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Closing the Gap: looking into scientific literacy for early childhood education

Noraini Abbas

Abstract
Many educational and cognitive theorists believe that attempts to teach young children scientific knowledge is doomed to failure as they have not reached the Piagetian developmental stage of formal operational thinking. I argue that this is not the case. Children can learn basic scientific concepts and models if they are given appropriate, well-designed instruction. Furthermore, scientific concepts are a good domain for teaching young children about the nature of scientific knowledge. This paper describes an approach that enables children, aged between three to four years olds, to develop a conceptual model that embodies the principles underlying floating, and to apply their model in making predictions, solving problems and generating explanations in their own way. The objective of this study is to enable young children to construct a series of increasingly sophisticated models for reasoning on the topic of buoyancy. This approach is an integration of several instructional strategies and it is linked to other subjects such as English, Mathematics and Art. Findings from this study will be useful in providing a range of effective instructional tools such as the conceptual change approach, to raise young children’s scientific understandings to a higher level. Furthermore, it could also close the disparaging gap between the different entry points of children’s scientific knowledge upon entering primary schools.

1. Introduction
Research on early learning suggests that the process of making sense of the world begins at a very young age. Children begin in preschool years to develop sophisticated understanding (whether accurate or not) of the phenomena around them (Wellman, 1990). Those initial understandings can have a powerful effect on the integration of new concepts and information. Unfortunately, science education is seldom included as a strong priority for the development of the child. Neither is science seen as one of the natural vehicles for the development of language, social communication, and exploring the environment. Matters are further aggravated as the early childhood educators have a tendency to take higher-level thinking skills for granted as they assumed that their students are too young to reach the higher level stages of thinking. This is certainly untrue. However, these educators do need to craft their activities well enough to provide proper scaffolding for the young children. These children are only beginning to develop their higher level thinking skills, so they do need an ongoing feedback structure in order to succeed.

This study is set with the goal to instill a sense of competence in young children by empowering them with the knowledge and skills through the use of science. Science education for young children is intended to support children’s natural curiosity about the world and to strengthen their reasoning abilities.

2. Objective
This study aims to explore a model that fosters science learning through systematic approach to understand language at increasingly higher levels of abstraction. It intends to use an adapted version of the mediated learning experience to scaffold the science learning environment of twelve children, between the age of 3 and 4. It intends to provide an example in the local context, of a workable program for developing science knowledge and language skills with young children that incorporates both explicit teacher-directed methods and exploratory, teacher-facilitated method.

3. Background and justification
In the recent years, socio cultural theory has provided an important conceptual tool for rethinking early childhood education (Anning, Cullen & Fleer, 2004; Edwards, 2003). It was once perceived that an individual as a “natural” agency of learning. Now, this position becomes increasingly challenged on both theoretical and practical grounds.

Two theories have contributed to the development of the mediational approach to learning. They are the Vygotskian sociocultural theory and Feuerstein’s theory of Mediated Learning Experience (MLE). MLE is not mere free play. It is defined as a quality of interaction between the learner and the world of stimuli the learner is coping.
Lately, a broad consensus has been achieved on certain principles that can guide the design of learning environment. Most researchers seem to agree that the support of active learning and the guidance of students towards the acquisition of self-regulated processes are important characteristics of powerful learning environments. Another principle that is widely agreed upon is the importance of having educational tasks that students find relevant and meaningful. Since learning is not an individual but a social affair, researchers usually agree that teachers should encourage collaborative learning in the classroom. Although these principles are necessary to be taken into consideration when designing learning environments, they are not sufficient by themselves. The body of knowledge that constitutes current science contradicts basic presuppositions of our intuitive knowledge about the physical world and requires radical conceptual change to be understood. In order to promote conceptual change in science, particular attention needs to be paid to the design of research-based, developmentally appropriate curricular, and the enhancement of meta-conceptual awareness and intentional (purposeful and goal-directed learning).

How does poor mediation relate to learning problems?

Some of the differences in the children’s capacity to benefit from new experiences are linked to the type of interactions they have had with the adults who cared for them. Children who lack mediation, are not tuned to detect fine differences between various things they perceive through their senses. Some grow up to be uninterested, apathetic and uninvolved. They do not search for meaning and seldom make comparisons between experiences. Many of these children do not see a need to express themselves verbally or communicate in a way that will be clearly understood by others. Lacking the experiences in which someone relates events to them or points out information about objects or people beyond what can be perceived directly thorough their senses. These children are not aware that something meaningful may be obtained through questioning or exploration. Most of these behaviours have been identified by Feuerestein (1979, 1980) as deficient cognitive processes related to poor mediation skills. Children who have these limitations may be considered as lacking flexibility of mind or as having difficulties in benefiting from new experiences.

Feuerstein (1980) claims that an insufficient amount or an inadequate type of parental or school-based teaching is responsible for the reduced learning potential of some individuals. MLE-deprived students can be classified as underachievers, learning disabled or even mentally retarded. MLE is thus capable of reversing the gap created due to children’s socio-economic background and significantly enhance their individual learning potential in science.

MLE is also a form of deliberate practice whereby the mediator uses many research-based instructional techniques such as bridging, making children’s thinking visible and facilitating students ability to restructure their own knowledge. It helps children know the world better by organizing materials so that young children can explore, question, reason and discover answers through their own physical and mental activities.

Therefore, science education for early childhood, can ‘bridge the gap’ by providing experiences that can modify the brains’ neural networks. It is most effective in laying down patterns for effective thinking skills early in childhood.

Social intervention in learning

An important aspect of social constructivism is the Zone of Proximal Development (ZPD). ZPD is defined as the difference between what the student can achieve alone and what the student can achieve with the help of social intervention (Galbraith and Goos, 2003) such as teachers, peers, parents or worked examples (Roschelle et al., 2000). Not only can people serve as guides or mediators to children’s learning, so too can powerful tools and cultural artifacts, notably television, books, videos, and technological devices of many kinds (Wright and Huston, 1995).

If the student on his/her own cannot solve the problem, the difficulty can be overcome with social intervention of a more experienced partner. As learning takes place, the individual capacity increases, his or her ZPD decreases due to increased practice. Hence, the main purpose of instruction is to scaffold the ZPD. Structuring the concepts into sub-concepts that leads to a “big picture” is an effective strategy to learn science for young children. Vygotsky’s scaffolding approach can yield optimal and optimistic estimates of children’s learning potential only if the learning potential
is realized. These predictions are doomed to failure if nothing is done to bring out the hidden potential of the child.

Individuals participating in peer collaboration or guided teacher instruction should be on different developmental levels. Collaborative work promotes bridging the ZPD when the students with mixed abilities are grouped together. Learning science would then mean learning to use the language of science through opportunities to practice the talking, reading and writing of science (Wilson and Mc Meniman, 1992). There are various ways to scaffold the proximal development. Problem simplification is one of the ways to do so. It includes structuring the problem into general cognitive processes such as the Bloom’s taxonomy. Structured questions help simplify complex problems, thus the ZPD in each question is smaller than the ZPD of the main problem. Providing clues with such supportive content knowledge helps activate relative knowledge that leads to significant positive effect.

Why teach young children science when they have not developed their language acquisition and mathematical concepts?

Teaching with subject integration in mind, is a productive way to make learning relevant and meaningful for children (Charlesworth & Lind, 2003; Harlan & Rivkin, 2004; Martin, 2003). The human brain seeks meaningful connections when presented with new information. Current knowledge of brain development strongly supports curriculum integration. Research supports the use of an integrated curriculum and instructional techniques that involve social interaction for children to achieve higher levels of thinking (Kellough et al. 1996).

This adapted MLE approach to learning actually emphasizes the “how” to find answers (habits of mind), as well as “what” can be learned. When science experiences are seen as part of the child’s continuous search for knowledge, it makes good sense to support and enable that search in the classroom by:

- Directing children’s involvement to organized materials.
- Providing a means of focusing the attention of the child.
- Adopting an integrated curriculum approach where language learning and content are integrated.
- Helping children to gradually replace their intuitive explanations to scientifically accepted ones.

4. Methodology

The Action Research methodology was adopted for this study. The cycle of Plan-Act-Observe-Reflect activities was adhered to. A case study approach was chosen, using action research as a way to examine this study systematically and carefully.

Data was collected through a reflective journal, audio and video recordings of students interviews during the duration of this study.

Design of study

This study was carried out in a neighbourhood childcare located at Chua Chu Kang, located at the northern part of Singapore. One of the nursery two class has been identified for this study because relatively little classroom-based research has been conducted for children of this age group. The pre-school level was selected because it provided an opportunity to investigate:

(a) children’s initial science understandings prior to extensive formal schooling.

(b) emerging literacy abilities of very young children in context of their developing science understanding

(c) social interactions between peers in the specific context of science experiences.

The children were observed in the course of 14 weeks from late June to early October 2006. The duration of each instructional period and data collection varied depending on the science concepts.

The intervention program described in this study can be characterized as a “design experiment” (Brown, 1992). Design experiments involve working with students, teachers and other members of the community to introduce design innovations and to “trace” learning in relation to each
intervention. As the design experiments develop theory based on practice, they are likely to lead to
the development of designs that are trustworthy, credible, transferable, and valid.

Participants
There were twelve participants from the nursery two class, ranging between three to four
years old. Of these twelve students, 5 were boys while 7 were girls. After an initial 4 weeks of
observation in Phase 1 and 10 weeks of implementation of the intervention project in Phase 2.

Selection of materials and activities on the topics related to buoyancy
Learning is not accidental; therefore, planning is a must when selecting activities and
materials. The following criteria were used in selecting and arranging the materials:
(1) Are the materials open-ended?
Water play provides children with the opportunity to explore measuring besides floating and
sinking activities

(2) Are the materials designed for action?
All the materials are available for the children to do the experiment to confirm their prediction

(3) Are the materials arranged to encourage communication among children?
Children either work in pairs or in groups. This encourages collaboration. They are allowed to
assist their friends if their friends require assistance.

(4) Is there a variety of materials? Do the materials encourage prediction?
The sink and float activity invites children to predict. It also creates situation for the child to think
deeper: What will happen if I place this clay ball on the styrofoam board?
What will happen if I placed this ball of clay on this wooden pencil? Would it still float? How do I
make this aluminum foil boat sink?

(5) Do the materials allow for individual differences such as ability, interest, working space, and
style?
After conducting activities related to the general characteristics of floating and sinking, children
began to consider the effects of size and shape on buoyancy. Some objects were purposefully
introduced at certain lessons to attend to misconceptions such as “All big objects sink and small
objects float” or “All metals sink” or “Heavier objects sink while lighter objects tends to float”.
These misconceptions were gathered during the baseline interviews.

(6) How much direction do the materials require?
It is very important to consider the age of the children when giving directions. As the participants
are just three to four-year-olds, personal directions work best for them.

(7) Do the materials emphasize process skills?
Process skills are the fundamental skills that are emphasized in science explorations with young
children. These skills will come naturally from manipulating materials.

Activities should provide children with opportunities to extend their thinking and allow them to
freely interact with their peers and adults. These activities can be introduced to all children as a
group during whole class instruction and then placed in learning centers to allow repeat
experiences. Repetition reinforces children’s awareness of their own competence and the
confidence that awareness brings (Winnett et al., 1996, p.3).

Instructional methods
This research emphasizes the development of children’s language skills through an explicit,
teacher-directed approach and an exploratory, child-centered approach to acquiring science
knowledge. There were two phases involved in this study. The lessons were crafted out after about
four weeks of observation. It was designed based on a few guiding principles. Young children have a
natural tendency to explore. There will definitely be some “science” in children’s current daily playtime
activities. Science education in school unites cognitive development and children’s prior knowledge
and experience with intuitive scientific theories to formulate new ideas. Rather than looking at isolated
science concepts, science for early childhood education is intended to show children the “big picture”
This study also adopts the interactive analytic approach whereby children are encouraged to describe, communicate their ideas as they make sense of their own learning, drawing prior knowledge and asking questions to acquire information.

Developmentally appropriate practices are being adopted in this program. They provide standards for identifying high-quality early childhood education program. Appropriate opportunities for learning are further supported by providing an environment that cultivates receptive and expressive language and cognitive development.

Problem solving is a way of life. Even the youngest of children face problems in their daily activities. Children should be presented with teaching models that require them to demonstrate various characteristics of effective problem-solving skills, methods, and strategies such as persistence, tolerance of ambiguity, use of related knowledge, use of logical reasoning, finding patterns, trial and error, dealing with data, planning a solution, solving a challenge, analyzing and evaluating solutions and working cooperatively.

In the development of process skills, the researcher used checklists to trace the development of conceptual development and process skills as a tool to assist in the process of scaffolding children’s thinking towards a more accurate level of understanding (Rogoff, 1990; Vygotsky, 1991).

Using checklists in dynamic assessment
Checklists can be used in more than one way to monitor and evaluate the children’s understanding in science. Besides using the checklists to evaluate or determine mastery, the researcher used her checklists to gather information to identify the specific stage of development of the concepts in each child and then used this information to plan appropriate materials and learning experiences to scaffold children’s learning in the zone of proximal development. Besides using checklist during the science activities and during interviews, it would be useful to gather information for all children during their free play activities. This would be a better judge of the transfer of knowledge without a need for prompting. During the course of the study, children require prompting. With prompting, transfer of learning can improve quite dramatically (Gick & Holyoak, 1980; Perfetto et al, 1983).

Data collection
Primary data sources for this study included audio and videotaped recordings of both class and small group classroom practice in order to document the social interactions and other reactions during the science activities. All children’s work during the science activities were collected as artifacts of children’s understanding and action. Conversational interviews (Patton, 1990) were conducted with both teachers and children to obtain their interpretation and explanation of spontaneous events that might occur in during the science activities. The researcher also compiled field notes documenting the various observations seen during the period of the study.

Data analysis
Methods of single-and cross-case analytic induction (Patton, 1990) will be used to analyze the data. The researcher attempts to construct a set of categories that allow her to describe individual patterns as well as patterns across cases. Triangulation will be ensured through the use of multiple data sources and methods of data collection, and through the analysis of the data.

5. Findings
This study has revealed some interesting results in the area of language acquisition in science education. It supports previous findings that highlight the need to run through a systematic approach to understanding language at increasingly higher levels.

Not only does language supports the learning of science, science itself supports the environment for language acquisition. Science activities require children to communicate their ideas both verbally and in written form, thus this forces that to acquire the language to do so.

Young children construct better understanding on the complex physics concepts such as buoyancy through active discussion (pole bridging) with an adult acting as a mediator. Pole bridging is
a deliberate attempt by children to verbalize their internal understanding using the appropriate language.

Lemke (1990) demonstrated how content knowledge can be communicated and jointly constructed by teachers and students by introducing the useful concepts of the “thematic pattern”. The most essential element in learning to talk science is mastery of the thematic patterns of each science topics. These patterns of semantic relationship among scientific terms are inter-related. For example, the concept on “buoyancy” has a pattern of meaning expressed through such concepts and expressions as

- Upthrust of water
- Density (Mass & volume)
- Surface tension
- Trapped air helping buoyancy

The process-oriented inquiry method of early childhood science education encourages teaching that fosters children’s construction of their own conceptualization in ways that make sense to them. For this study, we are more concern in the “valid” answers rather than the “right” ones. It is rather impossible to expect 3 to 4 year-old children to understand comprehensively all the factors that work together to enable buoyancy in an object. Children were shown the “big picture” and the unifying concepts leading to the it along with the sub-concepts that scaffold children’s idea of this “big picture”. With this, we saw a distinct improvement in these 3 areas:

(1) They have developed in their ability to provide higher-order explanation to their answers or observations. This reflects that deep learning has taken place.

<table>
<thead>
<tr>
<th>Nature of explanation</th>
<th>Lower-order explanation</th>
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<tbody>
<tr>
<td>Higher-order explanation  (Deep approach of learning)</td>
<td>Vague and non-specific</td>
</tr>
<tr>
<td>Describing unobservable entity</td>
<td>Cannot relate to the cause and effect. Look at it as discreet items/events</td>
</tr>
<tr>
<td>“Air in the glass bottle helps it to float”</td>
<td>Usually given when solicited. Requires much probing and scaffolding to produce a more complete explanation</td>
</tr>
<tr>
<td>Cause and effect relationship</td>
<td></td>
</tr>
<tr>
<td>-“If I put many marbles in this boat, it will sink”</td>
<td></td>
</tr>
<tr>
<td>-“If I put this clay ball on this boat, it can now float”</td>
<td></td>
</tr>
<tr>
<td>-“If I leave this aluminum foil flat, water comes up and it will sink, but if I make it into a bowl, it can float and even carry this clay ball!”</td>
<td></td>
</tr>
<tr>
<td>More detailed and elaborate, incorporating examples, analogies, real-life experiences.</td>
<td></td>
</tr>
<tr>
<td>-“If I take out the cap of this glass bottle, there got bubble, air come out, glass bottle sink”</td>
<td></td>
</tr>
<tr>
<td>-“If I go to the beach, I use the buoy, got hole in buoy, air come out, I cannot float with the buoy anymore, must blow some more, buoy bigger than I can float”</td>
<td></td>
</tr>
<tr>
<td>More forthcoming. (ie. Spontaneously generated requiring little or no prompting)”</td>
<td></td>
</tr>
</tbody>
</table>

(2) They have develop in their ability in making predictions

<table>
<thead>
<tr>
<th>After lessons</th>
<th>Before lessons</th>
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</thead>
<tbody>
<tr>
<td>Tend to give prediction almost spontaneously</td>
<td>Tend to be apprehensive about making prediction as they fear it might be wrong</td>
</tr>
<tr>
<td>All predictions are supported by explanation (explanation might not be the “right” answers but they are “valid” answers as they have a logically reasoning behind it)</td>
<td>Have difficulty supporting their prediction. Done at random.</td>
</tr>
<tr>
<td>T: “What will happen to this object when I release it to the water”</td>
<td></td>
</tr>
<tr>
<td>C: Sink</td>
<td></td>
</tr>
<tr>
<td>T: “Why”</td>
<td></td>
</tr>
<tr>
<td>C: Dunno</td>
<td></td>
</tr>
</tbody>
</table>
They are starting to ask questions that reflect deep level learning (higher-order questions)

<table>
<thead>
<tr>
<th>Asking questions</th>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Deep approach</strong></td>
<td><strong>Surface approach</strong></td>
</tr>
<tr>
<td>- Focus on explanations and causes</td>
<td>- Focus on factual recall of information</td>
</tr>
<tr>
<td>- Willing to make predictions</td>
<td>“This toy, sink or float”</td>
</tr>
<tr>
<td>- Reflect curiosity and puzzlement</td>
<td>“Oh, sink, ok.”</td>
</tr>
<tr>
<td>“This aluminum foil boat floats but this folded one sink. Why?”</td>
<td></td>
</tr>
<tr>
<td>“Her boat float, mine sink. How to make my boat float like hers?”</td>
<td></td>
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6. Problems encountered

Throughout the course of study, the researcher stumbled across several difficulties mainly due to the deficit in language and mathematical logical skills. The table below briefly states the problems encountered.

<table>
<thead>
<tr>
<th>Learning Outcomes</th>
<th>Difficulties encountered</th>
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<tbody>
<tr>
<td>Students experiment to clearly understand the concept of floating and sinking.</td>
<td>Children are still confused with the terms ‘float’ and ‘sink’. Most of them prefer to use their terms to explain the concept by stating ‘on water’ and ‘in water’.</td>
</tr>
<tr>
<td>Students test a variety of items based on size.(same material/same shape)</td>
<td>Children lack the concept of size. Although they know what is big or small, they tend to relate increasing mass to increasing size. (Children tend to predict that the ping pong will sink because it is larger than the marble so it is heavier than the marble) What is heavy, what is light? What does heavier than means?</td>
</tr>
<tr>
<td>Students test a variety of items based on shape.(same material/same size (mass))</td>
<td>Children have great difficulty associating shape to buoyancy. Some could grasp the concept that a boat-like shape tends to float better</td>
</tr>
<tr>
<td>Students test a variety of items based on material.(same material/same size (mass))</td>
<td>Children do not know the different types of materials. Due to time constrain, this concept was removed in the post assessment</td>
</tr>
<tr>
<td>Students learnt the effects of air on buoyancy</td>
<td>Children do not have the concept of air being a matter. They were not even sure what air is. This led to lessons addressing the concepts about air</td>
</tr>
</tbody>
</table>

Gallas (1995) argues that students, together with the teacher, need to move towards “an inclusive kind of talk about science where everyone is allowed the appropriation of a science discourse”. The mediator needed to establish a set of scientific terms that have the same meaning to both the children and the mediator. This is important in order to establish a clear communication and to assist children in their need to verbalize their ideas on the concepts.

As the preschoolers proceed through stages of language development and cognitive growth, they gain skills in acquiring vocabulary, following instructions of increasing complexity and learning about causal relations. Their expressive skills expand to use grammatically appropriate sentences and learn how to exchange ideas, discuss why something happens and ask questions. As these young children expand their vocabulary, they begin to differentiate likeness and differences and to match, discriminate, and categorize objects and events through paired comparisons. As young children gradually refine their visual perception and explore their environment, they learn to sequence events in a logical order. They begin to make association and can compare objects on the basis of different attributes. These abilities lead to higher level skills of planning, making judgments and solving problems.
7. What implication for pre-school practices?

Mixed-age groupings

One of the key features of this intervention program is the opportunity for children to work collaborative, not only with their classmates and the mediator but at times, incidentally, the Kindergarten 2 children who are sharing the same area during free play, give assistance to these young children, thus raising their ZPD. Through the discussions, children acquire their scientific vocabulary in a more meaningful way. As these children mature in their ability to communicate, they will also develop their scientific knowledge on scientific discourse on the topic on buoyancy.

The early childhood educational institutions in Singapore are still giving too much weight to specific age experience. The age at which children begin to contribute activities is strongly related to the social constraint offered by their community (Rogoff, 2003, p17). Development is viewed as the relationship between the child and society, it flourishes within a particular community where cultural diversity exists.

We propose building in structures that encourage collaboration across the different levels. A buddy support system whereby the older children guide the younger children during exploratory activities is one way to encourage collaboration among different age groups.

Talking science

Pole bridging is one type of “talking science” that requires the child to notice what he or she is doing. It requires children to pay attention to phenomena and comment aloud on the process they observed. It encourages observation of detail, classification, reflection and speculation. All these are actually powerful tools that are required to develop higher levels of thinking skills.

When a child does this at a very early age, he lays down discreet neural pathways, connecting language sites with other “poles” within the brain.

The role of teachers as mediators

The importance of the mediator’s role in guiding children’s scientific learning and their ability to sieve “alternative framework” are essential to enable this approach to succeed. The teachers would require to equip themselves with the skills needed by mediators to use the proper scientific language to guide children’s progress in their conceptual understanding and to also use the proper scientific language to guide children’s progress in their conceptual understanding and to also monitor children’s progressive learning sequence to bridge the naive understanding with the mature scientific understanding. In good teaching, there is a great deal of repetition, use of examples, and implicit use of terms and of principles across a variety of context (Lemke, 1990). Teachers must be aware of their role as mediators in a mediated learning experience. Teachers must be available to interact with children, even during free play, as they listen to their conceptions, preconceptions, and misconceptions. Teachers can encourage “talking aloud” about how a child arrived at his or her answer and encourage listening skills as children nearby explain their solutions (Sperry Smith, 2001). Questioning and guidance by teachers can lead children to the next level of learning.

Dealing with linguistic problems

In this study we realized the importance of mediating closely the role of language in the teaching and learning of science. Language acts as a vehicle to communicate scientific ideas. For young children, it is imperative that the mediator communicate to them the difference between the everyday language meanings of certain key words and their scientific meaning or explanation.

Sensitivity to the order of the concepts to be taught

A great deal of attention needs to be given to the sequence in which the concepts were introduced in order to avoid the formation of misconceptions and to overcome existing alternative framework.

8. Conclusions

The use of deep processing strategies is necessary for meaningful learning in science. Reasoning is often messy and difficult for young children. Being young, they are still grappling with nascent ideas in their groping and exploration as they construct meanings, develop conceptual knowledge, and restructure their conceptual frameworks to accommodate new understanding. This is
apparent for activities dealing with the misconceptions on buoyancy. They also need to search for the “right” words or the scientific terms to express or support their answers.

This study also demonstrates the importance of deliberate practice and having mediators to provide feedback for ways of optimizing performance (Minstrell, 1989). If students had simply been given problems to solve on their own, it is highly unlikely that they are able to understand the complexity in the concepts on buoyancy within the short period of time.

References


