Development of a Multiple Choice-test on Newtonian Mechanics for the lower secondary level

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Abstract. As part of a broader project on students understanding of Newtonian mechanics, a new test-instrument on two-dimensional motion with 36 items has been developed. The instrument probes students understanding on speed, velocity, change of velocity, the relationship between force and motion and the 3rd Newton Law. The test is administered to 140 lower secondary school students aged 12-14 in Austria. Data analyses is done with the WINSTEPS software for Rasch analysis. Test development process and results will be presented on the poster.

Introduction

Previous research indicates widespread difficulties among students of all levels in mechanics, including a lack of distinction between speed, velocity and acceleration and an inability to correctly interpret forces and identify inertia [1]. Physics education researchers have thus far provided teachers with various teaching concepts aimed at addressing these difficulties. One such concept for the 7th grade (the 2DD-concept) was developed in Germany in the last decades. [2] It concentrates on two-dimensional motion and entirely omits the term "acceleration." The new middle-school curriculum in Austria also emphasizes teaching two-dimensional motion and advocates for digitalization in schools, necessitating adjustments to the 2DD- concept. To evaluate the effectiveness of this approach, a new conceptual instrument is required.

A literature review highlights various evaluation tools focusing on mechanics, such as the *Force Concept Inventory (FCI)* [1] and its variations (*Half-FCI* [3], *Animated FCI* [4], *Representational Variant of the FCI* [5] and *Gender-FCI* [6]), utilized to identify alternative ideas in mechanics among college and high school students. The *Simplified-FCI* [7] is unique, as its adapted language allows it to be applied to middle school students. Another tool, the *Mechanics Base Line-Test (MBT)* [8], is recommended for high school and college students focusing on kinematics, energy, forces and momentum, similar to the *Force and Motion Conceptual Evaluation* [9], which was developed in 1998 and revised several times since. Additional university-level assessment instruments for mechanics include the *Force, Velocity and Acceleration-Test* [10], the *Mechanics Diagnostic Test* [11] and the *Inventory of Basic Conceptions-Mechanics* [12].

Research goals

As can be observed, numerous instruments exist for testing mechanics understanding at high school and university levels, but a research gap exists for middle-school students. Additionally, the new tool should cover basic two-dimensional motions. The primary research objective for this segment of the study is to develop an instrument for assessing conceptual understanding of mechanics at the lower secondary school level. The central research questions are: Can a new instrument identify the established difficulties students have with mechanics, and can the developed questions establish a stable construct?

Research design and methods

In the initial phase of the developing process, the research group defined and discussed learning goals for lower secondary school students, concentrating on Newtonian mechanics. Based on previous research and existing instruments, a new tool was developed. It covers: description of motion, concepts of speed, velocity and change of velocity, the relationship between force and motion and the 3rd Newton law. Fig. 1 shows an exemplary item.

Item 13: Your friend claims: „As long as all cars on the motorway are travelling with the same velocity the entire time, no accidents can occur, regardless of the speed limit.“ Is this statement true/not true and why/why not?			
◯ No, because even though cars are travelling in the same direction, cars with higher speed can collide with slower cars.	◯ Yes, because same velocity means that all cars drive in the same direction and the distance between them remains the same for the whole time.	◯ No, because moving with a higher velocity increases the probability of accidents.	◯ Yes, because the probability of an accident does not depend on velocity, but on the driver´s attentiveness.

Figure 1: Example of an item from the new instrument

The instrument has been administrated to 140 seventh grade students from Austrian middle and lower secondary schools (“Gymnasien”). All students had previously had approx. 20 teaching periods of instructions on mechanics. The data was analysed with the WINSTEPS software [13] for Rasch modelling in order to obtain linear measures for item difficulties and to check if the new instrument builds the stable construct.

Results and conclusion

The test analysis is still ongoing. Therefore, the results will be presented on the poster at the conference.

References

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