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Children's block-building: How do they express their knowledge of geometrical solids?

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Introduction

The main focus of the study is on primary students' concept knowledge about geometrical solids. In particular, we intend to detect the development of geometrical concept knowledge of Year 3, 4 and 5 students (aged 8 to 11). We investigate young children's knowledge of geometrical solids by providing wooden blocks in construction tasks: 52 third-graders (German and Malaysian children), 30 fourth-graders and 9 fifth-graders were asked to construct cuboids and cubes according to their knowledge and visualization. Results are interpreted according to the Van Hiele framework. In addition, we have a closer look on the variety of cube and cuboid constructions and raise conclusions concerning the development of children's conceptual knowledge.

Theoretical framework

The customary conception of a *concept* comprises the "ideal representation of a class of objects, based on their common features" (Fischbein, 1993, p. 139). In this sense, *geometrical concepts* refer to common features of a class of geometrical shapes or solids which can be visualized or perceived when encountering concrete representatives. Typical representatives (prototypes) depict specific features of the class of geometrical figures in particular (Mitchelmore & White, 2000). Based on this notion, students' conceptual knowledge of geometrical solids reaches beyond the capability of correctly naming concrete representatives or giving a verbal definition. It rather comprehends the perception, visualization and identification of distinctive properties which refers to individual mental images students have while thinking of a specific solid (Tall & Vinner, 1981). The development of geometrical concept knowledge from primary to secondary has been described by the well-known Van Hiele Model which defines five levels of development (Van Hiele, 1986). Yet, most research which refers to the Van Hiele framework has been concerned about children's geometrical concept knowledge of 2-D shapes, whereas little is known about children's concepts of 3-D solids. Based on this theoretical framework, we assume that analyses of similarities and differences in individual construction processes and products of Year 3, 4 and 5 children provide deeper insights into children's visualization of geometrical solids, regarded to be a core element of geometry and mathematics education in primary schools.

Research questions, methods and results

The results of the study are expected to contribute to a deeper understanding of the development of children's concept knowledge of geometrical solids at primary level.

- How do Year 3, 4 and 5 children (aged 8 to 11) articulate their conceptual knowledge of geometrical solids via construction activities with wooden blocks (cubes, cuboids, prisms and Froebel's Gift No 6)? Are these constructions in line with their verbal explanations?

- What kind of cuboids and cubes do they construct and which variations occur? Do they possess particular approaches in their activities?
- How can we interrelate these results to the Van Hiele framework and is there a necessity to enrich the *Model of Development of Conceptual Knowledge*?

We analyse the conceptual understanding, strategies and reasoning of Year 3, 4 and 5 children when observing and video-taping their construction activities of 3-D solids (cuboids and cubes) with wooden blocks. In a first step, German and Malaysian children were asked to explain their ideas and knowledge of geometrical solids in a short dialogue with the interviewer. Afterwards, a variety of tasks invited them to express their knowledge of cuboids and cubes via construction activities. During their constructions children were encouraged to describe their strategies. Data was coded with software support by *Atlas.ti*. A coding-guideline was developed mainly according to *Grounded Theory Methods* (Corbin & Strauss, 2015), trying to detect facets of articulating children's conceptual knowledge of geometrical solids and to relate our first results with the Van Hiele framework (Van Hiele, 1986).

Our results show an impressive variety of different types of constructed cuboids and cubes and of individual approaches, which indicate a wide variety in children's geometrical concept knowledge of the selected solids. Relating to cubes, most children focus on a square-base area during their constructions, some German and Malaysian third-graders only built one quadratic layer and name this a *cube*. Furthermore, we detected ambiguous mental images in children's concept knowledge concerning cubes. Relating to cuboids, our results illustrate the existence of prototypical representatives, e.g. convex constructions with various layers, followed by constructions only consisting of one layer. Furthermore, children's constructive activities can be (partly) interrelated to the Van Hiele framework, most children are at level of *Visualization* ("It's a cube because it looks like a cube."), resp. *Analysis* ("It's a cube because all surfaces are the same."). None of the children are in the phase of transition from *Analysis* to *Abstraction*, all children Year 3, 4 and 5 faced difficulties in realizing relationships between a cube and a cuboid.

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