Physics of the Earth in introductory geosciences: an exploration of interdisciplinarity

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Abstract. Topics from physics occur frequently in the geosciences and are among those reported to cause students most difficulty. One topic that uses physics in a Earth setting is isostasy that accounts for many Earth features as the interplay of elasticity and buoyancy of the Earth's outer mechanical layer (the lithosphere). We explore the presentation of isostasy in introductory undergraduate geosciences textbooks and use a framework for interdisciplinary reasoning and communication to analyse the demands made on students. Presentations are highly variable and often complex; the buoyancy-only model is emphasised and a prior knowledge of hydrostatics typically assumed.

Introduction

Interdisciplinarity has received much attention and popularity in university education. However, while much emphasis has been placed on the promises of interdisciplinarity for solving complex and so-called 'wicked' problems, the process of interdisciplinary working has been relatively little studied. Geosciences is inherently interdisciplinary, making use of topics from other science disciplines, particularly physics and chemistry, and provides an established discipline in which to explore interdisciplinarity.

Physics topics in geosciences education: the example of isostasy

Topics involving material from other science disciplines are seen as particularly difficulty for geosciences students [1]. A disproportional number of physics- and chemistry- based questions in the Geosciences Concept Inventory showed low gain in matched pre- and post-test questions, but with low switching rates compared to low-gain geosciences questions, which has been interpreted as reflecting conceptual entrenchment [2]. Despite these reported difficulties, and the importance of physics and chemistry knowledge for geosciences, there has been little exploration of *why* these topics are difficult.

Isostasy originates from the proposal that gravitational anomalies in Northern India could be understood if the height of the Himalayan mountains corresponded to a projection of less dense rock into the denser underlying mantle, a situation analogous to a log floating in water [3]. Extending this reasoning leads to the explanation of large scale topography and bathymetry on the basis of the physics topic of buoyancy (hydrostatics), with elevations reflecting thickness and density variations. This buoyancy-based model is found in introductory geosciences textbooks where we found that presentations had high demands for forwards transfer (using prior physics knowledge in a geosciences context) [4, 5] on the basis of (incorrectly [6, 7]) assumed knowledge of hydrostatics.

However, the buoyancy model of isostasy presented in introductory textbooks does not reflect the modern understanding of a flexure *plus* buoyancy model [8, 9]. The flexural model of isostasy explains a number of important Earth features and behaviours, for example post-glacial adjustment in Northern Europe and North America [9]. The rising of previously depressed regions (e.g. the Baltic Sea and Gulf of Bothnia are becoming shallower) is relatively well known and can be understood on the basis of a buoyancy model of isostasy. However, the flexural model is necessary to explain the corresponding 'sinking' of the non-glaciated region that includes the Netherlands which bulged upwards when Scandinavia was ice covered.

Considering that the mathematical description of the flexure model is not likely to be accessible to the majority of students taking introductory geosciences courses at university, the importance of establishing an accurate conceptual understanding becomes apparent. The elasticity of rocks is a vital element in for the flexure of the lithosphere, but is another example where students struggle with physics in a geoscientific context [10].

Conclusions

While focused within on a single topic, our approach indicates the usefulness of the Interdisciplinary Reasoning and Communication framework [4] and highlights the geosciences as a field in which interdisciplinarity may be explored. Moreover, areas of geosciences (e.g. meteorology) can be summarised as 'geophysical fluid dynamics applied to [*context*],' but fluid mechanics is one of the areas most likely to be omitted from introductory physics courses [6, 7]. This problematises the relevance of traditional introductory physics (mechanics) courses for subjects such as geosciences where continuum mechanics is the most relevant area of physics.

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