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ABSTRACT

The Learning in Science Project (Primary)--LISP(P)--investigated the ideas and interests children have about hot and cold. Data were obtained from 25 children (12 boys and 13 girls), ages 8 to 11, using the "interview-about-instances" (IAI) procedure. Areas investigated included: (1) the meanings of the words "hot," "cold," "colder," "hotter," and "temperatures"; (2) temperature change when water volumes are changed or mixed (both qualitatively and quantitatively); (3) the temperature of ice in relationship to volume of ice and melting; (4) temperature measurement (using the hands and a thermometer); and (5) the process of heating and cooling. Results are presented, analyzed, and discussed in separate sections representing each of these areas. Findings indicate that children's intuitive ideas about temperature and temperature change of objects and events within their normal experience seemed fairly sound, that their subjective knowledge may influence what they actually "observe," and that their understanding of quantitative temperature did not match their understanding of qualitative temperature. In addition, children generally believed there was no difference between heat and temperature and that the greater the volume, the greater the amount of heat (or cold). These results are consistent with the findings reported in other research studies (IAI cards are included in an appendix.) (JN)

LEARNING IN SCIENCE PROJECT (PRIMARY)

CHILDREN'S IDEAS ABOUT HOT AND COLD

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INTRODUCTION

A major thrust of the Learning in Science Project (Primary) has been to investigate children's ideas about a range of topics. The criteria for selection of topics for study was considered by Biddulph, Osborne and Freyberg (1983) and later by Harlen and Osborne (1983).

The criteria were:

Topics should be ones which

- have significance for making sense of everyday events,
- can be related by children to their own prior knowledge and experience,
- can be placed in a socially meaningful context,
- will help rather than hinder further learning in science,
- can be tested by children through simple investigations,

(Harlen and Osborne, 1983: 17, 18)

From consideration of these criteria, a list of topics was proposed, one of which was 'Hot and Cold' (Harlen and Osborne, 1983). The New Zealand Department of Education has produced teacher guide booklets on many topics, and was reviewing the trial booklets on heat. It was therefore considered appropriate to examine children's ideas about hot and cold to serve as a research base for that review.

A SUMMARY OF LITERATURE ON CHILDREN'S VIEWS ABOUT HEAT

Children's ideas about heat and temperature have been examined by several researchers in recent years. Quite a few have focussed on heat transfer (Tiberghien, 1980; Erickson, 1979; Watts, 1983), change of state and kinetic theory (Driver and Russell, 1982; Cosgrove and Osborne, 1981;

Erickson, 1980). These studies have revealed similar patterns in many children's thinking about heat:

Heat has substance, and has the two forms 'hot' and 'cold' which can interact (Erickson, 1979; Driver and Russell, 1982).
Heat (and cold) are equivalent to hot (and cold) air (Watts, 1983; Erickson, 1979; Cosgrove and Osborne, 1981).
Heat rises (Erickson, 1979).
Heat flows over the surface of objects, or through holes to the centre of objects (Tiberghien, 1980).
Heat behaviour is explained better by a calorific view than by a kinetic view (Driver and Russell, 1982; Erickson. 1980).

Other research has concentrated on temperature, and the relationship between heat and temperature. Stavy and Berkovitz (1980) found children's conceptions of heat and of temperature were frequently influenced by the volume of the object under consideration. Strauss (1981), Erickson (1979) and Driver and Russell (1982) reported similar findings. The problem was particularly evident when numerical values of temperature were involved. Stavy and Berkovitz (1980) reported that many children gave contradictory responses when answering the same question in qualitative, then quantitative terms. For example, a child of 10/11 years may say that cold water mixed with an equal quantity of cold water gives water of the same coldness, yet think that equal quantities of water at 10° when mixed would be at 20°. About forty percent of 10/11 year olds interviewed by Driver and Russell (1982) showed a poor understanding of fixed temperature points, such as freezing point.

A PLAN FOR THE STUDY

Given that the scope of the topic 'heat' could be quite wide, and that many aspects of children's views of that topic had been identified in other research, it was decided to review the scope of the study. Since heat is a theoretical and abstract concept not directly measurable, it could be argued that an awareness of temperature and temperature change in many situations, may be a necessary precursor to the development of personal theories about heat. The topic 'Hot aned Cold' therefore focussed primarily on the directly measurable quantity, temperature and temperature change. An interview schedule, which was designed to validate views already revealed by research and to explore some of those ideas further, was prepared. The interviews attempted to find children's ideas about:

(i) the meanings of the words hot, cold, colder, hotter, temperature,

(ii) temperature change when water volumes are changed or mixed (both qualitatively and quantitively).

(iii) the temperature of ice in relationship to volume of ice and melting,

(iv) temperature measurement (using the hands and a thermometer),

(v) the processes of heating and cooling.

The above sequence of ideas does not match the sequence in the interview schedule, which was re-organised to allow the most effective interaction with the child.

DATA COLLECTION

After several exploratory interviews to develop and refine the interview schedule, twenty-five children (12 boys and 13 girls) were interviewed in the age range 8 to 11 years. The interviews were modelled after the interviews-about-events technique (Osborne, 1980), and used either concrete materials or pictorial representations of events to stimulate discussion on each question. All interviews were audiotaped, and were later transcribed for analysis.

THE INTERVIEWS AND SUMMARY OF DATA

(a) Identification of terms: hot, cold, hotter, colder

Each child was told that the topic for the interview was 'Hot and Cold', and was then presented with three bowls of water at about 45°, 20° and

8°C. They were asked to feel the water in each bowl and describe how it felt. Of the first two bowls, they were asked which was colder, and of the last two bowls, which was hotter. All children used the terms 'hot' and 'cold' in the conventional way. The words 'hotter' and 'colder' were also used conventionally by all but two children who preferred 'warmer' to 'hotter' because, as one child put it: "neither of them is hot". For these two children the term 'warmer' was substituted for hotter' in the subsequent interview questions.

(b) <u>Qualitative temperature: a small amount taken from a larger amount</u>

A bucket of tap water (18°-22°) was provided. After each child felt the water, half a cupful was removed and each child was then asked whether the water in the cup was hotter, colder, or the same as the water in the bucket, and why.

Twenty-three of the children said it would be the same, with reasons such as, "It's the same cold water when you took it out of the bucket". The other two children (10 and 11 year olds) thought it would be hotter because "It's in a smaller jar", and "You've taken a little bit from the bucket and it's by itself an'll get more heat temperature from the air than the bucket."

This was repeated, but only a small quantity of water (about 2 ml) was taken from the bucket. The children were again asked to explain their answers. Children's responses were the same as before except that two children now considered this water would be colder than the water in the bucket and one considered it would be hotter.

All five children who did not think it would be the same, related this to the small amount of water:

> "(Colder) because it hasn't got much water in it." (8 year old)

However, one child also explained that the water in the cup would be hotter because it would warm up:

"(Warmer) cause it's not so big. Cos sometimes air gets into it an' the air's hot and sometimes it's a bit warm." (8 year old)

Three of the nineteen children who thought it would be the same qualified their answer with a similar statement about the water in the cup warming up after awhile.

(c) The melting of ice

The stimulus provided was a card depicting a small and a large ice cube. Each child was asked what would happen to them if left on the table. All children said that they would melt. The next question probed the children's ideas about which ice cube would melt first (or both at the same time), and why.

Twenty-three children indicated that the smaller ice cube would melt first:

'Well (the small ice cube) only takes a little time (to melt) because it's so big (indicating size with fingers) ... an' that's a bit smaller than that (large) one so that (large one) would just take up a lot of time to go right down." (8 year old)

A few children initially interpreted the question to mean 'which would begin melting first', but this idea was corrected during the interview.

Two nine year old children thought that the large ice cube would melt first. One of these explained her answer:

"It's bigger and it melts easier",

but could not elaborate further. The other child's response seemed unreliable in that the child seemed to be searching for clues from the interviewer. She initially said they would melt at the same time (misunderstood the question), then changed her mind to the large one after the question was clarified. Her explanations related to the sun warming the ice up, so perhaps the question was still not understood.

(d) Temperature change in heated water

Each child was shown a picture of a small beaker containing a small amount of water and a larger beaker almost filled with water, both being heated by candles. Each child was told that both beakers of water had felt the same at the start, and that both candles had been lit at the same time. They were then asked which beaker, if a finger was put into each, would get too hot for the finger first, or whether they would get too hot at the same time. The children were also asked to explain the reasons for their responses. One child said the large one would get too hot first, three said both would get hot at the same time, but all other children said the small one would get hot first.

Most explanations related to the smaller quantity of water, but the three children who had indicated 'same' thought this would happen because the starting conditions were the same:

> "Because you made sure you had, you lit the candles at the same time and you made, you made the water both the same coldness."
> (9 year old)

(e) Mixing of water of the same temperature (qualitative)

Two cups containing identical quantities of water were tested by each child to establish that they were both the same (room) temperature. The question asked was: "If I pour these two cups of water into this third cup, will it be hotter, colder or the same? Why do you reckon that?"

Twenty children thought it would be the same and, of these, eighteen explained that this was because it was the same water, or that it would feel the same. Three children thought it would be colder, and one thought it would be warmer. Their reasons all related to adding the quantities of water, and therefore the heat or cold:

> "Cause when you add the two, one's cold and one's cold. That'll make it a little bit colder." (11 year old)

All children who made this type of response were 10 or 11 yea. olds.

(:) Measuring temperature by hand

Each child was asked to put one hand in a bowl of cold water, and the other in a bowl of hot water, then both hands in a bucket of tap (cool) water. They were then asked: "Ho' does the water feel to this hand? to that hand?" Table 1 summarizes the responses:

Hand from cold water Hand from hot water	....	now feels the water is warm/hot) now feels the water is cool/cold)	11
Hand from cold water Hand from hot water	....	now feels the water is cool/cold) now feels the water is warm/hot)	7
Hand from cold water Hand from hot water	....	now both feel the same (i.e. tap water)	4
Hand from cold water Hand from hot water	....	other responses (e.g. water feels hot to both	3

TABLE 1: Measuring temperature by hand

The fourteen children who did not give the expected response (the first in Table 1) which is based on the unreliability o the sense of touch, were asked to repeat the activity. However, this time two cups were filled from the bucket, and each child placed a hand in each cup instead of in the bucket. They were then asked, "Which cup feels warmer?"

C .y five of the children gave the response that the water as measured by the 'cold' hand had appeared warmer than the water as measured by the 'warm' hand.

The children's difficulties may have been related to the temperature used for the bowls of water: the cold water may have been too cold, the cool water could perhaps have been warmer. For instance, one child commented that this hand was 'still numb' from the cold water.

Those who had given the expected response were asked to explain what they thought was happening. Four of the children described to how their hands felt rather than how the water felt:

"This hand here felt warmer cos it's been in the cold for so long, for awhile, and this one felt cold because it's been in the hot." (10 year old)

An 11 year old explained it slightly differently:

"Cause my hands changed from that heat (the hot water) before going into that (bucket)."

Another idea was:

"... it gets so cold that um it feels hot - like you can get cold burns." (10 year old)

Two children mentioned the idea of the hands "getting used to" the hot or cold water.

"That was cold water and that hand's used to the cold water." (10 year old)

(g) Recognition of a thermometer

Each child was shown a mercury-in-glass thermometer, and was asked what it was. Children who were uncertain were told its name. Each child was also asked what the thermometer does (tell us). Again, those who were uncertain or did not know, were told: "It tells us how hot or cold something is."

Three children did not recognise it as a thermometer and did not know what it did. The others compared it to clinical thermometers or pool thermometers. Twenty children said it told how hot or cold something was, or said that it told us the temperature of something. These children explained temperature as "how hot or cold some water is". All of the children who had difficulties were 8 or 9 year olds.

(h) Awareness of typical temperature in degrees

At this stage each child examined the -10° to 110°C thermometer, and read the air temperature. Help was provided if necessary, to assist the children to recognise the scale and the mercury column which indicated the temperature reading. Each child was then asked "What number would the thermometer go to if we put it in:

> some water we just boiled to make a cup of tea?
> a cold drink with lots of ice in it?"

Figure 1 summarizes the children's responses:

Boiled Water

									xx	x	x		
				x			x		xx	x	x		x
			x	x	x		xx	xx	xx	xx	x		x
Bottom	-10	0	10	20	30	40	50	60	70	80	90	100	110	Top
x	x	xx	xx	xx	x	x								
	x	xx	x	x										
	x	x		x										
	x	x												
		x												
		x												
		x												

Iced Water

Figure 1: Children's views about the temperature in degrees Celcius of boiled and iced water

The temperatures the children suggested were almost all qualified by terms like 'about' or 'probably', and a temperature range (e.g. 70° to 80°) was often suggested rather than a particular temperature. This seems to indicate that the children were uncertain about the temperature, and some may have been guessing just to satisfy the interviewer's request for a number. This was confirmed for five children (e.g. some who said boiled water would be around 10-30°C) who admitted to guessing, when their answer was probed further.

One child gave no temperature for the iced water because "(the thermometer's) used for measuring heat".

(i) Measuring temperature

Each child took the temperature of the available bowls of water, using the thermometer. Help was provided as necessary. Only forty-two percent of the measurements taken by the children during the interviews were accurate to the nearest degree on their first try at any particular measurement.

(j) Thermometer operation

When asked how they thought the thermometer worked, nine children said they did not know, but thirteen attempted some explanation. Eight of these suggested that the thermometer was sensitive to heat, or 'made to' go to the right number:

> "There's something that makes it go. Maybe there's something in the silver bit here that when you put it in a container it goes up to a number." (8 year old)

> "It's sensitive to hot and cold water." (10 year old)

Two children explained it by the idea of pressure, or pushing:

> "When it gets hot the ... it starts to squeeze out. The pressure's hot ..." (10 year old)

Three children mentioned that heat rises:

> "... heat rises and um that could be so like that (the mercury) rises with it. And um cold goes down lower. Cold might go down lower and that's why it (the mercury) goes down." (10 year old)

> "... when the mercury gets hot it rises." (11 year old)

However, the children did not show great commitment to their ideas;

they generally were speculative and added qualificatory words such as 'probably', 'perhaps' and 'maybe'.

(k) <u>Recognition of air temperature and it's relationship to daily weather temperatures</u>

Each child's attention was drawn to the thermometer reading (in the air), and was asked what the thermometer was measuring:

> "I wonder what the thermometer's reading now? - it's not in anything."

After the child's idea was discussed and clarified, the relationship between air temperature and daily (T.V.) weather temperatures was probed:

> "I wonder if that's got anything to do with the T.V. weather temperatures? ..... Do you think they might use a thermometer like this?"

Table 2 summarizes the children's responses:

	Response	No of Responses
It's measuring:	the air, the heat of the day or the air	18
	your fingers or hand	4
	air pressure	1
	you're moving it	1
	don't know	1
		25*
T.V. weather:	they would use a thermometer like that	8
	they would NOT use a thermometer like that	4
	could be/maybe	8
	don't know	2
		22

* Some children gave more than one response.
N = 22 for this question.

TABLE 2: Children's views about what a thermometer in air was measuring, and the relationship between a thermometer and T.V. weather temperatures.

Children who did not think the T.V. weather temperatures were obtained using thermometers often suggested weather balloons or the weather satellite:

"They've got a big round thing on a planet ..." (8 year old)

"I thought they use weather balloons." (11 year old)

"They got it from a satellite that goes up there (gesture)." (10 year old)

(1) Quantative temperature: a small amount taken from a larger amount

Task (b) was repeated, but this time the temperature of the water in the bucket was measured with the thermometer, and each child was asked what number he/she thought the thermometer would go to if it were placed respectively in the half-filled cup, and the cup with the small amount of water. The children's responses were compared with the measured temperature of the water in the bucket. A summary of their responses is shown in Table 3.

Response	No of Responses
Temperature of half-filled cup:	
same as the bucket temperature	16
greater than the bucket temperature	3
less than the bucket temperature	5
	24
Temperature of small amount in the cup:	
same as the bucket temperature	10
greater than the bucket temperature	4
less than the bucket temperature	10
	24

TABLE 3: Children's views about the temperature of two different amounts of water drawn from the same bucket.

The children were asked to explain their answer. Those who thought the small amount of water would be at a higher number than that in the bucket were all 10 or 11 year olds; they thought it would be warmer because it would warm up:

"Cause air's got into it and heated it up a tiny bit." (11 year old)

The children who indicated that the small amount of water would be colder tended to relate this to the quantity of water:

"Cause there's less water in." (11 year old)

"Cause there's not very much water in it." (9 year old)

(m) Temperature of ice of different volumes

Each child was referred to the picture of the two ice cubes, and was asked what number the thermometer would go to for each of the ice cubes. Eleven children were also asked about the possible temperature of an iceberg.

Table 4 shows the children's responses on these tasks.

Responses	No of Responses
Large and small ice cubes the same	6
Large ice cube less number than the small ice cube	12
Large ice cube greater number than the small ice cube	5
	23
Iceberg number the same as the ice cube	-
Iceberg number less than the ice cube	6
Iceberg number greater than the ice cube	5
	11

TABLE 4: Children's views about the temperature of two different sized ice cubes and an iceberg.

Four of the children mentioned zero degrees for one of the temperatures, but eighteen gave all temperatures greater than zero. One child suggested all temperatures would be negative, and four suggested both positive and nagative temperatures. No child thought that the temperatures of the two blocks of ice and iceberg would be the same.

When those children who had given different temperatures for the different volumes of ice were asked their reason for saying so, fourteen mentioned that coldness is related to size. In their view, a greater volume of ice would be colder than a smaller volume. Thus, for example, one child said that the larger ice cube would be a lower temperature than the smaller ice cube.

"Because it's bigger and it's got more coldness in it."
(9 year old)

However, three of the children who thought the larger blocks of ice would be colder gave a higher temperature rather than a lower temperature. Only one of these children had earlier shown similar ideas about a higher temperature being colder, and all had used the thermometer in iced water. A further seven children may have given a similar response if they had not had the experience of measuring the temperature of the iced water. Their initial responses for the larger ice blocks were greater numbers than those given for the small ice cube, but these were quickly amended. In other tasks all of these children talked in terms of higher temperatures being hotter and were seemingly unaware of any contradiction.

The converse idea was explained by two children who thought the larger ice block would be hotter, and so gave a greater temperature for it:

"Cause it's larger. If it's larger it got more heat."
(9 year old)

One child suggested a temperature differential between the interior and exterior of the ice block:

"In the middle it would be a bit colder - in both of them ..."
(10 year old)

(n) Cooling rate of different volumes of water

For this task a picture of a jug of hot water and a cup of hot water were used. It was explained that the water in the cup was poured from the hot water jug. The children's ideas about the initial temperatures of the water in the cup and jug were investigated first. Each child was then asked which (of the cup or jug of cooling water) the interviewer would be able to put his finger in first without getting it burnt, or whether he could put a finger in each at the same time without getting them burnt. The children's responses are shown in Table 5. Again, children were asked to explain their responses:

Response	No of Responses
Initially, cup is hotter	2
Initially, cup is colder	10
Initially, cup is same	10
	22
Cup would cool first	16
Jug would cool first	1
Would cool at the same time	5
	22

TABLE 5: Children's views about the temperature of two different volumes of water from the same source, and about the cooling rate of the two volumes.

With respect to the initial temperatures, eight children thought the water would be cooled by putting it in the cup:

"When you poured it back (i.e. out), well it goes cold."
(8 year old)

Four related the temperature to the volume of water. For example, one child said the jug of water would be hotter.

"Cos it's got more water in." (8 year old)

With respect to cooling rate, children who thought that the jug and cup of water would cool at the same rate related this to the constant conditions:

"They were the same temperature when it came out of the jug, and you cooled them for the same time." (10 year old)

The reasons given for the cup cooling first related to the smaller quantity of water:

"Cause there's less (water in the cup) to cool down ... This (jug) has more water so it will take longer to cool down." (11 year old)

(o) Mixing of water of the same temperature (quantitative)

This task was a repeat of task (e) but using temperatures measured with a thermometer. After measuring the temperature of the water in each of the two cups, 15 children (11 of whom were 10 or 11 year olds) thought that the mixture in the third cup would be the same number:

"(Cups at 20° and 20° mixed to give 20°) cos they're both equal to 20°." (8 year old)

However, nine children (seven of whom were 8 or 9 year olds) thought that the third cup would be at a higher temperature, and six of these children gave the numerical sum of the temperatures of each cup:

"Cos 22 plus 22 gives 24 ..... 44." (9 year old)

"(Cups at 20° and 20° mixed to give 30° or 60°) because the heat in this (cup) will make the heat in this (other cup) warm up." (9 year old)

One nine year old thought that the mixture would be colder because there was more water.

(p) As a final question, each child was asked for his/her ideas about why things like the bowl of hot water cool down, and why things like the bowl of iced water warm up.

A wide range of ideas was expressed. Examples of these are given below. Some children discussed heating and cooling in relation to some other tasks as well, and those ideas are also included here. The numbers in brackets indicate the number of children who seemed to hold that particular idea. Some children made statements involving more than one idea.

(i) Temperature difference between the object and the surroundings - (14).

"When you've got something on a cold thing it's um gunna get cold, colder, an' when you've got it on a hot thing it'll go hotter." (8 year old)

"Cos of the temperatures of the air ... the air can cool it down." (10 year old)

This idea was frequently held in conjunction with other ideas, such as those of (ii) and (iii).

(ii) Air gets in to cool or warm the object. Air is seen to be similar to heat or cold - (8).

"(Air) gets into the glass and um it cools it down." (10 year old)

"It would have cooled down because the cold air could penetrate it and cooled it down ..." (10 year old)

I: Well how does the heat get out of the jug do you reckon?

P: "No idea. It does. Just cools it down when the air goes into it ..." (11 year old)

(iii) Heat and cold are real (but different) entities - (11).

"... the (cool) air ... gets the warm stuff out." (8 year old)

"... there's a greater amount of heat than in that one." (11 year old)

"If you put (the thermometer) in cold water it measures how cold it is. If you put it in hot water it measures how hot it is." (9 year old)

"(the water) was the same coldness and the same hotness." (10 year old)

(iv) Heat rises - (5).

"Well the heat rises from the jug and it's just left cold."

(v) Things cool by losing steam (seen as equivalent to heat) - (4).

"... it will cool down at the top with the steam coming off." (11 year old)

"the steam's all the hotness." (9 year old)

I: Can you see (heat) come out of the top (of the jug)? (Child nods). What's it look like?

P: "Just steam coming out the top." (9 year old)

(vi) Cold water remains cold - (5).

I: If I came back tonight would the basin (of iced water) be hotter, colder, or the same as it is now?

P: "Colder ... Cos it's been left on something cold (the cold room)." (8 year old)

(vii) Heat disappears, evaporates, or dries into the air - (4).

I: What happens to the heat?

P: "I don't know but it just dissolves away." (8 year old)

BROADER ISSUES

(a) Children's intuitive ideas about temperature and temperature change of objects or events within their normal experience seemed fairly sound

Most of the children apparantly have experiences with everyday objects over the range of temperatures 10° to 50° that enabled them to build up a reliable intuitive view of relative temperatures, cooling and warming, and the independence of the temperature of water from volume. (See tasks a, b, c, d, e, n.) Similar findings were reported by Stavy and Berkovitz (1980) and Driver and Russell (1982).

However, the children's ideas about temperature and temperature change of objects or events beyond the children's normal experience seemed to be less supportable by experimental evidence. All of the children, for example, considered that the temperature of ice was dependent on its volume. Driver and Russell (1982) also reported that the volume of ice influenced children's idea of the ice temperature. The younger children seemed to abandon their intuitive idea that volume and temperature of water are related (Stavy and Berkovitz, 1980) in the face of contrary experiences, but retained this idea for <u>ice</u> till a much older age. Driver and Russell (1982) reported that by the age of 13/14 years, ninety percent of the children surveyed thought that two different sized blocks of ice would be the same temperature.

Another area where the children's intuitive ideas seemed less sound was in the cooling and warming rates of different quantities of water. Only three children were aware that a smaller quantity of water would warm up faster than a larger quantity of water, (task (b)), but even they thought this would happen almost immediately.

P: "(The small amount in the cup is warmer) because it's less water an ... it's easier to warm up a little one than a big one. It take more time to."

I: How much time would it take this (cup to warm up from 21° to 22°)?

P: "It might take about a minute." (10 year old)

Another example was the 27 percent of children who, on task (n), did not think that a small cup of water would cool more quickly than a jug of water at the same starting temperature.

The experiential base for developing intuitive ideas was highlighted by one child who gave contradictory explanations when discussing the (qualitative) temperatures of half a cup of water and a small amount of water taken from a bucket (task (b)).

P: Well I think this (half-full) cup's gunna be warmer.

I: Warmer. Why do you think it will be warmer?

P: 'Cause it's in a small container ..... (The cup with a small amount will be) colder.

I: That'll be colder. Why do you think it'll be colder?

P: 'Cause there's less in it .....
'Cause that's what happens at home. I did a little experiment like that ... (11 year old)

Inconsistent tactile impressions gave rise to contradictory views, but the child was prepared to live with contradictions rather than reject her sensory impressions. Biddulph and McMinn (1983) have commented on children's tendency to make conclusions from unreliable data.

(b) The children's subjective knowledge may influence what they actually 'observe'

This appeared to happen whem some children did task (f) (trying hands in water of different temperature). Why did children give inappropriate responses to such an apparently simply activity? A possible explanation is that the children said what their common sense or intuitive knowledge told them should happen. The actual sensations experienced were either not noticed or ignored. For example,

> Common sense would suggest that a hand which has just been in cold water is going to remain cold for awhile, even if it is ..n some other water; similarly for a hand which has been in hot water. Therefore the children observed that the 'cold' hand still felt cold, and the 'hot' hand still felt hot. Again, common sense would suggest that if both hands are put into the same bucket of water, then both hands must feel the same sensation. Hence some children 'observed' that the water felt the same.

(c) The children's understanding of quantitative temperature did not match their understanding of qualitative temperature

Few children said that they had had experience with a thermometer other than a clinical thermometer, and even that experience appeared to be fairly limited. It is not surprising then that the children's ideas about quantitative temperatures were contrary to what actually occurs. For example, when the children estimated temperatures, most could not even quantify common temperatures reasonably accurately.

However, this point is perhaps best exemplified by the parallel qualitative/quantitative tasks where children removed small quantities of water from a larger amount, and mixed two cups of water (tasks (b) (1) and (e)/(o)). Table 6 summarizes the comparative data from these tasks. A similar decrease in performance on the quantitative task compared to the same qualitative task has also been found by Stavy and Berkovitz (1980) and Driver and Russell (1982) for the same age group. Stavy and Berkovitz (1980) and Strauss (1981) suggested that the children see the situation as a numerical problem, and their learned techniques for solving numerical problems interfere with or over-ride the children's (correct) intuitive responses. The presence of numerical values make the problem a new and less familar school situation which is seen as being different from the situation where intuitively knowledge about hot and cold applies.

Response		Percentage responses Qual. task	Quan. task
½ cup taken from bucket	- same	92	67
	- hotter	8	12
	- colder	0	21
small amount from bucket			
	- same	80	42
	- hotter	12	16
	- colder	8	42
mixing cups of equal temp.			
	- same	84	62
	- hotter	4	38
	- colder	12	0

TABLE 6: Comparison of children's responses on the qualitative and quantitive tasks.

(d) The children's general ideas about heat which emerged were:

(i) There is no difference between heat and temperature

This idea emerged most noticeably in the task involving cooling of different quantities of water, and the melting time and temperatures of different sized ice cubes.

Five of the children showed confusion between heat and temperature when they suggested that a jug and a cup of hot water would both cool down at the same rate, because they had the same initial temperatures.

Another child's comment in relation to this task demonstrates this confusion of heat and temperature:

> "(The large jug of water is hotter) cos there's much more heat, there's a greater amount of heat ..."
> (11 year old)

Although all of the children seemed to grasp the idea of heat in relation to the ice cubes melting, the idea that more heat (or cold) means a greater temperature was demonstrated by five children. They thought that a large ice cube would have a higher temperature than a small ice cube because it is colder (or hotter).

(ii) The greater the volume, the greater the amount of heat (or cold)

This idea, taken with that above, resulted in the view that the greater the volume of water, the higher the temperature (or the lower the temperature for cold things).

Twelve children thought that a larger ice cube would be at a lower temperature than a small ice cube because it would be colder, and that it was colder because there was more ice:

"That would be a greater amount of ... coldness ... All the cold's um sort of compacted (in the larger ice cube) sort of." (11 year old)

The following temperatures were suggested by a 10 year old:

Small ice cube	-6°
Large ice cube	-10°
Iceberg	-400° or 500°

Both of these ideas about heat have also been reported by others such as Erickson (197[illegible]) and Driver and Russell (1982).

CONCLUSION

The children's ideas about heat and temperature revealed in this study are consistent with the findings of others (see p. 2). The investigation also highlighted children's intuitive understandings of temperature and contrasted these with their views derived from learned school methods for solving numerical problems. Areas where children's experiences seem to have been fairly limited, such as temperature of different volumes of ice and cooling rates of different water volumes, have been demonstrated as well.

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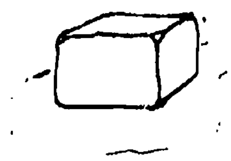
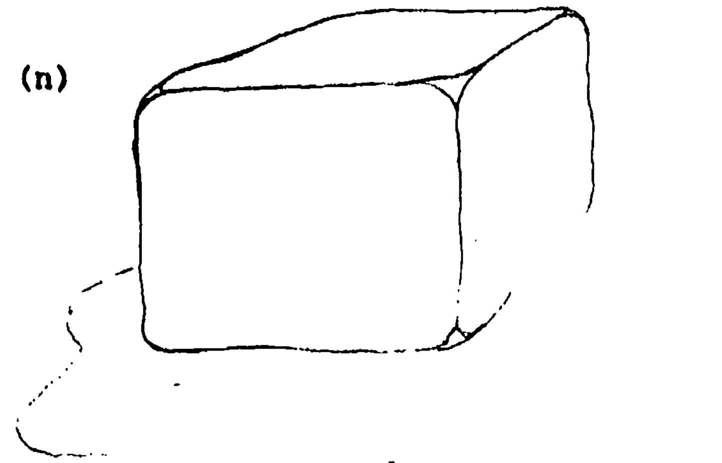
APPENDIX 1

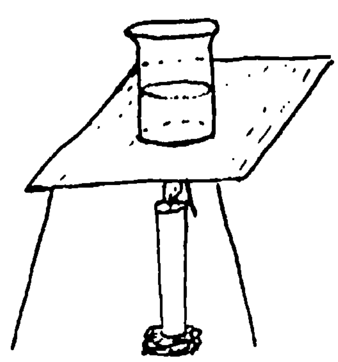
The cards used in tasks (c) and (m), (d) and (n)



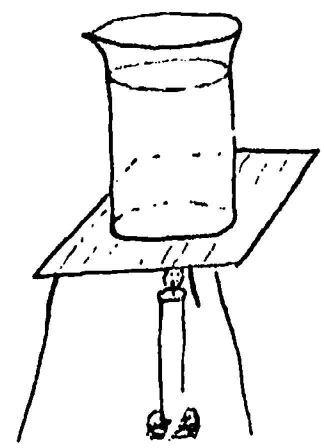
small ice cube



large ice cube

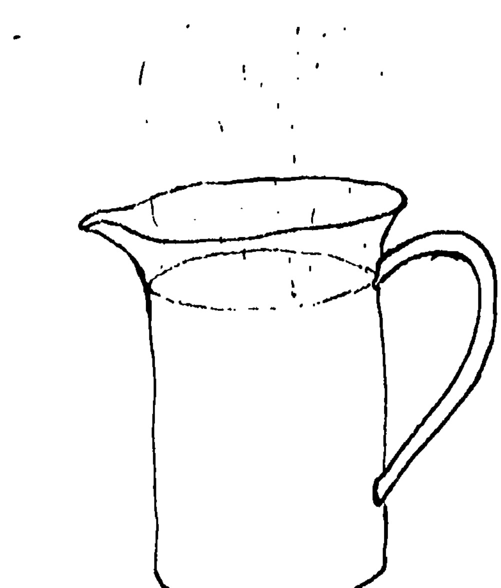


small beaker of water



large beak·r of water

cup of hot water



jug of hot water

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