Teacher Attitudes towards Misconceptions in Physics Learning

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Abstract: *This is a study of the relationship between teachers' views about misconceptions in secondary physics learning and their classroom teaching practices. An in-depth exploration of individual teacher viewpoints was conducted using Q methodology. A 50-statement Q sample was sorted by 23 physics teachers (14 experienced and 9 novices). Items were obtained from the literature and were chosen after pilot testing with a group of trainee graduate science teachers. Results showed 3 distinct viewpoints that reflected the "conception of misconceptions" in physics learning of two thirds of the participant teachers. Factors found were: tolerant/positive acceptance, confrontational/non-acceptant or less aware/indifferent about the nature of misconceptions and how to address them. Little difference was seen between the views of novice and experienced teachers. Implications for the next stage of research are discussed.*

Introduction

Teachers are key players in the learning processes of pupils. Their perspectives may influence their sense of how to help pupils appreciate the scientific endeavor during the process of acquiring scientific knowledge. The aim of the research is to examine different viewpoints of teachers about misconceptions encountered by pupils learning physics. In a review of research on teacher beliefs and practices, Fang (1996) noted that one of the more neglected aspects of this research area is how teachers deal with problems of misunderstanding of a domain-specific concept. In addition, there has been evidence that points to a large gap between research implications and current classroom practices. Passmore (1999, cited by Osborne and Monk 2000) reports a claim made by the chief inspector of schools in the UK that most educational research is irrelevant and impenetrable. Whether or not this claim is justified and backed by supporting evidence, it raises some concern as to the ability of educational research to inform the practice of teaching. Investigating the perspectives of teachers through their beliefs and understanding of a phenomenon (in this case, misconceptions in physics learning) might be one way of bridging this gap.

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There are many studies that explore science teacher perspectives (e.g., about the nature of science or the nature of teaching and learning) and their effect on instructional practices. Very few studies, however, explore teachers' understanding of the nature of misconceptions and its relation to handling misconceptions in the classroom. A recent study by Morrison and Lederman (2003) specifically identifies some strategies used by secondary science teachers to diagnose the misconceptions of pupils through interviews and classroom observations. However, it involved only four experienced teachers selected as *exemplary* by their respective schools. Some limited research explores teacher awareness of misconceptions (Osborne, Bell, and Gilbert 1983; Berg and Brouwer 1991), and these are concerned with whether teachers identify the statements of wrong ideas in some area of physics.

In this research we are concerned with determining the conceptions of misconceptions held by teachers. This research attempts to narrow the gap between the findings of educational research and the utilization of that knowledge to inform the teaching of science.

Research Context

When discussing and researching pupils' ideas in science, the interest is usually in the faulty ideas that pupils bring into the classrooms, though there are exceptions to this practice (Clement 1993; diSessa 1993). Research and theoretical discussions often refer to *pupils' ideas* synonymously with misconceptions. Hence the label *misconceptions* is widely accepted by researchers and science educators to refer to the flawed ideas of pupils from the viewpoint of current scientific perspective. Misconceptions are typically difficult to change. Although labels such as *alternative conceptions, children's science*, etc., have been used by some researchers, *misconceptions* remains the popular label, especially amongst teachers. It was fashionable, especially during the late 1970s and early 1980s, to write or speak in terms of pupils having *misconceptions*, or any of the various other terms for erroneous ideas (Rowlands *et al.* 1999).

By the late 1980s and 1990s there were concerted efforts among researchers and educators to investigate the learning processes that would lead to a deeper, more robust understanding of physics (Niedderer *et al.* 1992, 10). These efforts led to a heightened sensitivity about the worth of the ideas of pupils and the crucial role of interpreting their reasoning skills within a particular context, whilst taking account of the affective aspects of the situation. It is now quite unfashionable to view the misconceptions of pupils as outrightly wrong and needing to be replaced or discarded in favour of more scientifically accurate conceptions. Some researchers suggest using the term *unproductive* (Smith *et al.* 1993/94), implying that misconceptions so labeled require refinement or reorganization rather than total discard.

What is a misconception?

In the pertinent literature, the term is rarely defined explicitly. Some researchers have taken a *macroperspective* approach in attempting to analyse pupils' ideas and misconceptions, viewing them as *theory-sized chunks*, which form part of a larger, more complex repertoire of cognitive structure. Hammer (1996) used the term misconception perspective, while others refer to it as the alternative framework movement (Gilbert and Watts 1983), or alternative conceptual framework view (Carey 1986). The macroperspective approach has been widely accepted among those involved in science education research (Hammer 1996). This perspective defines the misconception as a one-sentence characterization (Carey 1986, 1128); for example 'motion is always in the direction of force,' or 'whenever there is motion, there must be a force.' This parallels Linder's (1993) *mental model-based perspective*, where a scientific concept is characterized as a "tangible *inside-the-head* construct made up of structured propositional patterns of reasoning" (p. 294). In addition, misconceptions are said to be internally consistent and coherent, relatively stable across different contexts, and different from scientific conceptions, having, therefore, lower status than the scientific counterparts. Further, misconceptions are usually strongly held, resistant to change, particularly by traditional teaching methods, and can seriously interfere with learning. For these reasons misconceptions need to be confronted, eventually eliminated, and replaced by the accepted scientific concepts.

Other researchers take a *microperspective,* looking at a smaller, more elemental and abstract, concept-sized unit. Examples are: diSessa's *phenomenological primitives* or *p-prims* (1993), Minstrell's *facets of knowledge* (1992), and the *mental enactment and prototypes* of Yates *et al.*(1988). Linder (1993) categorizes this view as an experientially based perspective. The microperspective emphasizes the relationship between the learner and the context in which the notion of the concept takes place. "Without context it is not reasonable to claim that conceptions are appropriate, legitimate, correct, or otherwise" (Linder 1993, 295). P-prims are cognitive structures more fundamental than misconceptions that, when appropriately cued and activated, lead to a correct conclusion, and when inappropriately cued and activated need to be restructured and refined (as opposed to removed and replaced) in order to build expert understanding.

Method

Q Sample

Statements for the Q sample were gathered from the literature in the field of science misconceptions. The phenomenon of interest here is the cataloging of viewpoints about misconceptions in physics. It is helpful to conceptualise the phenomenon around the simplest structure consisting of only two categories, viz., the macro- and microperspectives, bearing in mind that there are issues on which individuals with these perspectives can agree. The statements were structured loosely around the nature, origin/sources, and pedagogical issues concerning misconceptions. Fifty statements were chosen for the Q sample and pilot tested with trainee graduate science teachers from The University of Manchester. (Tables 3-6.)

Person Sample

The nature of this study requires inclusion of novice and experienced teachers. Participants include nine secondary physics teachers, with less than two years experience teaching science, and fourteen physics teachers with more than ten years experience. The teachers were recruited from nine different schools in the Manchester and the Greater Manchester area.

Q Sort

Marker cards were placed on a 7-point distribution scale like that in Table 1, and participants were instructed to rank order the statements from -3 for strongly disagree to +3 for strongly agree. Sorting usually took about forty minutes to an hour, depending upon any verbal elaboration made by the sorter during a post-sort interview which was audio taped. The full description of the methodology can be found in Brown (1980).

Table 1. Q sort distribution

Description	*Strongly disagree*	*Disagree*	*Slightly disagree*	*Neutral*	*Slightly agree*	*Agree*	*Strongly agree*
Score	-3	-2	-1	0	1	2	3
Frequency	5	7	8	10	8	7	5

Factor Analysis

The PQMethod version 2.11 (Schmolck 2002) software package was used to analyze the data. Factors were extracted using the principal component solution, and judgementally rotated to produce a simpler structure, hence improving factor interpretability .

Results and Interpretations

From a statistical standpoint, a 3-factor solution was selected on the basis of two conditions, viz., factors that contain significant factor loadings, with a value greater than 0.4 (Stevens 1992) and factors that contain a minimum of four participants with significant loadings. According to Brown (1980), the latter condition can improve the reliability of the results. From a theoretical standpoint, the literature suggests two major categories to be represented by a 2-factor solution, but one additional factor was included to represent any other category emerging from the data. The 3-factor solution accounted for 52% of the variance in the participant set, with 15 of 23 participants included.

For Factors 1-3, there are 4, 7, and 4 significantly loading participants, respectively, which suggests greater factor stability (Fairweather 2001). Table 2 shows only moderate correlation among the three factors.

Table 2. Correlation between Factors

Factor	*1*	*2*	*3*
1	1.00	-	-
2	0.39	1.00	-
3	0.32	0.40	1.00

Consensus Items

Table 3 shows six statements for which the rankings do not differ significantly among the three factors. Half of these are statements that all participants ranked towards the middle of the distribution, and hence are of little significance to them. Among the more prominent are statements 12, 16, and 36. The participants acknowledge to varying degrees the positive role misconceptions can play in learning (12). They admit teachers are one of the sources of misconceptions (16). but indicate searching regularly for innovative teaching strategies to deal with misconceptions (36). All factors, however, ranked Statement 40 towards the middle of the distribution (0, 1, -1), indicating that research findings on misconceptions do not directly impact their teaching practices.

Table 3. Consensus Statements

No.	***Statement***	***Factor Scores***		
		F1	***F2***	***F3***
6	Many students tend to finish college physics courses with the same misconceptions with which they began.	-1	-1	0
11	The same misconception may arise in some contexts but not in others.	1	0	1
12	Misconceptions can be viewed as useful raw material out of which students can construct more sophisticated understandings of physics.	2	1	2
18	Misconceptions result from the lack of reasoning abilities.	-2	-2	0
32	Viewing misconceptions as flawed ideas to be rejected conflicts with the basic premise of constructivism: that students build more advanced knowledge from prior understandings.	1	0	0
36	I regularly search for innovative teaching strategies to effectively handle students' misconceptions in class.	1	2	2

Consensus statements provide an insight into the views of teachers about misconceptions, but in order to describe and theorise about the distinct factor viewpoints, it is necessary to examine statements that clearly distinguish one factor from the others (*distinguishing statements*). Factors were also interpreted through an examination of statements each factor scored +3, +2, -3, and -2. Provisional names reflect general themes of the factors albeit not in their totality, since complex subjective viewpoints are seldom so easily encapsulated. The factors should be considered operant categories, since they arise from the Q sort data rather than logical categories (novice or experienced view) or theoretical categories (micro- or macroperspective). Science generally prefers to base its hypotheses on the former (Brown 1980).

Factor 1: Tolerant/Positive Acceptant

One novice (11% of novice sorters) and three experienced (21% of experienced sorters) teachers defined this factor. Teachers in this factor are more tolerant than those on other factors towards the misconceptions of pupils. Distinguishing and high scoring statements for Factor 1 are shown in Table 4. Their tolerance is evidenced by the way they advocate addressing the problem of pupil misconceptions, where promoting multiple ways of looking at a problem is favoured over the more linear confront and replace approach (35):

> "The word confront is too harsh, it reduces the confidence of the pupils ..."
>
> (Jim, 16/7/02)
>
> "Promoting multiple ways of looking at a problem, I do that every time."
>
> (Barbara, 30/1/03)

This attitude also manifests itself in statement (29) where teaching by confronting is declared as misguided. These teachers also have a high regard for the role misconceptions play in the learning process (4), and are not sure whether misconceptions hamper the progress towards expert conceptions at all (3):

> "Misconception is a misunderstanding or a lack of understanding. It is not a mistake. It is just a child's handling of a concept. ...If you're teaching a concept and you are regarding a child's interpretation of that concept as a mistake, then it is the teaching that is a mistake."
>
> (Barbara, 30/1/03)

However they believe that in order to resolve the conflict between the viewpoint of the pupil and that of the scientist, pupils need to be aware of their misconceptions and feel dissatisfied with them (20). That they do not bother to differentiate between preconceptions and misconceptions (2) and do not reject the idea of a misconception as an alternative way of looking at a phenomenon (39) is further evidence of tolerance towards the misconceptions of pupils. Teachers in Factor 1 are sceptical about the conventional teaching methods for addressing misconceptions. In their view neither lectures (22) and classroom experience can (10), nor the conventional laboratory is effective in eliminating misconceptions (24):

Table 4. Salient Statements for Factor 1

No.	Statement	Score	Z
20	Resolving misconceptions requires that learners be both aware of the misconception and dissatisfied with it.	3	1.97**
35	Promoting multiple ways of looking at a problem is more fruitful than confronting and replacing a misconception.	3	1.44**
4	Misconceptions can play a productive role in learning a science concept.	3	1.39†
30	Some misconceptions may be helpful when a student attempts to handle day-to-day experiences.	2	1.00**
48	Misconceptions tend to get resolved with further exposure and experience even without challenging them explicitly.	2	0.97**
8	Misconceptions are widespread, occurring at all ages and educational levels.	1	0.73**
29	Instruction that confronts misconceptions is misguided.	1	0.36**
2	Not all students' preconceptions are misconceptions.	0	0.21*
3	Misconceptions do not interfere with students' development of scientific understandings.	0	0.07**
39	What is considered as a misconception should be regarded as an alternative or a different way of looking at a phenomenon.	0	0.06**
24	The conventional physics laboratory is an effective strategy for dealing with students' misconceptions.	-1	-0.32**
13	Some misconceptions are easily removed in the course of instruction.	-1	-0.43**
47	The physics curricula used in most schools today do not help remedy the problem of persistent misconceptions amongst students.	-1	-0.44*
37	In depth physics knowledge rather than pedagogical knowledge is required to effectively deal with students' misconceptions.	-2	-0.95**
10	Physics classroom experience does eliminate misconceptions.	-2	-1.34**
5	Proficiency in solving quantitative problems is an indication of the absence of misconceptions.	-3	-1.79**
22	Lectures in conventional physics classrooms can eliminate misconceptions.	-3	-2.14**

*Note. *Significant at $p<0.05$; **$p<0.01$. †High scoring but non-distinguishing*

> "They'll go out not understanding what they've done. They just sets up circuits and ...[were]...done, but they don't really understand what's happening." (Bob, 16/6/02)

These teachers disagree with Statement 13, believing that misconceptions are not easily removed by conventional methods of instruction:

> "I don't think they …[misconceptions]…are easily removed at any time. I think the first thing you've got to [do is] break down that misconception and build new ideas. Very often you need to take things back a few steps."
>
> (Jim, 16/7/02)

Their belief that the pedagogy a teacher employs is as important as the knowledge the teacher possesses (37) further demonstrates their emphasis on teaching methodology.

Factor 2: Confrontational/Non acceptant

Factor 2 has more loaders than the others, with three novices (33% of novice sorters) and four experienced teachers (29% of experienced sorters) as significant pure loaders. These teachers appear to accept the widely held macroperspective view on pupils' conceptions and misconceptions. Distinguishing and highly ranked statements for Factor 2 are shown in Table 5. These teachers are quite unsympathetic towards pupil misconceptions. They tend to believe misconceptions are inherently flawed (43) (33) (39):

> "It is a mistake and not an alternative viewpoint."
>
> (Andy, 5/6/03)

> "I wouldn't consider a flat earth as a different way of looking. I think it is wrong and should be removed." (Tom, 7/5/03)

Misconceptions are also seen as unproductive in terms of helping pupils progress toward expert conception (43):

> "I wouldn't start teaching a new scientific concept by using a misconception. I might bring misconceptions to it later but I wouldn't base a lesson on that misconception" (Sue, 27/1/03)

Hence, they strongly advocate confronting misconceptions (29) in order to replace them by the appropriate conceptions (21):

> "The instruction should confront the misconception [wherever you find them], so if you're saying that instruction that confronts misconceptions is misguided, [then] I'm disagreeing with it [because] you should have instruction that confronts misconceptions." (Roger, 12/6/02)

They acknowledge the widespread occurrence of misconceptions at all ages and educational levels (8), but tend not to believe misconceptions are helpful even for everyday experiences (30):

> "I'm sure there's misconception all the way through university, at degree level, and even at university physics there'll be some …
>
> (Roger, 12/6/02)

Interestingly they do not put the blame on physics curricula (47) and express neutrality towards current conventional classroom practices (22) (26) (10).

Table 5. Salient Statements for Factor 2

No.	Statement	Score	Z
8	Misconceptions are widespread, occurring at all ages and educational levels.	3	1.67**
17	Physics textbooks contain misconceptions.	3	1.45**
25	Historical approaches to teaching physics can help students see their understanding of physics to just be incomplete or immature as opposed to wrong.	2	1.12*
43	Misconceptions cannot act as a basis for learning scientific concepts because they are flawed.	2	0.97**
13	Some misconceptions are easily removed in the course of instruction.	1	0.96*
20	Resolving misconceptions requires that learners be both aware of the misconception and dissatisfied with it.	1	0.83**
15	Misconceptions reflect a basic lack of knowledge.	1	0.64**
40	Research findings on misconceptions have a direct impact on my teaching practices.	1	0.58*
22	Lectures in conventional physics classrooms can eliminate misconceptions.	0	0.29*
26	Students' verbalization of their understanding of a physics concept can help them clarify their misconceptions.	0	-0.04**
10	Physics classroom experience does eliminate misconceptions.	0	-0.08**
50	Misconception as a term tends to devalue students' prior knowledge.	-1	-0.23*
19	Illustrating relationships between concepts by drawing lines linking keywords is a useful tool for discovering and confronting students' misconceptions.	-1	-0.33**
33	Misconceptions can be both flawed and productive, depending on the problem that is faced.	-1	-0.36**
48	Misconceptions tend to get resolved with further exposure and experience even without challenging them explicitly.	-1	-0.72*
30	Some misconceptions may be helpful when a student attempts to handle day-to-day experiences.	-1	-0.75**
23	A common misconception in mechanics is that if an object is at rest it cannot be accelerating.	-2	-1.11**
47	The physics curricula used in most schools today do not help remedy the problem of persistent misconceptions amongst students.	-2	-1.19*
39	What is considered as a misconception should be regarded as an alternative or a different way of looking at a phenomenon.	-2	-1.32†
21	Student misconceptions should not be replaced by appropriate conceptions.	-3	-1.69†
29	Instruction that confronts misconceptions is misguided.	-3	-1.88*

*Note: *Significant at $p<0.05$; **$p<0.01$; †High scoring but non-distinguishing.*

Factor 3: Less Aware/Indifferent

Factor 3 teachers seem less aware or indifferent about the status of misconceptions. Two novice (22% of novice sorters) and two experienced (14% of experienced sorters) teachers define the factor as significant pure loaders. Distinguishing and high scoring statements are shown in Table 6. Teachers in Factor 3 tend to be uncertain and sometimes have conflicting feelings with regards to the worth of misconceptions and how to deal with them:

> "...whether it (*promoting multiple ways of looking at a problem*) is better than confronting and replacing a misconception, I don't know...."
>
> (Wendy, 24/1/03)

> "I don't have any preconceived strategies what I'm going to do. I would like to but, I have no time to find out beforehand what misconceptions are likely to be..."
>
> (Jack, 5/3/03)

They agree that misconceptions differ from scientific conceptions (1), but they are not sure whether misconceptions can be regarded as mistakes (27):

> "..is it a mistake, is it a misunderstanding? It is difficult to say. ...a misconception is you get in there with preconceived ideas that are wrong."
>
> (Jack, 5/3/03)

> "Yeah, (*it is a mistake*) but I don't know really... I have to go away and think about it."
>
> (Wendy, 24/1/03)

They strongly feel that misconceptions are not consistent and coherent (9), but do not think they are formed spontaneously either (31). In terms of addressing misconceptions, they have trust in physics lessons (10) but not in physics curricula (47). They tend not to put the blame on poor teaching as the cause of persistent misconceptions (46), and further believe that some misconceptions are easily removed by instruction (13). They are uncertain about the role of misconceptions in everyday lives (30) and whether reasoning abilities have any bearing on having misconceptions (18). Their unawareness of the extent of the problems of misconceptions is seen in statements (8) and (45). They are not sure whether misconceptions are widespread (8) and strongly believe that pupils will be free of their misconceptions in the end (45):

> "Children gain their own perspective of the world and they change their own misconceptions of the world as they grow up. So they do tend to get rid of (*the misconceptions*)..."
>
> (Bill, 30/1/03)

Table 6. Salient Statements for Factor 3

No.	Statement	Score	Z
7	Misconceptions can result from misinterpretation of analogies.	3	2.19**
13	Some misconceptions are easily removed in the course of instruction.	3	1.57*
1	Misconceptions are conceptions that differ from scientific ones.	2	1.21**
10	Physics classroom experience does eliminate misconceptions.	2	0.97**
47	The physics curricula used in most schools today do not help remedy the problem of persistent misconceptions amongst students.	1	0.65**
27	Casting misconceptions as mistakes is too narrow a view of their role in learning.	0	0.14**
30	Some misconceptions may be helpful when a student attempts to handle day-to-day experiences.	0	0.11**
18	Misconceptions result from the lack of reasoning abilities.	0	-0.07*
48	Misconceptions tend to get resolved with further exposure and experience even without challenging them explicitly.	0	-0.10*
8	Misconceptions are widespread, occurring at all ages and educational levels.	0	-0.28**
22	Lectures in conventional physics classrooms can eliminate misconceptions.	0	-0.31*
34	Literal replacement of misconceptions with new scientific knowledge oversimplifies the changes involved in learning physics.	-1	-0.48**
31	Misconceptions are formed from spontaneous reasoning in an unfamiliar situation.	-1	-0.51*
28	Replacing misconceptions is not always desirable.	-1	-0.57**
46	Persistent misconceptions are due to poor physics teaching that takes place in schools.	-1	-0.90**
45	Students never really let go of their misconceptions and these remain part of their conceptual repertoire throughout their lives.	-2	-0.93†
20	Resolving misconceptions requires that learners be both aware of the misconception and dissatisfied with it.	-2	-1.20**
29	Instruction that confronts misconceptions is misguided.	-2	-1.20*
41	Misconceptions are stable and emerge in students' reasoning across different contexts.	-2	-1.31**
9	Misconceptions are internally consistent and coherent.	-3	-1.58**

*Note. *Significant at* $p<0.05$*; ***$p<0.01$*. †High scoring but non-distinguishing*

Although they advocate confronting misconceptions as a way of resolving them (29), they think that pupils need not be both aware of and dissatisfied with them (20):

> "A lot of students will just do what you say. If you say electricity flows through wires, they'll go away and say electricity flows through wires, ok, and they will discard everything else that they formerly thought. So they don't have to be aware of their former misconceptions, they would just take what you say and then that's brilliant. Their former misconceptions fall by the line"
>
> (Bill, 30/1/03)

Their uncertainty with the status of misconceptions continues with statements (28) and (34). There is subdued support for the replacement of misconceptions (28), but do not feel that literal replacement oversimplifies the learning process (34).

Crosstabulation

Crosstabulation provides one way of presenting data in order to examine the relationship between level of teaching experience and factor type. The small sample in this study however precludes the use of inferential statistics such as chi-square tests. Table 7 shows the crosstabulation table produced by SPSS which contains the number of cases that falls into each combination of categories. The table provides a summary of previously quoted percentages. In general there appears to be no directional pattern in terms of the relationship between level of teaching experience and factor type as seen from the small differences between the '% within factor' for both levels of teaching experience and factor type 2 and 3 (Refer to the lightly shaded cells) The only relatively large difference is for factor type 1 where relatively more experienced teachers (75%) loaded onto it than novice teachers (25%) (Refer to the darker shaded cells) This finding appears to suggest that there is little association between level of teaching experience and factor type for this group of participants.

Discussion and Conclusions

This study examines the views of teachers about issues related to student misconceptions in physics learning. Through Q methodology three distinct subjective viewpoints emerged from factor analysis of the Q sort data. With regard to the status of misconceptions and how to address them, two thirds of the participants operationally fall into the categories of tolerant/positive acceptant, confrontational/non-acceptant, or less aware/indifferent. There are similarities, however, on some dimensions among teachers who hold different overall perspectives. Q-factor analysis does not assume that categories are mutually exclusive: people can resemble more than one factor to differing degrees. "People rarely fall into clean, mutually exclusive categories" (Western 2002, Q method discussion list). In other words, the loading for each Q sort indicates the degree to which the sorter's viewpoint resembles the characteristics ascribed to a particular factor. The Q sort with the highest loading is most representative of the factor.

Table 7. Level by Factor Type Crosstabulation

Level		***Factor Type*** ***1***	***2***	***3***	***Total***
Novice	Count	1	3	2	6
	% within Level	16.7%	50.0%	33.3%	100.0%
	% within Factor	**25.0%**	**42.9%**	**50.0%**	40.0%
	% of Total	6.7%	20.0%	13.3%	40.0%
Experienced	Count	3	4	2	9
	% within Level	33.3%	44.4%	22.2%	100.0%
	% within Factor	**75.0%**	**57.1%**	**50.0%**	60.0%
	% of Total	20.0%	26.7%	13.3%	60.0%
Total	Count	4	7	4	15
	% within Exp	26.7%	46.7%	26.7%	100.0%
	% within Factor	100.0%	100.0%	100.0%	100.0%
	% of Total	26.7%	46.7%	26.7%	100.0%

% *Relatively large difference between novice and experienced teachers*

% *Relatively small differences between novice and experienced teachers*

Among the one third of the teachers who did not load on one of the three interpreted factors, eight loaded significantly onto two or more factors. One defines none of the main factors, which means that he has a unique perspective. "Generally it is not worth examining a factor that explains only one Q sort" (Brown 1980, 232), unless there is a reason to purposefully examine that particular person's view (e.g. the head teacher's view).

Tolerant teachers (Factor 1) have a more positive attitude towards the misconceptions of pupils and do not reject the idea that a misconception can be considered as an alternative way of looking at a problem situation. Although they advocate ultimate replacement of a misconception with the appropriate scientific explanation, they support a multiple perspectives approach towards reaching understanding about a flawed concept. They do not support 'teaching by confronting' misconceptions in order to resolve them. They are not convinced that misconceptions interfere with the learning of scientific conceptions. They think that some misconceptions are helpful for everyday purposes. For example, the idea of 'force causes motion (velocity)' is helpful when you wish to move something around the house. From the macroperspective view however, this constitutes a misconception, since the Newtonian conception of motion states that 'force causes change in motion (acceleration)' not velocity. They believe that it requires a good balance between the subject knowledge of the teacher and pedagogy to address misconceptions in class. Hence there is a lack of support for conventional teaching methods, which usually include one-way lectures and a recipe-based laboratory. In many ways tolerant teachers appear to subscribe to the microperspective view of the misconceptions of their pupils. The only major difference is that the microperspective view does not advocate replacing misconceptions, since it does not see pupils as *having* misconceptions. The Q sample does not include enough specific statements pertaining to this issue to allow a fuller analysis of this difference in viewpoints. Writing Q sample statements that reflect microperspective accounts of the conceptions of pupils was difficult because the literature is replete with jargon. An example is: "Students' responses are situated acts of conceiving involving p-prims" (Hammer 1996, 98). The word p-prims itself is technical jargon that teachers likely never encounter. Therefore, it can be argued that the participants not have thought of misconceptions in terms of 'an act of cuing and activating a generic and abstract element of knowledge to a problem situation, which is dependent on a specific context.' None of the participants made any comments during or after Q sorting that reflected the p-prims approach to understanding the misconceptions of pupils. If included in the Q-set, such statements would most probably be put in the middle of the distribution, as was evidenced from the results of pilot testing with several statements containing technical terms such as *conceptual change* and *concept map*. In effect the interview reveals that *all* participants acknowledge that pupils have conceptions that are flawed but are useful or productive to varying degrees. 'User-friendly' Q-set statements that can definitively reveal this account of microperspective, if it exists, are needed.

By contrast, confrontational teachers (Factor 2) have a negative attitude toward pupil misconceptions. They believe misconceptions are inherently flawed, and hence are neither useful material for building expert conceptions nor useful for everyday purposes. These teachers prefer a confrontational approach when dealing with misconceptions in class, because they believe misconceptions will not go away with further exposure and experience. They are, however, ambivalent towards conventional teaching methods, but think that the physics curricula do address misconceptions. For example, one of the most common misconceptions can be found in the topic of electricity (that current is 'used up') being inserted in the National Curriculum in England (1999) for a science program. All these views seem to align well with the macroperspective way of looking at the misconceptions of pupils, except that Factor 2 teachers are uncertain whether misconceptions are as stable and consistent as proponents of the macroperspective view appear to believe.

Factor 3 teachers seem to be less aware or even indifferent about misconceptions. They are uncertain about quite a lot of crucial issues concerning misconceptions, such as the worth of misconceptions in learning and everyday lives, the extent to which the problem affects learners, and the way to address the problem in class.

The results suggest little difference between the views of novice and experienced teachers. Without the use of inferential statistics it cannot be inferred with confidence whether the observed difference is statistically significant. However the data show that every factor type is represented by both groups of teachers. This suggests that experienced teachers can be just as tolerant, confrontational, or unaware of misconceptions as novice teachers. It also means that teachers don't necessarily improve in terms of awareness and understanding of the misconceptions of their pupils simply by having years of teaching experience. Studies on teacher awareness and knowledge of pupil misconceptions as cited in the literature review support this finding. In a study by Morrison and Lederman (2003), assumptions include an invalid view that exemplary experienced teachers would have "a concern for students' understanding and would be more likely to pay attention to students' conceptions than normal teachers" (p. 851) . None of the teachers in the study has a clear vision of what the preconceptions of pupils are, and there appears to be a lack in the repertoire of teaching strategies to diagnose the preconceptions of pupils. Q methodology has provided a useful strategy alternative to the often used methods of survey and direct interview. On the other hand, teachers' knowledge of representations of subject matter and understanding of pupil learning difficulties (termed *Pedagogical Content Knowledge* by Shulman 1987) typically broadens only through continuing professional development (Scott 2001). Hence it is not unreasonable to associate more years of teaching experience with greater teacher awareness and understanding of the conceptions and misconceptions pupils. However the result suggests that it may not be so simple a linear relationship.

Only recently the Initial Teacher Training National Curriculum (DfEE 1998) has put an emphasis on pedagogical content knowledge in the area of misconceptions of pupils. It specified that teacher trainees be taught about the misconceptions of pupils in terms of types, origins, and how to deal with misconceptions in class. Prior to this, higher education institutions (e.g. universities and colleges) had greater control of the curricular content and processes used in training teachers (Scott 2001). If the new curriculum has any significant effect, novice teachers emerging fresh from initial teacher training would be expected to be more aware of pupil misconceptions. Unfortunately both novice and experienced teachers agree that initial teacher training does not adequately address the issues related to the conceptions and misconceptions pupils, as evidenced in this work from the universal disagreement with statement (38). This is further corroborated by comments made during and after Q sorting:

> "I don't really feel any better able to teach physics...We came out more confused than we went in... I don't think we are being taught..(what student teachers should be taught)."
>
> (Novice, 28/3/03)

> "I would like to have strategies for dealing with this, being a second year teacher, I don't. When will I have it? I don't know. I feel as though it would be nice to have been given, or been able to have time to formulate strategies before this point, but things that have been done on PGCE (Post Graduate Certificate in Education) courses don't deal with misconceptions. You might be looking at maybe an afternoon lecture and a very small amount of follow up work, or reading or whatever. Although I've been given some sort of indication on how to go about dealing with it, it's not something I've ever practiced doing. So it is a very slow process...If more time had been spent during PGCE perhaps I would find much easy to do it (handle misconceptions) at this point."
>
> (Novice, 5/3/03)

> "I'm thinking back to when I was training (1980's) and I don't think it was ever mentioned."
>
> (Experienced, 16/7/02)

Some of the more experienced teachers welcome the emphasis placed on the misconceptions of pupils during training:

> "Well, it's a long time since I did my teacher training. But I know there was no mention of misconception when I did my training 30 years ago. That's very important (emphasizing misconception in teacher training)."
>
> (Experienced, 16/7/02)

Implication for future research

All three factors analyzed in this study recognize teachers as one source of misconceptions. While they say that they individually search regularly for innovative teaching strategies to deal with misconceptions, none felt that research findings on misconceptions directly impact their teaching practices. These responses can only be confirmed by directly observing teachers at work in their respective classrooms, which will be another part of the overall research.

Several questions arise that will focus the research based on these three perspectives. What do the teachers see as the tasks for teaching? Results suggest that all three perspectives have similar judgments about teaching tasks. All advocate that misconceptions need to be replaced with the appropriate conceptions. Universal support for a *remove and replace* approach is not surprising, and it most probably arises because pupils eventually will face a fairly severe assessment based largely on their knowledge and understanding of science. This evaluation will reflect to some extent how well they have been taught. The difference among the factors is in the way the teachers go about removing and replacing misconceptions. One perspective prefers the *softly*-softly approach, another is confrontational, and the third view is clouded with uncertainties. How do the three approaches translate into classroom practice? Does each one specifically address the misconceptions of pupils during lessons? How do these practices compare with the ones research findings in this area advocate as potentially superior in terms of resolving misconceptions? It will be useful to learn if these practices relate to the views of teachers and attitudes towards misconceptions found in this study.

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References

Berg, T. and Brouwer, W. 1991. Teacher awareness of student alternate conceptions about rotational motion and gravity. *Journal of Research in Science Teaching* 28(1):3-18.

Brown, S.R. 1980. *Political subjectivity: Applications of Q methodology in political science.* London:Yale University Press.

Carey, S. 1986. Cognitive science and science education. *American Psychologist* 41(10):1123-30.

Clement, J. 1993. Using bridging analogies and anchoring intuitions to deal with students' preconceptions in physics. *Journal of Research in Science Teaching* 30(10):1241-57.

Department for Education and Employment (DfEE) and Qualification and Curriculum Authority (QCA) 1999. *Science in the national curriculum for England.* London: Her Majesty's Stationery Office and QCA.

DfEE 1998. *Teaching: High status, high standards: Requirements for courses of initial teacher training circular 4/98.* London: Department for Education and Employment.

diSessa, A.A. 1993. Toward an epistemology of physics. *Cognition and Instruction* 10: 105-225.

Elby, A. 2000. What students' learning of representations tells us about constructivism. Retrieved February 27, 2001. URL *http://www2.physics.umd.edu/~elby/papers/contructivism/representations.htm.*

Fairweather, J.R. 2001. Factor stability, number of significant loadings, and interpretation: Evidence from three studies and suggested guidelines. *Operant Subjectivity* 25(1):37-58.

Fang, Z. 1996. A review of research on teacher beliefs and practices. *Educational Research* 38(1): 47-60.

Gilbert, J.K., and Watts, M. 1983. Concepts, misconceptions and alternative conceptions: Changing perspectives in science education. *Studies in Science Education* 10:61-98.

Hammer, D. 1996. Misconceptions or P-Prims: How may alternative perspectives of cognitive structure influence instructional perceptions and intentions? *The Journal of the Learning Sciences* 5(2):97-127.

Linder, C.J. 1993. A challenge to conceptual change. *Science Education* 77(3):293-300.

Minstrell, J. 1992. Facets of students' knowledge and relevant instruction. In *Research in physics learning: Theoretical issues and empirical studies,* 110-27. Edited by R. Duit, F. Goldberg, and H. Niedderer. Kiel, Germany: Leibniz-Institut für die Pädagogik der Naturwissenschaften (IPN).

Morrison, J. A. and Lederman, N.G. 2003. Science teachers' diagnosis and understanding of students' preconceptions. *Science Education* 87:849-67.

Niedderer, H., Goldberg, F., and Duit, R. 1992. Towards learning process studies: A review of the workshop on research in physics learning. In *Research in physics learning: Theoretical issues and empirical studies,* 10-28. Edited by R. Duit, F. Goldberg, and H. Niedderer. Kiel, Germany: Leibniz-Institut für die Pädagogik der Naturwissenschaften (IPN).

Osborne, J. and Monk, M. 2000. *Good practice in science teaching: What research has to say.* Buckingham: Open University Press.

Osborne, R., Bell, B.F., and Gilbert, Y.K. 1983. Science teaching and children's view of the world. *European Journal of Science Education* 5:1-14.

Rowlands, S., Graham, T., and Berry, J. 1999. Can we speak of alternative frameworks and conceptual change in mechanics? *Science and Education* 8:241-71.

Schmolck, P. 2002. PQMethod (Version 2.11, adapted from mainframe-program Qmethod written by John Atkinson, 1992) [Computer Software]. Neubiberg, University of the Bundeswehr Munich. Available as freeware at:*//www.rz.unibw-muenchen.de/~p41bsmk/qmethod/*.

Scott, P. 2001. The initial teacher training national curriculum for secondary science: on learning to be a high school physics teacher. *Physics Education* 36(5):394-8.

Shulman, L.S. 1987. Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review* 57:1-22.

Smith, J.P., diSessa, A.A., and Roschelle, J. 1993/1994. Misconceptions reconceived: A constructivist analysis of knowledge in transition. *The Journal of the Learning Sciences* 3(2):115-63.

Stevens, J.P. 1992. *Applied Multivariate Statistics For the Social Sciences (2nd Ed.).* Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Yates, J., Bessman, M., Dunne, M., Jertson, D., Sly, K., and Wendelboe, B. 1988. Are conceptions of motion based on a naïve theory or on prototypes? *Cognition,* 29:251-75.