Addressing Misconceptions in Buoyancy Through Inquiry and Experimentation

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This study addresses persistent misconceptions about buoyancy, a key concept in fluid dynamics, through the development of an inquiry-based learning module as part of the "Vigyan Pratibha" initiative. Misconceptions, such as buoyancy being solely dependent on the weight or volume of the object have been reported in the literature. To address these, a hands-on, inquiry-driven learning module was developed which allows students to recognise multiple physical factors of the object and medium affecting buoyancy. The module, tested iteratively in classrooms emphasises experimentation, scaffolded tasks, and conceptual reflection on buoyancy principles.

Keywords: Buoyancy, Sink and Float, Physics, Misconceptions, Conceptual Change, Vigyan Pratibha, School Education

Introduction and Theoretical Framework

The concept of buoyant force is fundamental to understanding fluid dynamics and has practical implications in fields ranging from engineering to everyday phenomena, such as why objects float or sink. Despite its importance, buoyancy is one of the most misunderstood topics in physics, with persistent misconceptions observed among both students and educators. Misconceptions, such as buoyancy being solely dependent on weight or hollowness, or being considered an "anti-gravity" force, have been well documented in the literature (Buteler & Coleoni, 2000; Kallery, 2000; Unal, 2008). These misunderstandings often stem from oversimplified textbook explanations and a lack of inquiry-based learning opportunities that allow for deep exploration of core scientific principles (Kallery, 2000). In this study, we present the journey of development of the learning module informed by textbook analysis, classroom trials, teacher workshop trials, and preliminary data analysis of students' worksheets.

Key misconceptions about buoyancy, floating, and sinking include the belief that heavy objects sink and the light ones float (Kallery, 2000), that buoyancy exists only when an object is floating (Buteler & Coleoni, 2000), and that volume alone determines whether something floats (Unal, 2008). Some students think air inside an object makes it float and that the liquid's properties don't affect buoyancy (Harrell et al., 2022). Additionally, buoyancy is often misunderstood as an intrinsic property of objects rather than a force from displaced fluid (ibid.).

Textbook Analysis

Initially, we did a critical analysis of the NCERT textbook. The topic of buoyancy is included in the class 9 science textbook at the end of the "Gravitation" chapter. We looked at both the general text on the concept and summative and formative questions in the text. In the NCERT textbook, buoyancy is introduced *"as the upward force exerted by a fluid on an object, which counteracts the object's weight"*. The text explains this through examples like floating corks and sinking nails but lacks opportunities for students to relate in these explanations with buoyancy, density and how they are mutually related. The abrupt transitions between terms like buoyancy and density can lead to confusion without proper elaboration or experimental reinforcement. In another example, the textbook prompts students to think about the nature of the buoyant forces and how it can be explained with Archimedes' principle. This is done without introducing hands-on activity or visual representation which may risk leaving students with an abstract understanding.

Development of the Learning Module

The learning module was developed iteratively, undergoing multiple rounds of discussions, testing and modification based on feedback from classroom visits and teacher workshops. A few highlights of the module are mentioned herewith: Throughout the module, students are encouraged to explore the relationship between buoyancy force, object properties (e.g., weight, volume), and fluid properties (e.g., saltwater vs freshwater). For example, one of the questions in the module asks students to identify the forces acting on an object underwater by drawing diagrams, encouraging them to visualise the forces involved and better connect to the concept. Similarly, Q12 (see Fig. 1) further pushes students to explore the relation between the weights of the objects in the air and underwater, fostering critical thinking about how buoyancy works.

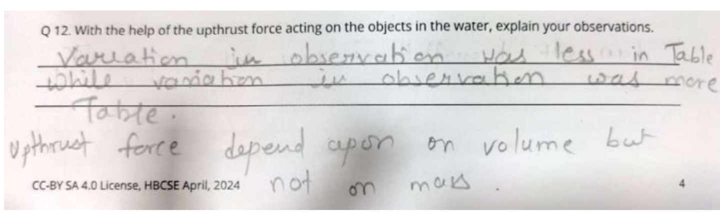
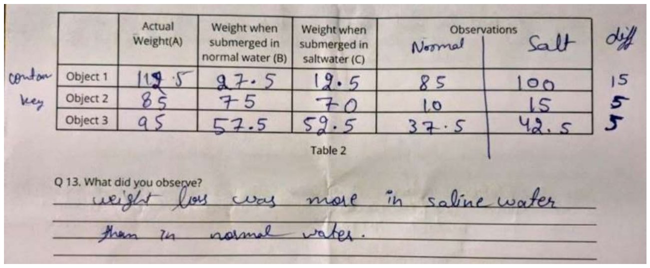


Fig. 1. Example response to question Q.12 from the learning module.

By looking at the response to Q12, we note that students relate their experimental observations (volume -- buoyancy dependency) and comment about the buoyancy force. The learning tasks build progressively, introducing basic concepts [e.g., forces in Task 1 (check the students concept regarding the nature and direction of forces on an object underwater)] before moving to more complex relationships between object properties and buoyancy [e.g., Task 2 (experiment to check the dependency of weight on buoyancy), Task 3 (experiment to check the dependency of volume on buoyancy) & Task 4 (experiment to check the dependency of buoyancy on density of the medium, see Fig. 2)]. Task 2 and 3 engage students in measuring and observing how weight and volume impact buoyancy force. This promotes an exploratory approach where students investigate scientific principles and build a relation between weight/ volume of the object and the buoyancy force. Task 4's investigation into the difference between saltwater and freshwater highlights how students learn through experimentation with real-world examples. This scaffolding allows students with different levels of prior knowledge to gradually build their understanding.



	Actual Weight(A)	Weight when submerged in normal water (B)	Weight when submerged in saltwater (C)	Observations Normal	Salt	diff
Object 1	112.5	27.5	12.5	85	100	15
Object 2	85	75	70	10	15	5
Object 3	95	57.5	52.5	37.5	42.5	5

Table 2

Q 13. What did you observe?
weight loss was more in saline water than in normal water.

Fig. 2. Observation table and follow-up question for Task 4, in this task weight of an object is compared in two mediums of different densities, checking the dependency of buoyancy on the density of the liquid.

As seen by the response in Fig. 2, the student has advanced to address complex scenarios, comparing buoyancy forces in two different situations and predicting where the force is greater. The student is also testing how the density of the fluid affects the buoyancy force on an object. Overall, we feel that the module emphasises student agency, allowing them to draw conclusions from their own experiments.

Future Work

In future work, we aim to expand the analysis to include content from both formal and informal Indian textbooks to understand how concepts of pressure, force, weight, volume, density and buoyancy force are discussed in these resources. Additionally, we will conduct extensive trials of our learning module presented above in selected schools to assess its impact. We will conduct focused group discussions with students to explore their prior knowledge, motivation, and post-intervention learning experiences. Feedback from teachers and administrators will be sought to evaluate the module's feasibility and identify potential limitations.

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