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The role of age in constructing, applying theory and responding to cognitive and social challenges: Investigating children's scientific thinking about floating and sinking objects.

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Abstract: The study investigated how children of different ages constructed and applied their theories about floating and sinking objects and evaluated their responses to cognitive and social challenges. This was an experimental study in which the role of age in constructing, applying and responding to cognitive challenges was tested. Focus was on children's scientific thinking about the concepts of floating and sinking objects. The study was informed by Piaget's and Vygotsky's constructivism and social constructivism conceptual frameworks respectively. Basically it was hypothesized that children's cognitive development followed a sequence and that they constructed their understanding of the environment independent of the teacher or an adult. On the other hand, Vygotsky postulated that adults were important for scaffolding and enabling children to reach higher levels of understanding. Children's reasoning was sophisticated and embedded in social interaction while Piaget postulated that learning was an individual activity. Interviews and practical experiments were used to collect data from the two children aged eight and twelve years respectively. Initial predictions showed that the young attributed floating or sinking for more than 80% compared with 40% for adults. After the cognitive challenge only 40% were attributed to weight and material compared with 31%. Common explanations for sinking and floating by the adult were, mass, material and size. Responses to scaffolding challenge revealed the young as sticking to 'heavy', size, compared with the theory of mass and size of the object by the adult. Initial predictions did not show significant differences in the accuracy of predictions between the young and the adult. However, significant differences occurred in their explanations of causes of sinking or floating. The older and more cognitively mature managed to explain floating in a variety and conceptual ways. Both used physical and observable properties but differed in the proportions. Following the cognitive challenge, both found themselves giving broader explanations to justify observations some of which challenged earlier predictions. From the study, it was concluded that age had an influence on cognitive processes but challenges did not alter their original theories while commonsense required an alternate hypothesis. There was consistency in scientific their understanding and thinking about the role of air. Age influenced the role of scaffolding in understanding and reasoning. It was therefore concluded that age determined scientific thinking and reasoning when constructing understanding of the environment. Social interaction helped raise the level of understanding. Cognitive challenge led the participants to change strategy but not the original theory of understanding the environment which involved scientific knowledge and commonsense.
Keywords: cognitive, scaffolding, float, sink, conceptual, constructivism, challenge.

INTRODUCTION

The research problem falls within Piaget's and Vygotsky's constructivism and social constructivism conceptual frameworks respectively. Key issues are: a) cognitive development follows a developmental sequence, b) children constructed own understanding of the environment independently without the a need for a teacher, c) young children depended on concrete and perceptual experience to think and categorize objects while adults used abstract and conceptual understanding, d) proximal, social and cultural tools and interaction were vital for cognitive development, e) Adults were important for scaffolding and enabling children to reach the zone of proximal development (ZPD)-a higher level of understanding, f) social interaction introduced alternative views which caused cognitive conflict in learning thereby forcing cognitive change in problem solving. Knowledge of science constitutes a way of thinking rather than acquisition of facts [1-4].

Children's reasoning was sophisticated and embedded in social interaction hence the need to present tasks in a manner that made human sense[5]. Piaget conceptualized learning as an individualized activity and played down the teacher and cultural tools like language. Vygotsky was also criticized for according the teacher a dominant role yet help was contingent [6, 3].

Learning science is concerned with consistency and rules to explain experiences hence outcomes inconsistent with rules were rejected. Reasoning was based on abstract aspects of the world such as mass. Real life was dominated by common sense hence alternative solutions were sought whenever observations were inconsistent with expectations. For example, 'heavy things sink'. If they floated, cognitive conflict occurred and an alternative explanation (hypothesis) sought without discarding the original theory. This is cognitive change that can be facilitated by the child's own actions and interaction with others. Significant others help to sustain scientific thinking and reasoning to some logical conclusion [1-13].

With maturity children think in abstract terms such as proportions-'heavier than water,' 'floats if there is more air 'etc. Success depends on well developed cognitive structures which receive and store the experiences for later use [10].

In view of the above, the study investigated the question: *'Is there a difference in ways children of different ages constructed and applied theories about floating and sinking objects, and responded to cognitive challenges?'*

METHODOLOGY

Design: Interviews and practical experiments.

Participants: Two children aged 8 and 12 years, an investigator, classroom assistant, film producer, two camera operators and sound recorder.

Materials and apparatus: A camera, sound recorders, eighteen objects (floaters and sinkers), bowl of water and balance scale and data sheets.

Aim: The study investigated how children of different ages constructed and applied their theories about floating and sinking objects and evaluated their responses to cognitive and social challenges.

Ethical issues

Participants' parents signed consent forms authorising their participation**,** and use of the video recording in the course. Participants could withdraw from the investigation at any point. Age and first names were the only personal information collected to maintain anonymity of the investigation. Participants were put at ease at the beginning.

Procedure

The investigation was organized in three parts.

Part A: assessed participants' initial understanding of light objects that floated (ball, wood, birthday candle, pencil) and heavy objects (spanner, baked beans, rock, skimmed milk) that sank. Predictions were tested by placing objects in a bowl of water and explained.

Part B: assessed participants' understanding of five light objects (tin lid, needle, penny, eraser, rubber band) that sank and five heavy objects (grapefruit, wood, painted wood, red and white big candles) that floated. Predictions were tested and cognitive challenges were presented to test their thinking. They explained why objects sank or floated.

Part C: developed children's understanding in general about the concepts of floating and sinking, with special reference to inconsistencies, ratios and relationships. A balance scale was used to develop the concept of proportions by comparing weights and sizes, and to illustrate the principle of floating and sinking conceptually in relation to mass. Two tins made of the same material, same shape but different sizes were used. The same amount of lintels (familiar food) was put in each. Participants explained their observations and also gave a general explanation why objects sank or floated.

Participants worked with the same investigator but questions to the older child were clearer and systematic but rather haphazard and confusing for the younger child.

Participants' predictions and explanations were tabulated and coded (See Appendices 1 & 2), analysed separately (See Tables 1 & 2) to answer the hypothesis: There were no significant differences in ways young and older children thought and reasoned about their observations, and responses to cognitive challenges. Coding was difficult.

RESULTS

Initial predictions and explanations

The younger participant used weight and material to predict and categorize the first eight objects as floaters or sinkers for more than 80% of them compared with 40% by the older. The words 'heavy' and 'light' were used repeatedly to explain why objects floated or sank. For example, grapefruit…'feels heavy', rubber band '…lighter.', button'…lighter..' (See Appendix 1). The older used a variety of factors to explain. (For example, ball floats because it has air inside (2.25), wood is quite light, birthday candle is quite small, thin and light, spanner has more mass, rock sinks because it is very heavy, large wood block floats because it's made of wood and boats do not sink.' Grapefruit presented problems. Method of presentation for tin lid, button and rubber band determined whether they would sink or float for both. (See Appendix 2 The younger concluded that floating objects were light while heavy ones sank while the older attributed floating and sinking to mass, weight, air and material.

Explanations after cognitive challenge

For the younger participant, weight, and material explained about 40% of the floating and sinking objects, a much lower percentage than the initial prediction. Reasons such as mass, hole, size and presentation method were also given. For example, if dropped lid, button and rubber band would sink. (See Table 1) She had problems explaining grapefruit floating when it felt heavy. Floating was attributed to air and juice inside it.

The older participant gave more reasons for floating or sinking using previous knowledge. The percentage explained by weight declined from about 40% to 31%. Floating and sinking were explained by mass of objects in relation to water. Overall conclusion was that floaters had less mass while sinkers had more mass. (See Table 2).

Response to scaffolding:

Both participants were led through systematic thinking and reasoning by questions and demonstrations. Questions for the young were confusing at times and clearer for the older. However, the younger maintained the theory that heavy objects sank. She referred to heavy objects as having something in them that is, 'together or quashed' (compact or dense). Material in floaters was 'spread out/separated and less content' (33.53). Size was also referred to-'big, heavy and sank' while small sank as well if contents were packed. The older participant maintained theory of mass and demonstrated understanding of the relationship between mass and size of object. Her conclusion was that 'an object does not have to be lighter or less heavy to float or sink.' (30.30).

DISCUSSION

The results have demonstrated no significant difference in the accuracy of initial predictions between the young and the older participant. However, significant differences were noted in the way they explained the causes of sinking or floating. The younger attributed an overwhelming 86% to weight and material: 'light things float'; 'heavier things…sink,' (4.45) compared with a mere 44% for the older. The older participant's more mature cognitive development enabled her to explain floating in more varied and conceptual ways; '…are less dense than water'. (2.40). Both used physical and observable properties in their explanations (weight, material, size) but differed in proportions in support of literature on developmental sequence [1-3,10].

Following cognitive challenges, both found themselves giving more reasons to justify their observations some of which challenged earlier predictions-light needle and penny sinking or a heavy grapefruit floating. Both maintained the concept of weight to explain sinking and floating respectively but also managed to think of other qualities to explain their observations. For example, the material from which an object was made. 'Needle is made of metal, metals sink'; penny is solid and is made of metal, wooden objects float (20.14, 19.28, 17.57). Responses demonstrated that the participants had raised their level of thinking and reasoning to conceptual or more abstract in support of literature on cognitive change in the face of cognitive conflict which led to change of hypothesis [6, 3,11]. Reference was also made to past experience, penny sinks in coke, I have seen it before…'(12.47); 'grapefruit floats …has got a liquid…(14.04); '…less mass than water'(15.35) in agreement with Selley [10] on use of evidence from varied sources as one grows older. The younger participant concluded that floaters were lighter and sinkers heavier. The older participant concluded that floaters were lighter and less dense or had less mass while sinkers had more mass than water. Conclusions showed that the younger was still thinking in concrete terms while the older was thinking and reasoning in both concrete and conceptual terms but still maintaining their original theories and that common sense demanded an alternative hypothesis instead of discarding it when faced with a one challenging theirs[3,8]. This agrees with Piaget's and Vygotsky's developmental sequence in the theory of cognitive development. Responses demonstrated consistency in their scientific understanding and thinking about air namely, presence of air makes objects float and absence makes them sink.

During the scaffolding scale activity, the young improved understanding and reasoning through interaction with the investigator. She demonstrated understanding of density in relation to air. She referred to density by using terms like, 'spread out/not together-more air' (less dense) hence floated; 'put together/quashed' (high density) hence sank. The response alluded to density when she said, 'there is something in it…' Language appeared to be a handicap. The older participant responded to scaffolding by demonstrating conceptual understanding of causes of floating and sinking by referring to the relationship between the mass of the object and that of water or air and the distinction between weight and mass when she said; '…it wasn't the weight that matters…it was the mass of it,(9.07). 'Mass …is how much inside. Weight is how heavy…'(14.57). 'Don't have to be lighter or less heavy to float or sink…'(30.30). The relationship between mass and size was also highlighted when she said, 'size matters.'(30.41). This summarizes her understanding of heavy floaters and light sinkers. The challenge helped to open up the children's minds enabling them to reach what Vygotsky[4] called zone of proximal development [4,3,7,11, 8].

The investigator planned and used cultural tools (objects, bowl of water, experiments, questions) and guided the participants to improve their understanding, thinking and reasoning about concepts of floating and sinking which they could not reach independently. The older found the leading questions helpful enabling her to unlock her understanding about floating or sinking objects. The younger found some of the questions confusing and at one point said, '…you are getting complicated' (25.39) and could not make sense of what she wanted. The scale activity clarified the concepts of mass and density demonstrating the positive role of the adult in making human sense in scaffolding as advanced by [4, 5,3]. Psychological relationship was generally beneficial in their scientific development. Reliability of results was marred by the investigator who behaved differently to the two participants.

CONCLUSION

The study demonstrated that age determined scientific thinking and reasoning when constructing understanding of the environment. Social interaction and cultural tools helped raise the level of understanding. Faced with a cognitive challenge, children changed strategy but not the original theory. Understanding of the environment involved a scientific knowledge and common sense. Further research can be carried out to find out the effect of gender on response to cognitive and social challenges.

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APPENDIX 1

Data Sheet
Participant: Remy Age: 8 Years

Objects	Prediction	Initial Explanation	Causal Codes	Later Explanation Stage 6/7	Causal Codes
Light floaters	Stage 2				
1.Wooden block	F	Quite light	W		
2.Pencil	F	Quite light	W		
3.Small candle	F	Lighter than heavier	W		
4.Ball	F	Really light, tested before	W		
Heavy sinkers					
1.Spanner	F/S	It's a heavy	W		
2.Stone	S	Heavier than baked beans	W		
3.Baked beans	S/F	Heavier if empty	W		
4.Tin lid	F/S	Quite light, volume of water, pushing	W		
Heavy floaters					
1.White candle	F	Light	W	Really light	W
2.Red candle	F	Light	W	Lightness	W
3.Large wooden block	F	It's wooden	W	Weight from water, don't know	W
4.Painted wooden block	F	Quite light	W	Wood floats	W
5.Grapefruit	S	It's heavy	W	Difficult to explain, has air and juice	W/M/A
Light sinkers					
1.Eraser	F	Lighter	W		
2.Needle	S	Too light, water can't hold it, water goes through it.	W/H	metal, metals sink, goes down when dropped, air crowds on it	M/P/A
3.Penny	S/F	Lighter	W	Made of metal, metals sink, heavy and strong	M/W
4.Button	F/S	That's like a penny, plastic sinks	W/M	Made of plastic, plastic sinks	M/W
5.Elastic band	F	Lighter	W	More weight when dropped	W/P
KEY TO CODING:	W=Weight F= Float	H=Hole S=Sink	M=Material	P=Presentation	A=Air

APPENDIX 2
Data Sheet
Participant: Jessica   Age: 12

Objects	Prediction	Initial Explanation	Causal Codes	Later Explanation Stage 6/7	Causal Codes
Light floaters	Stage 2				
1.Wooden block	F	Quite light/Hole	W/H		
2.Pencil	S/F	Has got lead in it,	M/W		
3.Small candle	F	Not much candle, small, thin	M/W/Sz/Sh		
4.Ball	F	Has got air inside	A		
Heavy sinkers					
1.Spanner	S	Heavy, has more mass	W,M		
2.Rock	S	Very heavy	W		
3.Baked beans	S	Has got air/stuff inside, quite heavy, solid inside	A/W/So		
4.Tin lid	F/S	Traps air/no air, like a boat, depends on how you place it	A/P		
Heavy floaters					
1.White candle	F	Light, wax	W	Made of wax like small candle	M/W
2.Red candle	F	Light, wax	W	Made of wax like small candle	M/W
3.Large wooden block	F	Holes, mass, wooden, boats don't sink	W	Floats like other wood	K/E
4.Painted wooden block	F	Heavy	W	Floats like other wood	K/E
5.Grapefruit	F	It's like a ball, floats	W	Less mass than water, Floats like lemons, not solid	W/K/E/So
Light sinkers					
1.Eraser	F/S	It's quite solid, very light	W/So	It's quite solid	W/So
2.Needle	F	Small, has a hole	Sz/H	Very small, made of metal, metals sink	Sz/M
3.Penny	S/F	Have seen it before, sinks in coke,	W	Made of metal, solid	M/W
4.Button	F	Holes in it, water goes through	W/M	Made of plastic, plastic sinks	M/W
5.Elastic band	F	Way of placing on water	W	Very light, depends on how you put it in water	W/P
KEY TO CODING:	W=Weight F= Float	H=Hole S=Sink; So=solid	M=Material;Sz=size;K= Knowledge; E= Experience; Sh= Shape	P=Presentation; Ma= Mass; D= Density	A=Air

Table 1: Frequency of causal themes identified in Remy's data

Code	Causal theme	Initial	%	Stage 6/7	%
W	Weight	11	73.3	8	40.0
M	Material	2	13.3	5	25.0
Ma	Mass	0	0.0	0	0.0
A	Air	0	0.0	2	10.0
H	Hole	2	13.3	0	0.0
So	Solid	0	0.0	2	10.0
Sz	Size	0	0.0	0	0.0
K/E	Knowledge/Experience	0	0.0	0	0.0
Sh	Shape	0	0.0	0	0.0
P	Presentation	0	0.0	3	15.0
D	Density	0	0.0	0	0.0
		15	100	20	100

Table 2: Frequency of causal themes identified in Jessica's data

Code	Causal theme	Initial	%	Stage 6/7	%
W	Weight	4	25.0	2	10.5
M	Material	3	19.0	4	21.0
Ma	Mass	1	6.2	1	5.3
A	Air	0	0.0	1	5.3
H	Hole	2	12.5	2	10.5
So	Solid	1	6.2	3	15.8
Sz	Size	1	6.2	1	5.3
K/E	Knowledge/Experience	3	19.0	4	21.0
Sh	Shape	0	0.0	0	0.0
P	Presentation	1	6.2	1	5.3
D	Density	0	0.0	0	0.0
		16	100.1	19	100.0