Report on testing learning environment: Nomogram

Module:	Nomogram Lower secondary
Responsible Partner:	Utrecht University, The Netherlands
Grade Level/Age Range:	Grade 9 (14-15 years old)
Sample size:	24
Brief Description of Testing / Invention:	The three learning modules have the following attributes: situational context, multi-touch application, action-based and perception-based design. This series of designs introduces the concept of function through a real-life context that is familiar to students, namely light rays. In the first module, most of the tasks are unimanual, perception-based tasks, addressing the input-output and covariation aspects of function and laying the foundation for the covariation, correspondence aspects of FT. In the second module, most of the tasks are action-based tasks that emphasize the covariation and correspondence aspects of FT through two-hand motion (multi-touch). The real-life context is removed here but the light ray model and the nomogram prototype are retained. The third module adds another presentation of function, the function graph. The connection and transition between the function graph and the nomogram are highlighted and explored through two-hand motion. The three modules can be accessed through the following links: Embodiment1 (dwo.nl) Embodiment2 (dwo.nl) Embodiment3 (dwo.nl)

Method:

The teaching experiment was carried out with students from one grade nine class from an international school (14-15 years old). With regard to the starting points and preliminary knowledge of these students, they had experience with reading off numbers from number lines, with forming an addition or subtraction expression to represent the relationship between two quantities, with using a ratio to describe the relationship between two quantities, with writing algebraic expressions to describe a real-world situation, with identifying values in a graph and with plotting number pairs (in Cartesian coordinate system).

The experiment, conducted from May 8-12, 2023, comprised three learning modules described above. Each module lasted for 60 minutes, summing up to a total duration of 180 minutes. There were 24 students who took the pre- and post-test before and after the experiment. The study utilized a digital learning platform where students engaged in embodied nomogram tasks using a multi-touch screen interface. Hang Wei, a project member, took the role of a teacher, introducing each lesson

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and facilitating whole-class discussions. Participants were motivated to engage in collaborative work and to raise questions throughout the sessions.

Results and Discussion:

Results

The results of our study show improvements in students' functional thinking as reflected in the pre- and post-test scores. The following table breaks down these results by showing the proportional increase in the scoring rates for item 3a and item 3b. The increases in scoring proportions and the decrease in blank answers from item 3c imply that the students were not only able to attempt the problems but also solve them correctly.

Item 3a

	Pre-test	Post-test
Proportion of scoring	66.67%	87.50%

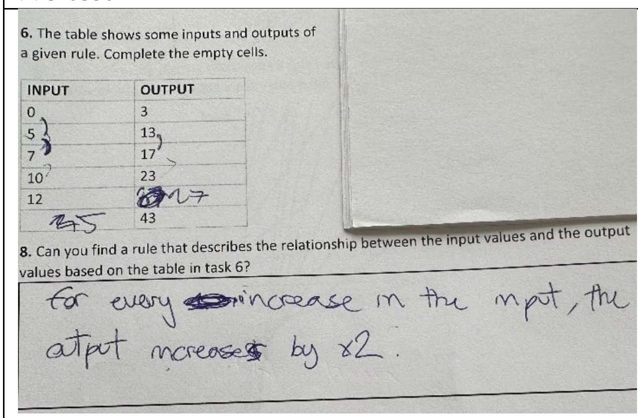
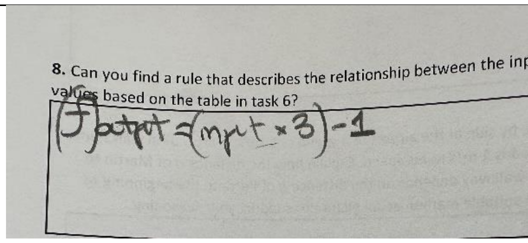
Item 3b

	Pre-test	Post-test
Proportion of scoring	38.10%	83.33%

Item 3c

	Pre-test	Post-test
Proportion of full score	47.62%	62.5%
proportion of blank	33.33%	20.83%

A clear example of developed covariation aspect of functional thinking can be seen in the students' responses to item 3c. In the pre-test, a student was only able to identify the multiplication factor of the relationship. However, in the post-test, the same student was able to correctly figure out the full rule, both multiplication and additive factors. This demonstrates a deepened understanding and improved capability in covariational reasoning, supporting our claim that the intervention has effectively enhanced students' functional thinking.

Pre-test	Post-test
	

Discussion

The results of this study provide compelling evidence that the embodied tasks involving nomograms contribute to developing students' functional thinking. The students improved their performance in the post-test, with higher proportions of scoring/full scoring and lower rates of blank responses compared to the pre-test, showing the potential of these tasks to advance functional thinking.

The intervention's success can be traced back to the approach of intertwining the bodily/embodied experience of the digital-embodied tasks, which provide concrete experience with the abstract nature of functional thinking. When the students physically engaged with the nomograms and could see the dynamic changes in functional relationships, it appeared to foster a more profound understanding of the underlying concept. For instance, the student who only managed to find the multiplication factor in the pre-test was later able to figure out the full rule in the post-test, providing further validation of our hypothesis. This improvement may be attributed to the potential of digital-embodied tasks to bridge the gap between abstract concepts of functions and their visualized and tangible representations.

The efficacy of this approach is echoed in other studies, where embodied cognition and hands-on learning have been found to aid in comprehending abstract mathematical concepts. By adding an embodied dimension to mathematical learning, students can make more meaningful connections and comprehend abstract concepts more deeply.

In conclusion, our study has shown promising results in the use of digital-embodied tasks involving nomograms for fostering functional thinking. The evidence presented herein paves the way for further explorations in the field and the development of innovative, effective instructional designs in mathematical education.