Network analysis to discover and characterise student responses to a conceptual survey about refraction

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Abstract. Students have been shown to make use of heuristics that may or may not be aligned with physics, when responding to conceptual tasks. This study analyses student responses (N=1368) to a conceptual survey about refraction. We use network analysis to identify 33 groups of similar responding students. We couple groups' responses to previously identified heuristics, and compare these to contextual data: Course, university, country, and physics enrolment. We find that groups show differential and nuanced patterns with regards to both responses and contextual data. This study argues that teaching of refraction should take these heterogeneities into account as possible outcomes.

Introduction

Student responses to conceptual surveys have been used to find gauge and classify student understanding of various areas of physics [eg., 1,2] . However, systematic, and large-scale studies that show differential patterns in student responses to conceptual surveys based on course and cultural contexts have not been made. Such differential patterns might provide information about how different courses, institutional contexts and cultural contexts are reflected in the understanding that underpin student responses. This study attends to this gap for the case of a conceptual questionnaire about refraction and apparent depth.

Theoretical framework, research and research questions, original aspects

The ability to interpret and use representational forms in physics appropriately and effectively in physics can be seen as a crucial aspect of learning physics [2]. At the same time, students have been shown to make use of heuristics that may or may not be aligned with physics, when responding to conceptual tasks [3]. A recent study identified three different heuristics related to refraction and apparent depth [see 2 for details]. Heuristics may be used to characterise subgroups in the student population. Students might make use of heuristic in different ways depending on the course they attended as well as the cultural and academic contexts in which students are embedded. Such tendencies can be investigated by identifying groups based on how similarly students respond [4]. This method allows us to capture nuanced patterns and connect them to both demographics and heuristics. Research question: Which groups of similarly answering students can be identified a set of conceptual responses, and how may groups be characterized in terms of heuristics , courses, cultural, and academic contexts?

Methods and findings

We made use of a previously collected and published conceptual questionnaire data within the subject of refraction [2]. The data set consists of responses from 1368 students from 22 different courses at 13 different universities in seven different countries.
We then followed [4] to construct a network of similarly responding students to identify groups in that network. We calculated the load of each identified similarity group on each heuristic

identified in [2] as the percentage of responses that fell within belonging to the heuristic (accouting also for responses that fell outside any heuristic). We tested each group for whether they displayed an overrepresentation [4] of students in terms of courses, universities, and countries. Furthermore, we coded and tested for physics instruction received based on student enrolment and year. All calculations were done in R [5]. We consistently find 33 similarity groups with a mean number of students of 41 (SD = 16). Groups load differentially on heuristics and display different patterns in overrepresentation. Here we focus on analysis of a 2 groups, as illustrated in Table 1.

Table 1. Characteristics of 2 of 33 groups identified in this study. Z-scores quantify overrepresentation relative to random expectation (tested via n=1000 permutations). Colors highlight significant loads and overrepresentations.

		Survey responses – load on identified heuristics				Overrepresentation (Z-scores)			
#	N	Heuristic 1	Heuristic 2	Heuristic 3	Other	Course	University	Country	Physics level
1	42	0.43	0.24	0.24	0.08	0.70	0.54	0.21	0.94
2	32	0.09	0.11	0.04	0.74	4.82	6.31	2.47	-0.50

Group 1 in Table 1 shows a preference for *Heuristic 1* but no pattern in overrepresentation. This group may then represent understandings of refraction that could be found in many cultural and academic contexts. Group 2 shows (as the only group of the 33) a high load on *Other responses* and a significant level of overrepresentation per course, university and country. This suggests that contexts *may* play a role for these students' responses and could be scrutinized further. We argue that teaching of refraction should take these results into account to design teaching that may help students develop their abilities in the cultural and academic context in which they are embedded.

Conclusion

Using network analysis to create a network of similar student responses, we were able to identify 33 distinct similarity groups that display differential response patterns and characteristics. These groups could be characterized via their load on previously identified heuristics as well as their displayed level of overrepresentation with regards to course, university, country and physics level.

References

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