Laboratory for Perceptual and Cognitive Systems

Development and testing of a tool for learning stereometry at high school

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Abstract

The focus of the current study is to develop and support spatial thinking skills for high school students. According to variety of research results (e.g., Uttal et al., 2013) the acquisition of spatial skills relates to the successful learning in STEM fields.[1]

In Latvian the high school program, spatial thinking and spatial skills are applied in the acquisition of stereometry (a direction of mathematics that studies geometric bodies and shapes whose points are not in the same plane).

In order to learn the concepts of stereometry more productively, National Centre for Education (NCE) recommends students using various digital tools while learning the subject. NCE is a public administration institution directly subordinated to the Minister of Education and Science. One of NCE's primary functions is to develop curricula for high school education.

Remote learning in current pandemic circumstances has raised issues about the provision of self-directed learning for students, including the use of digital tools in high school curricula. For the acquisition of stereometry concepts in the mathematics program for high school students, there are several tools that can be used to visualize and comprehend spatial objects. NCE recommends *MathIsFun* [5], *GeoGebra* [2] and *Uzdevumi.lv* [3] as the self-learning support platforms for students.

Introduction

The aim of the research project was to study and compare the functionalities of the tools included in the high school mathematics program, to provide an overview of today's major research discoveries, as well as to develop guidelines for creating a new tool that would include the missing functionalities.

The design of the study involved a theoretical summary of the required functions for stereometry learning tools as well as a brief overlook of the high school mathematics program requirements. The practical part of the study included program testing with high school students.

Methodology

The design of the study involved a comprehensive theoretical summary of the required functions for stereometry learning tools as well as an overview of the requirements for high school mathematics program. The empirical part of the study included (a) the testing of the program on high school students; (b). survey concerning students' opinion and usage habits for the support tools for learning stereometry included in the current mathematics program. The methods used in the study were developed based on research on usability testing with adolescents in human-centered design and adaptation of selected UX analysis methods. The study applied a 5E usability development approach to assess the tools. A total of 78 students aged 16 to 19 in the 10th, 11th and 12th grades of Cesis State Gymnasium were selected for the research sample.

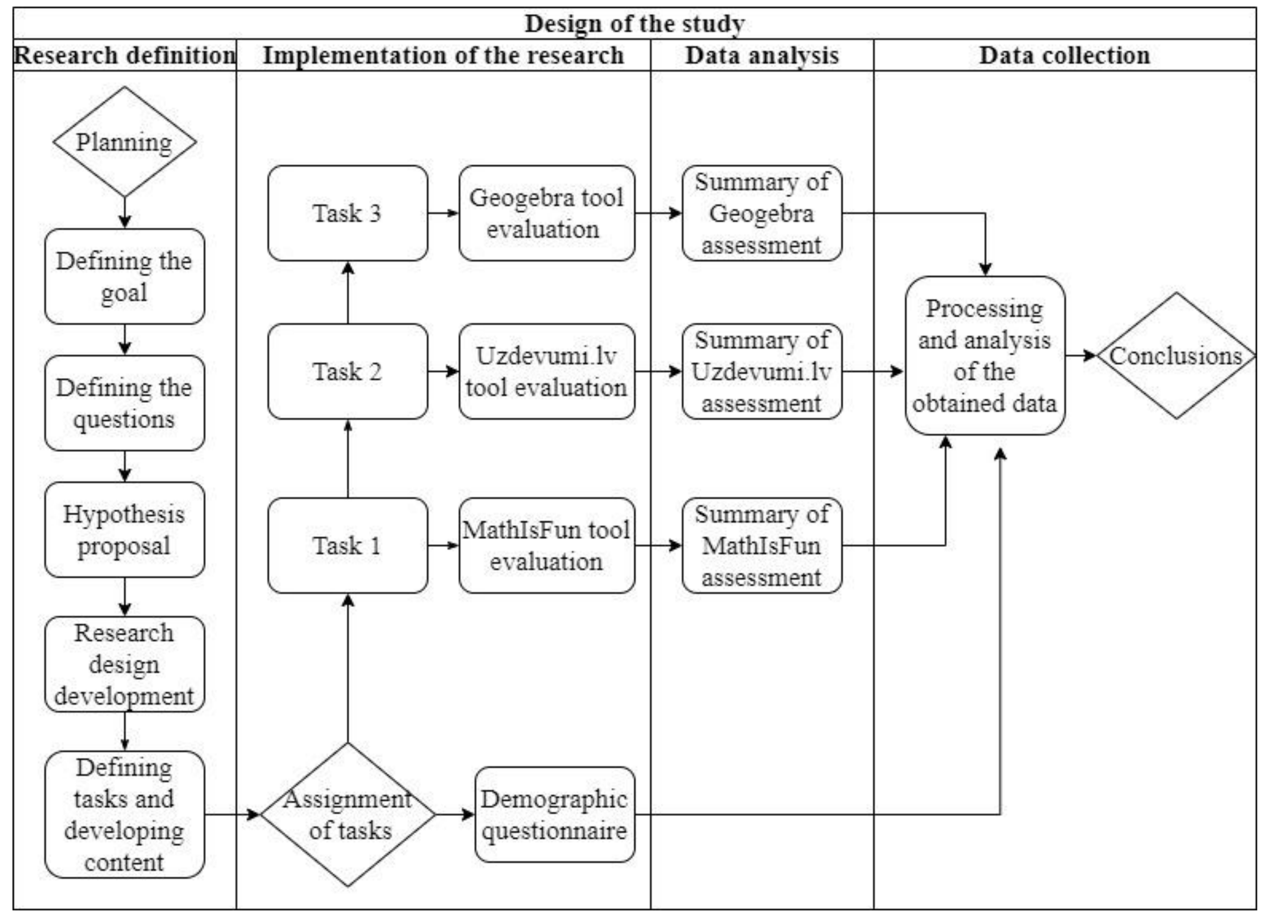

Figure 1: Diagram of the study design

In the study, students were given a specific task to be performed using one of the proposed stereometry learning tools. In total, the students completed 3 tasks. In each of the given tasks, it was recommended to use one of the support tools offered by NCE.

The tasks were compiled based on the course of stereometry acquisition in secondary school. In order to ensure as equal conditions as possible, the students performed the tasks simultaneously, divided into class groups.

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TASK 1

Create layouts of spatial bodies and calculate their areas:

1) Tetrahedron;

2) Regular hexagonal prism;

3) Cone.

Tool: *MathIsFun*

Example: Create a layout of tetrahedron $A=3a^2$, where a is the length of the side of a triangle

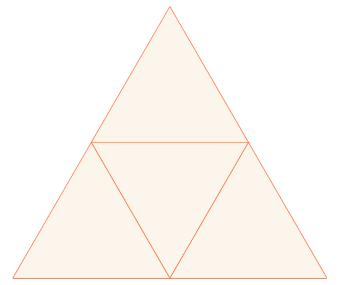

Figure 2: Task 1 solution example

TASK 2

On the Uzdevumi.lv website, perform the given tasks about a polyhedral section with a plane.

Tool: *Uzdevumi.lv*

Example: A cube is given. Points K, L and M are suspended on the edge of the cube.

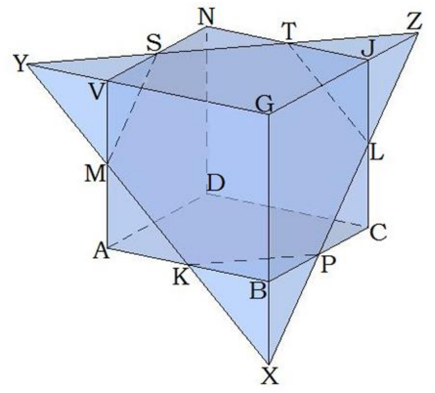

Figure 3: Task 2 solution example

Construct a section of a cube with the plane KLM!

Describe the progress of the construction!

TASK 3

Construct a section of a cube $ABCDA_1B_1C_1D_1$ with a plane if it passes through points KLM.

1) $K \in AB;\ L \in AA_1;\ M \in CC_1;$

2) $K \in AB;\ L \in AA_1;\ M \in C_1C_1;$

3) $K \in AD;\ L \in BC;\ M \in D_1C_1.$

Tool: *Geogebra*

Example: $K \in AD;\ L \in BC;\ M \in D_1C_1;$

1) KL

2) $KL \cap DC = E$

3) $ME \cap CC_1 = F$

4) LF

5) $MF \cap DD_1 = H$

6) HK

7) $HK \cap A_1D_1 = S$

8) SM

9)Section KSMFL

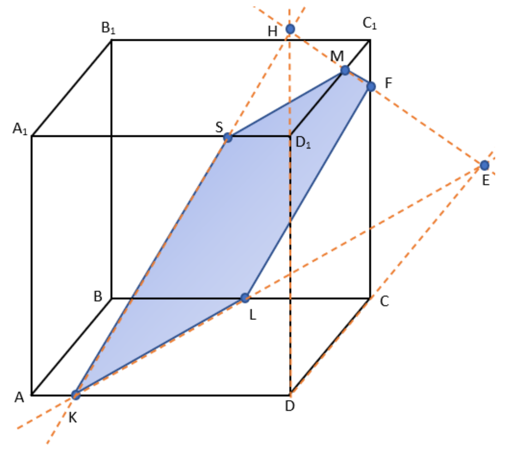

Figure 4: Task 3 solution example

After completing the tasks, the students were given an electronic questionnaire, in which the Likert scale was used to evaluate the tool used in each of the five dimensions of the 5E model. Before evaluating the tool, students were explained each of the dimensions of the 5E model so that students could more objectively evaluate the functionality of the tool. [4]

The 5E model is described by:

1) Effectiveness;
2) Efficiency;
3) Engagement;
4) Error tolerance;
5) Ease of learning.

The electronic survey has been supplemented with questions to find out what are the daily habits of students in their usage of stereometry learning tools. The result obtained by the performed tasks was evaluated as a percentage, based on the amount and accuracy of the work done.

Results

In all 5E categories, the research participants rated the tool Uzdevumi.lv the highest. The MathIsFun tool was also rated positively by students, giving an average score of 3.80 in all 5E categories. The Geogebra tool performed its functions less effectively, receiving the lowest rating of 2.18. Although Geogebra offers a wide range of functionality and includes interactive spatial visualizations, the complex UI implementation prevents students from taking full advantage of all the functionality offered by the tool.

Category Tool	Effectiveness	Efficiency	Engagement	Error tolerance	Ease of learning	Average rating
Math is fun	3.79	3.66	3.55	4.18	3.83	3.80
Uzdevumi.lv	3.56	3.62	3.88	4.06	4.34	3.89
Geogebra	1.96	2.16	1.91	2.99	1.87	2.18
Average rating	3.10	3.15	3.11	3.74	3.35	3.29

Table 1: Assessment of the 5E categories

Students from available tools would like to see more theoretical explanations and formulas tasks as well as more accurate visual representations of three-dimensional objects of different elements. Students especially emphasized the importance of visualizations of section constructions. The construction of sections requires good spatial visualization skills because when creating a section of a spatial object with a plane, it is necessary to understand parallelism, perpendicularity in space, as well as the ability to imagine the extensions of edges from different sides of the spatial object.

Conclusion

In general, the learning tools that NCE recommends for learning the concepts of stereometry for high school students contain important functionalities, but these tools do not provide a complete visualization of the concepts included in the high school mathematics program. One of the major flaws of these tools is also their UI implementation techniques that are not intuitive for the students.

The problem of insufficient earning tools could be eliminated by focusing on the requirement of the student's education curriculum. When considering the development of learning tools, the student's abilities, knowledge, previous experience and requirements should be evaluated before moving on to the development.

References

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Acknowledgments

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