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How Grade R pupils make sense of the 'scientist' and 'science'

Abstract

In this article we report on the 'sense-making' by children of a 'scientist' and 'science'. We investigated these conceptions through drawings by using the Draw-a-Scientist Test (DAST) developed by Chambers. We conducted the research in two urban schools; a public school located in a low-income previously designated black (African) suburb, and a private school in an affluent suburb. In theorising on the sense making of a 'scientist' and 'science' by children from these diverse learning contexts, we examined the notion of 'semiotic mediation', which is a central idea in Vygotsky's work. The results of the study show that children in the previously designated black school have little or no conception of science or a scientist. The significance of these findings needs to be considered against the inequities in education, and in particular in science education in this country due to the apartheid system. Despite Grade R being the first year in the twelve-school career of children we believe that the findings of this study do signal that concerted steps need to be taken so that children develop stronger conceptions of science and a scientist.

Keywords: semiotic mediation, sense making, draw-a-scientist test, conception of scientist

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Introduction

Over the past 50 years, a growing body of research has emerged on people's perceptions of science and scientists. Some of this research has focused on children's perceptions; how they make sense of the world. The implications of this research for science learning are important because of the glimpse it gives of how children view the world and how conceptions can be scripted culturally and educationally in children's interactions (Gopnik & Meltzhoff, 1997). Some studies have indicated that the perceptions of scientists held by students (or others) are related in some way to their attitudes toward science and science self-efficacy (e.g. Finson, 2000; Finson, Riggs & Jesunathadas, 1999), subsequently affecting their prospects of entering a science-related career (Zeldin & Pajares, 2000). If young children learn to see the world of science (and the work of a scientist) in a stereotypical way, and not related to their world, it may predispose them to a stereotypical view, coupled with a sense of exclusion. Losh, Wilke and Pop (2008) assert that

> youth become psychologically involved with or disengaged from science long before they enter college or choose careers (p. 775),

and so school experiences and particularly early experiences are important in nurturing an interest in science. In the context of this inquiry into the sense making of young children, the way the work of a scientist is encountered semiotically may have some impact on how children learn science in school and also how this may affect not only their achievement in school, but their career options later. Therefore, having some foreknowledge of children's perceptions of science and scientists is an important aspect of children's learning that teachers need to know if they are to effectively and positively impact children's experiences in science. It is also important for researchers, if they are to research science learning effectively. In explicating the sense making of young children of what constitutes a 'scientist' and 'science' we adopt a sociocultural perspective on learning, because we argue that early conceptions of worlds of knowledge, such as the world of natural science, are mediated interactively, thus socioculturally.

One of the most crucial aspects on which theories of learning differ is how they view the role of the social/cultural milieu in the development of psychological processes (Rogoff, 1990; Roth, 2010; Wertsch, Minick & Arns, 1984). According to neo-Vygotskian researchers such as Wertsch et al. an individualistic perspective on learning views

> human experience and environmental forces strictly from the position of how they influence the individual's psychological development (p. 151).

The most known individualistic theory in modern development cognitive psychology is that of Piaget, although his work has been followed by theories that award conceptual development earlier in a child's development and also not strictly in stages (Carey, 2009). We invoke the work of Piaget, however, because of how he examined social activity solely; from the perspective of how it influences the individual's development and how disequilibrium and perturbation, two of the concepts in his theory of cognitive development, have social origins. A sociocultural view of learning stands in contrast to such a strict constructivist position and according to John-Steiner and Mahn (1996) Vygotsky's work with his collaborators in Russia in the 1920s and 1930s still contain the essence of a sociocultural view on learning and development. One of his two main (completed) works (Vygotsky, 1978) explains the human 'mind in society'. The social/cultural context and history of individual cognitive activity are the roots of the 'semiotic mediation' that undergirds learning. Vygotsky proposes that

> [...] human learning presupposes a specific social nature and a process by which children grow into the intellectual life of those around them (p. 88).

The very nature of tools and practices are the semiotic medium that consistently interfaces children's learning. Their interaction with more experienced members of society and with their peers facilitates the interface, as do texts and other tools and signs. The signs of, for example, the work of science and the image of scientists, mediate young children's development of a conception of what a scientist is (and therefore also what science constitutes in society). Within the context of our study, the sense making of young children with regard to what constitutes a 'scientist' and 'science' would thus be mediated through the social/cultural activities of the social/cultural grouping in which a child first learns about science and scientists. On this view of learning and conceptual development learning is therefore also a form of enculturation, which occurs through adopting the cultural practices of a social group situated in its distinct culture. While much of the research in helping us understand how children come to know the world has been underpinned by Piagetian and post-Piagetian theorising, Robbins (2007) points out that

> there are challenges made concerning the ideas of the universality of childhood upon which many of these studies are founded (p. 46)

as the complex, dynamic and contextualised nature of thinking cannot be explained. In investigating the sense making of a 'scientist' and 'science' by children from diverse learning contexts we therefore considered it more appropriate to adopt a sociocultural perspective on learning, while not negating other views, such as those proposed by Carey (2009).

We wanted to find out how children in their first year of school view "the work of a scientist", not because of the image itself, but what it would signify in terms of the children's conceptions and sociocultural exposure to the notion of 'a scientist'. We conducted the research in two urban schools; a public school located in a low income previously designated black (African) suburb, and a private school in an affluent suburb. The public school is only populated by black children, and the private school was racially mixed. Although much research has been conducted worldwide with learners of different ages, race and ethnicity on their images of science and scientists, no such research has been done in South Africa. We consider this study of particular significance for this country in view of a thrust in government education policy for the improvement in the quality of school science for all learners, so that they may pursue tertiary studies in science, and thereby follow career paths in science.

In our investigation we started off by asking the following research questions:

1. What images do Grade R children in a previously designated black public school and a private school have of science and scientists?
2. Are there patterns in the images of science and scientists portrayed by these children?

In theorising on the sense making of a 'scientist' and 'science' by children from these diverse learning contexts, we examined the notion of 'semiotic mediation', which is a central idea in Vygotsky's work (Wertsch, 1990). For Vygotsky, semiotic mediation is the key to the appropriation of knowledge by the developing individual. Mediation takes place by way of semiotic mechanisms (tools and signs), which mediate social and individual functioning and connect the external and the internal, the social and the individual (Wertsch & Stone, 1985; Hardman, 2010). In its Vygotskian sense,

> mediation involves the use of culturally-derived psychological tools, such as utterances in spoken or sign language, in transforming the relations between psychological inputs and outputs (Fernyhough, 2008, p. 6).

Semiotic mediation thus occurs wherever discourse occurs, and that discourse is ubiquitous in the living of social life, enabling children to internalise the world they experience in the living of their life (Hasan & Cloran, 1990). Vygotsky (1981) listed a number of examples of semiotic means:

> language; various systems of counting; mnemonic techniques; algebraic symbol systems; works of art; writing; schemes; diagrams; maps and mechanical drawings; all sorts of conventional signs and so on (p. 137).

He argues for the central role of language in learning by maintaining that it mediates the communication through which thinking with others is made possible (Wells, 2007). According to Hasan (2002)

> in the Vygotskian oeuvre, the phrase 'semiotic mediation' has come to stand for 'mediation by means of the linguistic sign' (p. 1).

Halliday (1993) a sociolinguist, describes language as semiotic tool in learning:

> When children learn language, they are not simply engaging in one type of learning among many; rather, they are learning the foundations of learning itself. The distinctive characteristic of human learning is that it is a process of making meaning; a semiotic process; and the prototypical form of human semiotic is language. Hence the ontogenesis of language is at the same time the ontogenesis of learning (p. 93).

Hasan further explains the notion of semiotic mediation by invoking insights from systemic functional linguistics. She point out that the noun/gerund 'mediation' is derived from the verb 'mediate', which refers to a process with a complex semantic structure involving participants and circumstances that are potentially relevant to this process. The participants include someone who mediates, i.e., a mediator (the subject performing an action of mediation); something that is mediated (through the sign or tool); and someone who is the object of mediation, i.e. the 'mediatee'. The circumstances for mediation refer to the means of mediation, i.e. the modality and the location in which mediation takes place. Teachers can be viewed as subjects; books, texts, language and images can be viewed as mediating signs and tools; learning children can be viewed as objects of the action in the semiotic mediating activity.

The meanings of words as signs and of other signs as well do not remain constant for individual persons, but develop as they are encountered in new contexts of activity and as connections of various kinds are established with other meanings. This is an ongoing process of conceptual development (Vygotsky, 1987). Vygotsky makes a distinction between ‘meaning’ and ‘sense’, during conceptual development (Wells, 2007). ‘Meaning’ is relatively stable corresponds with the definition of lexical items as they are found in dictionaries, while ‘sense’ is a dynamic, fluid and complex formation that is significant for the user of the word. In our inquiry the notion of ‘sense’ is thus the focus. On this view we investigated the ‘sense making’ rather than ‘meaning making’ by children of a ‘scientist’ and ‘science’. We wanted to gain some insight into their conceptual development as captured in their expression of the idea of ‘scientist’ and of ‘science’.

The Draw-a-Scientist Test (DAST)

In this study the ‘sense making’ by children of a ‘scientist’ and ‘science’ is investigated through their drawings. Although language was the primary semiotic means on which Vygotsky focused much of his studies, he did consider drawings as one of the other means by which children ‘talk’ about their world, both to themselves and to others (Lindquist, 2001). In fact, Dyson (1982) cited by Ring (2001) draws attention to Vygotsky’s description of drawing as a kind of ‘graphic speech’. In exploring the young child’s drawing from a socio-cultural perspective, we can gain some insight into the influence of the views and beliefs of older and more significant others at home and at school settings (Brooks, 2009). Toku (2000) says that although in the early years of childhood children show similar patterns in their drawings, they

> show another important characteristic in their drawings; cultural specificity when they reach certain ages (p. 1).

This is also the perspective from where we conducted the study, trying to understand how two groups of Grade R children from two very different contexts make sense of ‘science’ and a ‘scientist’.

The instrument we used was designed by David Wade Chambers (1983). It has been used with people of all ages, from pre-school children to adults. Chambers developed the Draw-a-Scientist-Test (DAST) 30 years ago, and he patterned it after Goodenough’s Draw-a-Man Test (Finson, 2002). He had young children draw a scientist on a blank sheet of paper, and they then described the images of a scientist reflected in the drawing, which served as focal point and made the notion of ‘a scientist’ less abstract. This enabled him to derive some information on the perception of a scientist from young children up to Grade 5. We consider this test appropriate for the age group of children who formed the focus of this study, as young children have limited language skills to either write or speak about their conceptions of science and scientists, unless they have lived in an environment where this is part of the home or the pre-school discourse. Furthermore, Kahle (1993) cited by She (1995) has commented that since DAST does not require reading or writing skills, it minimises the possibility of 'socially desirable' responses that have been scripted into their vocabulary, although drawings are also inscribed by different examples and models of drawings that children encounter.

Chambers (1983) identified attributes or elements that consistently appeared in drawings of scientists, for example a lab coat (usually white), eyeglasses, scientific instruments and products of technology such as rockets. From these indicators, Chambers was able to show that views of scientists varied by age and grade level, and that children began to develop stereotypical views of scientists from a very early age. Finson, Beaver and Cramond (1995) developed further the Chamber's DAST by incorporating additional stereotypical images such as gender and age in a Draw-a-Scientist Test Checklist (DAST-C). We expected some variance in the two groups of children that we studied and it turned out that it was a credible expectation.

Method

The DAST was administered to Grade R children in a public school in Soweto and in a private school in Pretoria. The schools were demographically different with the Soweto school (School A) located in a low-income and previously racially segregated community, and the private school (School B) in an upper/middle-income community. The children in School A speak isiZulu and Sesotho as first languages. There were 34 isiZulu and 46 Sesotho speakers who were placed in separate classes, with each class being taught by a teacher in the respective first language. The 46 Grade R children in School B were taught in the medium of English, for whom this was also their home language in the majority of cases.

The DAST was administered by the class teacher, who asked the children, working separately, to "Draw a picture of a person doing science". This instruction was translated into isiZulu and Sesotho for students at School A. This translation was done by one of the authors of this paper and validated by a professor of African languages.

The following instruction was given to the children:

> isiZulu: *Ake udwebe isithombe somuntu owenza isayensi.*
>
> Sesotho: *Swantsha setshwantsho sa motho a etsa saene.*

The children were presented with a set of coloured crayons and a sheet of paper. The time for children to complete the drawing was not stipulated, but all children managed to do the drawing within half an hour. Some children inquired as to what they should draw; and they were assured that whatever they drew would be fine. This was a common question as evidenced in other studies (Finson, 2002; Monhardt, 2003).

Based on the DAST-C (Finson *et al.*, 1995), the following were chosen as indicators of the standard, conventional image of a scientist:

1. Lab coat (usually but not necessarily white)

2. Eyeglasses
3. Facial hair (beard, moustache, abnormally long sideburns)
4. Symbols of research (scientific instruments, lab equipment of any kind)
5. Types of scientific instruments/equipment – Symbols of knowledge (books, filing cabinets, clipboards, pens in pockets, and so on)
6. Technology (the 'products' of science) – Types of technology (televisions, telephones, missiles, computers, and so on)
7. Relevant captions (formulae, taxonomic classification, the 'eureka!' syndrome)
8. Male gender only
9. White only
10. Indications on danger
11. Presence of light bulbs
12. Mythic stereotypes
13. Indications of secrecy
14. Scientists doing work indoors
15. Middle-aged or elderly scientist

After having completed the drawing each child was interviewed and asked to talk about their artefact. In cases where the drawing of the image was not distinct, the children were asked to explain what they had drawn and what specific parts of the image represented for them. These follow-up interviews were deemed to be essential in order to get valid results, and this was also signalled in a study by Monhardt (2003). We had Piaget's clinical interviews in the back of our minds when we conducted the interviews, although there was no real protocol.

Each drawing was then analysed for the presence of indicators listed from the DAST-C. In accordance with the analysis of other similar research where the DAST-C test was administered, each indicator was marked only once, even if multiple counts of the same indicator were present in the drawing. All counts were then tallied and recorded on a frequency table.

Results: about 'complexes' and 'pre-concepts'

The mean indicator of the standard image of a scientist for the School A and School B children were 1.46 and 2.70 respectively (Table 1).

Table 1: Frequency of drawn indicators

	Number of children	Number of children	Mean indicators per child
School A	80	117	1.46
School B	46	124	2.70

The results show that 58.75% of School A children drew 0 or 1 indicators, and that 52.16% of School B children drew 3 or more indicators (Table 2).

Table 2: Distribution of indicator scores by school type

School type		Indicator score							
		0	1	2	3	4	5	6	7
School A	N	16	31	22	10	3	0	0	0
	%	20.00	38.75	27.50	10.50	3.75	0	0	0
School B	N	4	10	8	10	6	5	2	1
	%	8.70	21.74	17.39	21.74	13.04	10.87	4.34	2.17

Furthermore, the chi-square test showed an association between the school type and indicator scores less than three and greater than or equal to three ($\chi^2 = 27.73$) with children at School B more likely to draw three or more indicators than children at School A. It is therefore evident that children at School A have a much weaker conception of a scientist than children at the School B. The mean indicator scores per child for each category showed that School A children scored lower than the children in the School B in 9 of the 10 categories where indicators were registered (Table 3). School A learners only scored higher in the middle-aged or elderly person category. In Vygotskian parlance the children in School A had not developed conventional ideas and were expressing notions that can be described as 'complexes' (Vygotsky, 1987, p. 137). The chi-square test also showed an association between the school type and the indicators, symbols of research ($\chi^2 = 18.48$) and technology ($\chi^2 = 8.24$) with children at School B more likely to draw these indicators than children at the School A. These children thus encountered images or ideas of the type of person a scientist is and this can be described as 'pre-concepts'.

Table 3: Frequency and mean indicator scores

Indicator	School A (N = 80)		School B (N = 46)	
	Frequency	Mean indicator score per child	Frequency	Mean indicator score per child
Lab coat	0	0.00	4	0.09
Eyeglasses	0	0.00	1	0.02
Facial hair	0	0.00	0	0.00

Indicator	School A (N = 80)		School B (N = 46)	
	Frequency	Mean indicator score per child	Frequency	Mean indicator score per child
Symbols of research	2	0.03	13	0.41
Symbols of knowledge	0	0.00	0	0.00
Technology	13	0.18	18	.48
Indications of danger	0	0.00	0	0.00
Relevant captions	0	0.00	0	0.00
Male gender only	39	0.55	27	0.65
White only	8	0.13	24	0.52
Middle-aged or elderly	24	0.30	5	0.12
Light bulbs	7	0.10	7	0.15
Mythic stereotypes	0	0.00	7	0.17
Indications of secrecy	0	0.00	0	0.00
Scientist working indoors	24	0.30	18	0.43

The most commonly prevalent indicators of a scientist were symbols of research, technology, male gender, white race and the scientist working indoors. We will now describe some of the features that were evident in these indictors.

The common 'symbols of research' depicted in the drawings of the children who we would categorise as holders of 'pre-concepts' were test tubes and flasks, containing colourful liquids. When questioned on these symbols at the interview, children indicated they had seen such symbols on children's television programmes such as *Takhalane sesame* and *Thabang*. Only two children from School A reflected these symbols in their drawings.

In representing 'technology', children mainly drew laptops and rockets. The interviews revealed again that a probable source of these indicators was the image of science that was portrayed on television. However, two children both from School B in explaining why they had drawn the laptop alluded to the presence of the laptop at home and they believed this must have something to do with science. The following excerpt from the interviews attest to this:

> The laptop on the table is the one like the one my sister uses. She does science.
>
> It shows science working because of the importance. We have it in our home. I can also use it for stuff like animals.

No children from School A drew a laptop.

The indicator 'middle-aged or elderly' scored relatively high in the drawings of children from both schools. However, this finding needs to be interpreted with caution, as an indicator of a standard image of a scientist. The interviewed enabled us to shed more light upon these drawings. When interviewed on the drawing we established that in most instances the figures drawn did not in fact refer to a scientist but a member of the learner's family. The following excerpts from the interview illustrated this:

> My father is collecting cattle from the drinking place.
>
> This is my mother wearing a dress and high-healed shoes.
>
> My mother is asking her friend for directions.

We therefore infer that although a significant number of drawings of children from the School A reflected this indicator, this cannot be taken as evidence of their image of science and a scientist. It was merely a person whom they drew in order to draw as required.

For children at School B the situation was different as these two indicators appeared to be used in conjunction with other indicators. For example, where a child drew an elderly person, they showed the person engaged in a science activity such as building a rocket.

Another indicator which scored comparatively higher than others was 'male gender only'. We investigated the possibility that the gender of the children may have been a factor in the gender depiction of the person being drawn by doing a chi-square test. The result showed that there was a significant association between the gender of the child and that of the person drawn ($\chi^2 = 93.77$). Overwhelmingly, children had a figure of the same gender as their own. In fact there were only seven cases where a child had drawn a person of a different gender as their own. It is therefore questionable the extent to which this indicator can be considered to describe the learners' image of a scientist. The interview responses appeared to support this assertion, as children indicated a preference to depict their own gender in the drawings. The following responses indicate this when children were questioned on it:

> I showed the person like me. He is me doing science.
>
> I drew it to show me with the rocket. I want to make a rocket.

A similar argument can be advanced for the children's choice of race in their drawings as only 18 children of the 146 who participated in this study showed the race of the scientist to be different from their own race. This finding is substantiated by Dickson, Saylor and Finch (1990) cited by Finson (2002) who observed that people normally draw an image of their same sex when asked to draw a person, regardless of personality measures and family composition.

A sizeable number of children represented the 'scientist working indoors'. Table 3 shows that 24 School A children and 18 School A children showed the scientist working indoors. To a certain extent this finding correlates with other studies, which have overwhelmingly shown that children of all ages portray scientists doing work indoors.

Discussion

The results of the study show that children in the previously designated black school have little or no conception of science or a scientist. The analysis of drawings revealed little or no evidence of indicators such as a 'laboratory coat', 'symbols of research', 'technology' and 'symbols of knowledge'. The drawings by children from the private school showed a stronger conception of science and a scientist, as evidenced by the significantly higher mean indicator score per learner. With regard to the race and gender indicators, statistical analysis showed that there was an association between the race and gender identity of the child and the race and gender of the person depicted in the drawing. It is difficult to interpret this finding. On the one hand it is encouraging that the drawings by black and female children depicted images of their race and gender, as blacks and females have been traditionally underrepresented in science careers. However, as already mentioned the validity of this finding needs be explored as other studies have indicated that people tend to draw images of their own race.

As pointed our earlier apart from investigating the conception of a 'scientist' by children from diverse learning contexts, we wanted to know what this signifies in terms of the children's formation of this conception from a sociocultural perspective. We now explain the different results for the two groups of children by invoking the notion of semiotic mediation explained earlier. We have already referred to language as an important semiotic tool in learning, and we contend here that the vastly different sense-making of a 'scientist' and 'science' by children at the two schools may be attributed to the extent to which they have encountered these words within a particular social/cultural grouping. All the children at the Soweto school had either isiZulu or Sesotho as their home language, and the teaching and learning at the school took place in these languages. The word 'scientist' is therefore unfamiliar to them. We decided to translate the instruction "Draw a picture of a person doing science" into their respective home language. Despite this translation that was validated by a professor of African languages it is possible this translation was not appropriate to the language level of the children. This language difficulty with this term also became apparent from the interviews when children were asked in their home language what science was. They often responded with a blank expression without any plausible explanation. This was in contrast to children in the private school who readily responded to this same question by detailing relevant information on the subject. It is conceivable that children at both schools would have little exposure to science in their classroom instruction as the Grade R curriculum does not formalise the teaching and learning of science. In the South African curriculum, Natural Sciences as a learning area is only introduced from Grade 4 onwards. Consequently, children attending the township school would have not acquired the requisite vocabulary on concepts of 'science' and 'scientist'.

Another factor in the sense making of a 'scientist' and 'science' by the children is the status attributed to 'science' and 'scientist' by the community in which the school is situated. Lewin and Naidoo (1998) suggest that the negative experiences of black students at studying science in the apartheid years, many of who are parents of the present generation of students may have resulted in deep-seated attitudes towards science. If this is the case it is possible that children from the Soweto school (objects within a semiotic mediating activity) would have had only limited exposure to these conceptions through their interactions with elders (subjects) in their community. Furthermore, it is conceivable that these children would not in their lives have had access to mediating tools such as science books and magazines. Although we will not attempt to explain our findings with reference to social class, it is worth mentioning that cultural studies in other countries such as in the United States of America (Atwater, 2000; Zuniga, Olsen & Winter, 2005) point to social class as an important variable on importance attached to science education by sociocultural communities.

The significance of these findings needs to be considered against the inequities in education, and in particular in science education in this country due to the apartheid system. The economic development of South Africa depends upon a strong emphasis being placed on human resources in the fields of science and technology (Lewin, 1995). Historically, the proportion of people pursuing careers in science and technology has been small. This can be largely ascribed to the apartheid policies of the country, which sidelined black learners in the study of science at school. The Department of National Education's White Paper 1 on Education and Training (1994) provided a framework for the transformation of the education system. The main thrust for science education in this document is the improvement in the quality of school science for all students, especially black students so that they may pursue tertiary studies in science, and thereby follow career paths in science. As noted earlier children develop images of science and scientists from a young age, and these images do influence their attitude towards the subject. It is therefore a cause for concern that this study has revealed that Grade R children in a previously designated black suburb have little or no conception of science and a scientist.

Despite Grade R being the first year in the twelve-school career of children we believe that the findings of this study do signal that concerted steps need to be taken so that children develop stronger conceptions of science and a scientist. Although the Grade R curriculum does not making explicit reference to the teaching and learning of science, teachers need to explore other learning areas so that opportunity may be created for learners to develop images of science. For example, a goal of the Languages Learning Area is that it "develops the critical tools necessary to become responsible citizens" (Department of Education, 2002, p. 19). This particular goal can be pursued by engaging learners in an activity for example where they are asked to express their opinion on a science-related issue impacting upon society. Role models are also important in encouraging students in science and dispelling stereotypes students may hold about the race and gender of scientists.

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