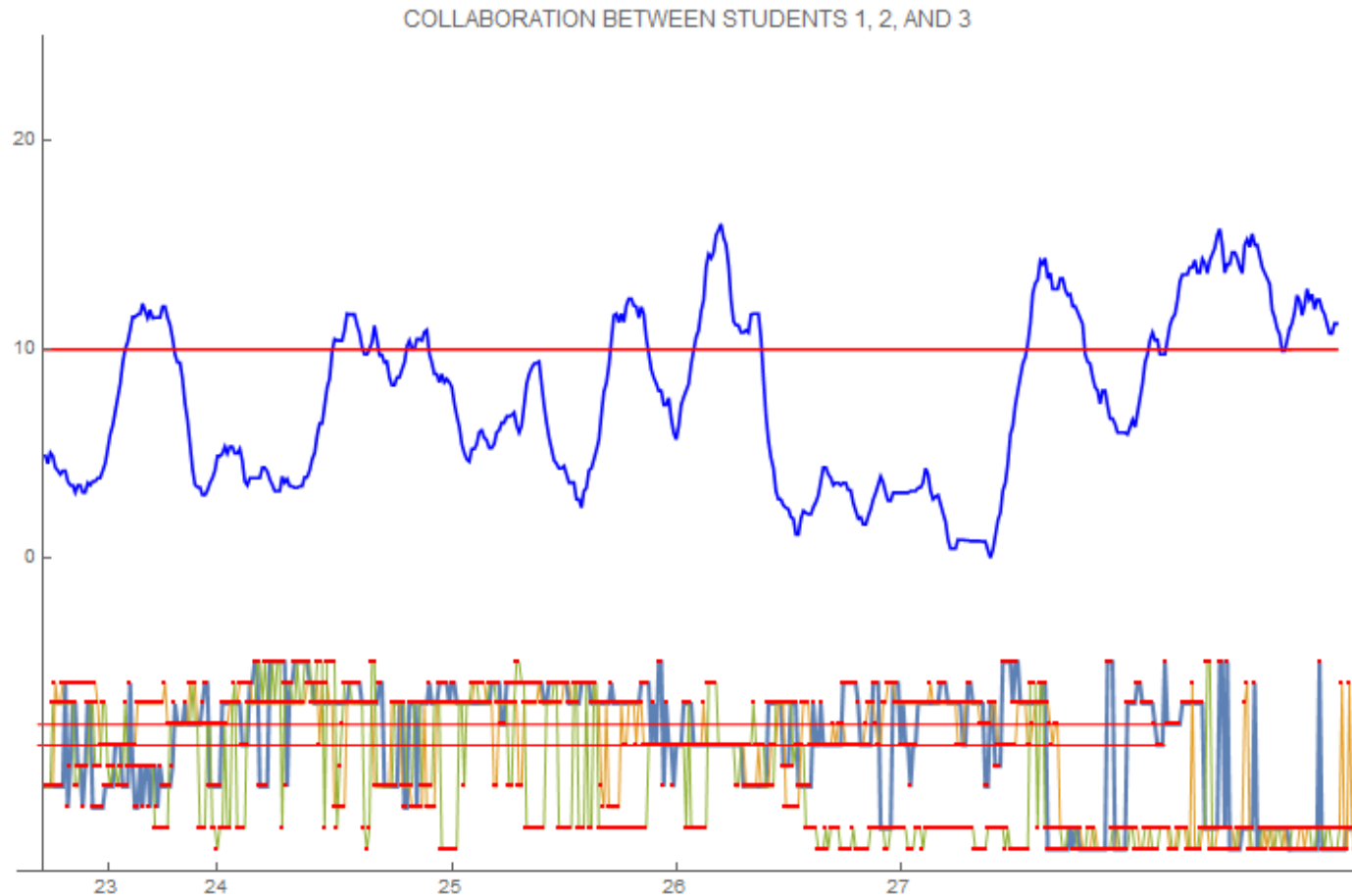
# Results – A first attempt to visualize gaze overlap quantitatively

All focus on smartboard





Improved graph – normalized to have a straight baseline, and a smaller running window to allow for greater detail in the overlap graph



# Further improvements for the graph in the future

- The preceding graph does not have a real time scale on the x-axis, but rather, a synchronization point as a unit. Note that towards the end the minutes are longer: this is useful information, it tells that towards the end eyes were moving a lot more, but still, there was quite a bit of overlap
- Standard deviation (symmetric along the base line) bands will be added. Note that there is not a real vertical scale unit, so these are needed.

# Results – discussion and statistics

- We can see from the figures, that students seem to alternate between working independently and working together. In particular, there is an event that brings students together (a solution is discovered), then they disperse (to work on it independently), another solution is found, and the best solution is identified (third blue peak) and finally, after independent work, students gather again to discuss.
- Statistics: we plan to obtain statistics, to see how much time students spend working alone, working in pairs, and working as a group. A moving average (obtained by integrating the blue and red curves) of collaboration measure should be interesting to see.

# Thanks

- Thanks to the organizers of the symposium for inviting the presenter to deliver this presentation.
- THE MATHTRACK TEAM – FACULTY OF EDUCATIONAL SCIENCES – UNIVERSITY OF HELSINKI
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