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How Aware Are Teachers of Students' Misconceptions in Astronomy? A Qualitative Analysis in Belgium

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ABSTRACT: Where previous studies have shown the existence of misconceptions in astronomy, this research focuses on the level of awareness that teachers have of these misconceptions and the possible strategies they use to change the students' mental models. Through focus group interviews with secondary school teachers and semi-structured interviews with teacher managers, this latent knowledge is made more explicit. The main findings suggest that the level of awareness about misconceptions varies considerably among the teachers. In general, the same pattern is found for the teacher managers. Some mental models, for example, the distance model are known by all the teachers whereas others are not known at all. Even though teachers acknowledge the importance of students' preconceptions in general, they have difficulties using their students' prior knowledge in an effective way in their teaching practice. According to the teachers, this is mainly due to a lack of time and difficulties experienced with differentiation. Suggestions are made to raise awareness on the one hand via teacher managers and teacher training programs for preservice, as well as inservice, teachers and to avoid further misconceptions on the other hand via a proper use of images in textbooks.

KEY WORDS: misconceptions, teachers, awareness, astronomy, pedagogical content knowledge

INTRODUCTION

We encounter astronomical phenomena daily, although we are not always conscious about them. The alternation of day and night, the seasons, the stars in the sky and different views of the moon, are just a few examples. Research indicates that many people have misconceptions about these topics (Brewer, 2008), whereby misconceptions, or naive models or theories, can be seen as mental models that do not correspond to a scientific model (Atwood & Atwood, 1996; Brewer, 2008). Much

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research has been carried out to clarify which misconceptions are held by students and how persistent they are (Brewer, 2008; Galperin & Raviolo, 2015; Lelliott & Rollnick, 2010; Miller & Brewer, 2010; Nazé & Fontaine, 2014; Starakis & Halkia, 2014; Vosniadou & Brewer, 1992). Other studies have investigated the relation between conceptual change and specific types of instructions (Celikten, Ipekcioglu, Ertepinar, & Geban, 2012; Lee, 2014; Trundle, Atwood, & Christopher, 2007). It is clear that the implementation of this kind of instruction can only be undertaken when teachers know the misconceptions in general, when they detect them in their students and when they are capable of implementing these strategies in their lessons. This connection is partly emphasized by Halim and Meerah (2002). Their results suggest that pre-service teachers who have less content knowledge are also less aware of potential misconceptions of students and, in consequence, are unable to propose different teaching strategies. This knowledge on students' misconceptions and on possible teaching strategies is part of what Shulman (1987) calls the pedagogical content knowledge (PCK) of teachers. PCK is described as "the special amalgam of content and pedagogy that is uniquely the province of teachers" (Shulman, 1987, p.8) and is an important element in the knowledge base for teaching. Therefore, PCK is not only about the amount of knowledge, but also about the quality of this knowledge and how teachers effectively use this in their everyday practice of teaching (Abell, 2008; Kaya, Kablan, Akaydin, & Demir, 2015).

As teachers need to decide in their classes which teaching strategies are best for their students in certain circumstances, it is interesting to study their awareness regarding the misconceptions of their students. Furthermore, the attempts teachers make to achieve conceptual change can be studied. However, very little research has been conducted on both themes. This is rather alarming as these misconceptions are known for their persistency (Brewer, 2008). Even after years of intensive training and education, some misconceptions remain unchanged. This is confirmed by Lightman and Sadler (1993) who compared the learning gains of the students as predicted by the teachers with the real learning gains after an Astronomy course. Their study shows teachers vastly overestimate their students' learning gains, and these overestimations are higher for the conceptual questions than for factual questions. Morrison and Lederman (2003) show that the teachers in their study are all convinced of the importance of knowing the preconceptions of students, but none of them use any formal assessment tool to identify these preconceptions. They all claim to use questions and conversations in classrooms, but these are mostly recall questions. Therefore, teachers have only a weak understanding of the preconceptions of the students.

Given the variety in and the importance of the awareness of teachers regarding misconceptions, the quality of the PCK in relation to

misconceptions in Astronomy and the use of PCK in teaching practices is investigated in this research. We seek answers to the following research questions:

1. To what extent are teachers aware of the mental models students have about astronomical concepts, more in particular about the cause of the seasons?
2. What kind of strategies do teachers use in order to achieve conceptual change?

METHODOLOGY

To get insight into teachers' awareness of student ideas in astronomy, focus group interviews with geography teachers, and individual interviews with teacher managers were conducted. In this section, the participants as well as the protocol of both interviews are described in detail.

The focus group interviews

In order to gain insight of participants' ideas and thinking on the teaching of astronomy, focus groups were preferred above individual interviews. The literature suggests that a group discussion, moderated by a researcher, can be stimulating allowing a more profound conversation since the ideas of others can activate people's own thinking and reasoning (Carey, 1994; Lederman, 1990). Furthermore, compared to a survey or questionnaire, a focus group interview better allows to capture the knowledge, point of views and attitudes of the individual participants since different communication forms are used during the group discussion such as joking, arguing, teasing and recapturing events (Liamputtong, 2011; Mortelmans, 2009).

Development of interview protocol

All focus group interviews followed the same structure based on a manual, developed on the basis of the aforementioned research questions. Not only did it enhance the reliability of the study since it was easier to replicate the study, but it also strengthened the content validity. Furthermore, three experts who were professors in science education at university, reviewed the manual beforehand and agreed with these questions and exercises to test the research questions on the one hand and with the proposed time schedule on the other hand.

The manual described the following steps. Firstly, A short welcome talk was held to explain the idea of the meeting. To avoid an adapted behavior of the participants, our goal to measure teachers' awareness of misconceptions was not mentioned. Secondly, All participants introduced themselves to each other and a short general

activity about teaching geography was held as an icebreaker. This first phase lasted around 10 minutes. Afterwards, the following activities were organized to stimulate the discussion:

1. Seven figures, used to explain the seasons in geography textbooks and on popular websites, were shown to the participants. Advantages and disadvantages of those figures were questioned (Figure 1). Teachers mentioning misconceptions spontaneously were considered as a clear sign of awareness. Around 25 minutes were foreseen and spent on this activity.

Figure 1: The teachers are discussing the different figures.

2. A short fragment of a movie, in which a student explained the origin of the seasons before being taught in class, was shown. In the students' explanation, a misconception was present. Prior to the movie, the participants were asked which explanation this student could give about the origin of seasons in Belgium. Afterwards they discussed whether they recognized the same misconceptions and ideas within their students. This activity took around 20 minutes.

3. The participants were stimulated to write down misconceptions they encountered while teaching astronomy. Those misconceptions were then situated on a graph with two axes, one representing the prevalence of the misconceptions by students and the other one representing the time the teacher spend on the content in class. By discussing the location of the misconceptions on the graph, it was possible to gather information on their thoughts concerning the prevalence of their students' misconceptions and how the teachers deal with them in class. This activity lasted around 25 minutes.

4. A representation of different sizes of the Sun and Earths were given to start a discussion about misconceptions on scale and distances in the universe. The teachers needed to choose which Earth had the correct size relative to the Sun. Furthermore, they discussed which size their students would choose and what kind of difficulties they face in class, in relation to scales and distances in the universe. This short discussion took 10 minutes.

5. Finally, three multiple choice questions (Figure 2) and eight quotes were used to stimulate a discussion of 20 minutes. These multiple choice questions were taken from a five-question survey from the Annenberg Media Math and Science Project Teachers' Lab, especially designed to find out students ideas about basic astronomy (Annenberger Foundation, 2014). The quotes were rather diverse and included general statements on students' prior knowledge, as well as specific statements about misconceptions in astronomy.

Three out of the eight quotes are listed here as an example:

- Students often believe there are more stars in our solar system besides the Sun.
- Pupils experience difficulties with distances in the universe.
- Students don't use their prior knowledge sufficiently.

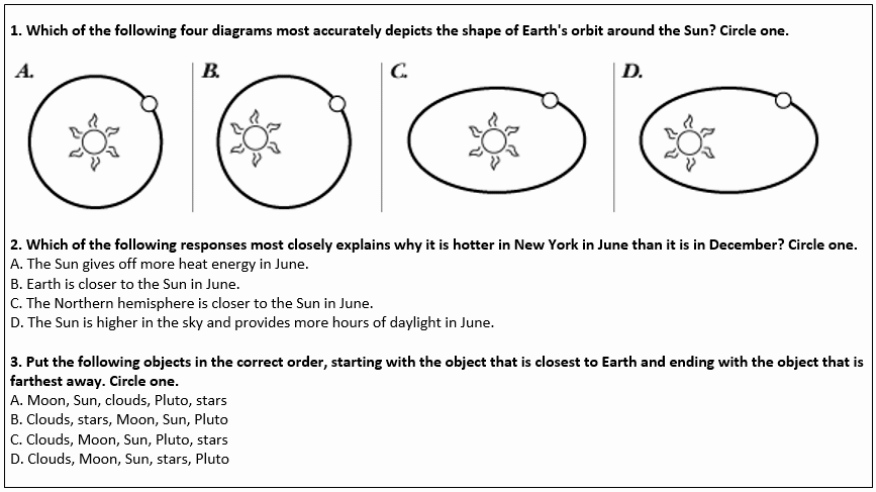

Figure 2: The multiple choice questions which were answered and discussed by the teachers (Annenberger Foundation, 2014)

Data gathering

Three focus groups were held, each in a different city in Flanders: Leuven, Antwerp and Ghent. They all lasted about two hours, as set by the proposed time schedule.

All three focus groups were audiotaped and two of them were also videotaped. In addition, they were all observed by two researchers to obtain information on body language and general impressions. They also added their own reflections, but did not participate in the discussion. The audio- and videotapes were used to transcribe the interviews literally and were supplemented with the notes from the observation. The combination of these recording techniques ensures the descriptive and interpretative validity of the study (Chioncel, Van Der Veen, Wildemeersch, & Jarvis, 2003). Furthermore, the three researchers held a discussion immediately after each focus group interview. The goal of this discussion was to reflect on the elements emerged during the conversation, the behavior of the participants and the format of the interview. These discussions were audiotaped as well, which made it possible to make minutes of it afterwards.

Participants

In total, 27 teachers participated in 3 focus group interviews. The focus groups in Leuven and Antwerp both consisted of 10 teachers, for the one in Ghent, 7 teachers were present. The teachers in the focus groups were asked to participate by spreading an invitation for a free training course about teaching astronomy in secondary education among teachers in geography. This invitation was spread via the association of geography teachers in Flanders, but was also sent to every teacher who had once participated in a professional development activity for geography teachers organized by the university. All the participants were geography teachers in upper secondary schools (grade 11- 12), where the topic of astronomy is part of the mandatory curriculum. In total, 11 out of the 27 teachers, or 40.7% were men, which is in line with the average of 36.4% male teachers in the whole of secondary education in Flanders in 2013-2014 (Departement Onderwijs en Vorming, 2014). They had also different backgrounds in education. The total group of participants consisted of 21 geographers, two industrial engineers, one bio-engineer, one economist and two historians. All of the participants had between 7 and 27 years of experience in teaching geography with the exception of two teachers with only two and four years of experience. A minimum amount of teaching experience in geography was set as a requirement to participate in this study, since it was assumed that experience was needed to be aware of students' misconceptions. The results of other studies also confirmed that teachers extend their pedagogical content knowledge over time (Henze, van Driel, & Verloop, 2008; Magnusson, Krajcik, & Borko, 1999; Meyer,

2004). Furthermore, they all taught in different schools, spread over Flanders where some of them taught students of the general secondary education and others students of the technical secondary education. Finally, in the group of teachers, at least three different textbooks were used. These variations in participants were important regarding the reliability and validity. A balanced reflection of the population of geography teachers was expected to increase the generalizing value of the results in the end.

Data analysis

The transcripts were analyzed by structuring the data in Nvivo (version 10.0). In a first cycle of codifying, all quotes about the same detailed topic were grouped in nodes, based on the misconceptions known from literature. This is illustrated by an example. The next quote was coded as 'distance Sun-Earth as cause for the seasons': "While the other pictures were maybe more clear, this one let the students think about the elliptical orbit and especially the fact that summer was not caused by a closer distance to the sun." In a second cycle, the codes were classified in broader categories. Examples of these categories are 'Earth revolution,' or 'magnitudes and structure of the universe.' In the further analysis, these categories, and the quotes within the categories, were compared with each other, to notice differences between the focus groups and with literature. During this comparison, the minutes of the discussions held by the researchers after each interview were read again, to notice whether former interpretations were maybe overlooked or detected during the thorough analysis in Nvivo.

Semi-structured individual interviews

Since the ideas of only 27 teachers could be obtained with the focus group interviews, also 4 managers of geography teachers were interviewed. Three of the four teacher managers had a degree in geography, while one had a degree in a different field. A teacher manager in Belgium who is responsible for geography, supports and helps geography teachers of different schools who have pedagogical and subject-specific questions. This support can both be given individually, or to groups of geography teachers. Teacher managers, for instance, coach new teachers, help them to implement new attainment levels and chair team meetings. The teacher manager also provides information on recent developments in geography and geography education. As a result, he or she is the go-to person for geography teachers and school principals on the one hand, and colleges and universities on the other hand.

The purpose of these individual interviews was to know to what extent the managers themselves were aware of misconceptions in

astronomy and what type of support they gave. Based on this goal, a protocol was developed. First, questions were asked about the problems raised by teachers concerning the topic of astronomy. Second, it was questioned whether they knew what kind of misconceptions students held. Third, the awareness of teachers about this misconceptions was discussed, together with the pictures that were also used in the focus group interviews. Sometimes quotes from teachers in the focus groups were mentioned, to see to what extent they recognize these reactions. Fourth, questions were asked about dealing with prior knowledge in general and with misconceptions in specific.

RESULTS

Awareness of specific misconceptions concerning astronomy

The focus during the interviews was on misconceptions about the existence and cause of the seasons. Brewer (2008) made an overview of the different mental models detected in students. Although there are different mental models, the core component is the belief that coming closer to a source of heat would heats you up. This general distance model explains the seasons by the varying distance between the Earth and the Sun. There are two variants of this model, namely the naïve model with the Earth in an elliptical orbit around the Sun on the one hand and the wobbly tilt model on the other hand. The elliptical orbit of the Earth around the Sun makes the reasoning possible that "summer occurred when the Earth's path along the elliptical orbit is closer to the Sun and winter occurred when its path along the elliptical orbit takes it farther from the Sun" (Brewer, 2008: p.192). The wobbly tilt model was described as "an alternative model in which the Earth's axis tilt flipped towards and away from the Sun to produce the seasons" (Brewer, 2008, p.192). The awareness of these different specific misconceptions is described in the following paragraphs. Furthermore, another misconception discussed, about the length of the day in the polar region, was not previously found in the literature.

Distance Earth – Sun as a cause for the seasons

The misconception that it is summer, when the Earth is closer to the Sun, seemed very well known to teachers. In all three focus groups, teachers mentioned this mental model of the students (Transcripts excerpt 1 and 2). No teacher denied the prevalence of this misconception, although some teachers also emphasized that there were students who did know that the tilt of the Earth axis was the cause for the seasons.

Only very few teachers explicitly mentioned they realized that misconceptions were robust against teaching (Transcript excerpt 2).

However, most teachers seemed to be convinced the survival of this misconception after teaching was a problem that occurred less frequently than students who started class with the wrong distance model.

Transcript excerpt 1. An excerpt from the third focus group interviews

Researcher:	What do you think someone immigrating from Guinea, in the fifth year [of secondary school], would answer to the question: what causes season change?
Teacher 25:	I always ask that question.
Researcher:	Do you? And what is the answer?
Teacher 25:	They always respond: "Since we are closer to the Sun, then."
	[Teacher1 and 7 confirm]

Transcript excerpt 2. An excerpt from the second focus group interview

Teacher 18:	Closer and further away from the Sun, I think is still…
Researcher:	Closer and further away from the Sun
Teacher 18:	Closer to and further away from the Sun, I suppose, survives with some of them, despite all effort.
Teacher 11:	Although, there are some students who do know. Some know the real cause.

Also different variants on the distance model, for example 'the northern hemisphere is closer to the Sun in summer', or 'the equator is closer to the Sun in summer' were indicated by the teachers themselves (Transcript excerpt 3).

Transcript excerpt 3. An excerpt from the third focus group interview

Teacher 21:	Sometimes I get answered "cause is the equator being closer to the Sun", particularly in low-science classes.
Teacher 25:	I often get a similar reply.
Teacher 27:	Even in high-science groups.
Teacher 21:	Definitely, it is a globe, you know, equator closer to the Sun.

Three of the four interviewed teacher managers in geography recognized the frequent occurrence of this misconception (Transcript excerpt 4 and 5).

Transcript excerpt 4. An excerpt from the semi-structured individual interview with teacher manager 1

Researcher:	Indeed, but which cause of seasonal change would they really put forward?
Teacher manager 1:	No, no. I suppose they are wrong there, thinking the Sun is at a greater or lesser distance, I wouldn't know, for Christ's sake. I reckon, though, that they have got knowledge of the length of the Sun and solar ray strength. They have already had a good deal of science, you know?

Transcript excerpt 5: An excerpt from the semi-structured individual interview with teacher manager 3.

Teacher manager 3:	About seasonal characterization?
Researcher:	Indeed.
Teacher manager 3:	I fear most of them (the students) will come up with the Earth's proximity to the Sun in summer. It is a repetitive response. Even some teachers still adhere to that conviction.
Researcher:	Blimey!
Teacher manager 3:	Not immediately teachers of geography, though. And the others, say, traditionally aren't really in for this train of thought.

It is clear, from these excerpts, that most teachers and teacher managers were well aware of the naïve distance model as a cause for the seasons. Even those teachers who did not mention it themselves recognized that said by their colleagues. Also, the variations of this mental model were mentioned by some teachers. Despite the recognition and awareness of the misconceptions, most teachers and teacher managers were not aware of their persistence. This lack of PCK of teachers could have serious consequences in the way they handled these students' ideas in their instruction in class. In addition, it could be assumed teacher managers would experience difficulties in convincing teachers of the importance of instruction methods in achieving conceptual change if they lacked this part of PCK themselves.

Elliptical orbit of the Earth around the Sun

The misconception described above about the distance to the Sun seemed to be very well known by teachers. However, the pronounced elliptical shape of the orbit of the Earth around the Sun, a misconception that was related to the distance model and very often used in geography textbooks (Coolsaet, Goethals, Longrée, & Plinke, 2010; Cox et al., 2004; Depuydt et al., 2004; Neyt & Tibeau, 2011; Van Hecke et al., 2006, 2013), was much less known. Only one teacher out of 27 in the focus groups

mentioned this. The other teachers in this focus group agreed with this problem, but it was uncertain whether every teacher was aware of this problem in advance. A strong counterargument was the fact that most teachers were not fully aware of the fact that the shape of the orbit approached a circle, which explained why most were not aware of this misconception. Indeed, while discussing different figures (Figure 1), many teachers preferred a figure with a more elliptical orbit (Transcript excerpt 6). There was even one teacher, who had a problem with the use of a circular shape to explain the seasons and another teacher who thought the circular shape would be too difficult to explain the changing distance between the Earth and the Sun during one year (Transcript excerpt 7). However, after a short discussion, all teachers agreed that the use of a circle would be helpful to avoid the distance model to explain seasons.

Transcript excerpt 6. An excerpt from the second focus group interview

Teacher 18:	Plus orbit, contrary to that figure [the teacher points to one of the figures laying on the table]…more ellipsoidal. I don't know. I think this one [the teacher points to another figure laying on the table] approaches less the real shape. Could be just an idea.
Researcher:	So ellipsoidal is better?
	[mumblings of consent by a. o. teacher 18 and 20]
Teacher 18:	Hits upon truth slightly more, I suppose.

Transcript excerpt 7. An excerpt from the second focus group interview

Researcher:	So, this is one of the most occurring misconceptions. Actually on our part, too, as we have grown so used to that image that we hardly reflect about its accuracy.
Teacher 13:	Problem is obviously that if you intend to explain to them that summer occurs because of the northern hemisphere's inclination to the Sun, rather than eccentricity, you need to magnify, or you won't be able to make it dawn upon your student while stepping towards your circle.
Researcher:	Unless you clarify that in that circle distance…
Teacher 11:	Doesn't matter
Researcher:	Indeed, actually to be put on a par
Teacher 13:	right
Teacher 11:	It is of no concern. You could as well approach the issue from that angle.
Teacher	So true.

13:

To summarize: the excerpts confirmed that the misleading figures widely used in textbooks had created problems among students and teachers. Not only were the teachers less aware of the existence of this naïve model in their students, but quite a few of them also seemed to have the misconception themselves. Subsequently, the potential threat of using these misleading figures was seriously underestimated, together with the contribution of this naïve model in the existence and persistence of the naïve distance model.

Wobbly Tilt Model

In two focus groups, a minority of teachers explicitly mentioned the wobbly tilt misconception, the belief that the Earth axis tilts from one side to the other during a year. Moreover, some of those teachers also actively tried to avoid this misconception, for example by turning off parts of a web-based application (Prentice Hall Production Team, 2013) or showed the particular application only for the December Solstice in which the axis was tilted the same way as in the Earth profile or they never used the application anymore. Nevertheless, there were also teachers who admitted that they never thought about it (Transcript excerpt 8). In the third focus group, there was one teacher who mentioned the problem, but only when we kept asking about a specific problem in the shown application with the tilt axis of the Earth.

Transcript excerpt 8. An excerpt from the second focus group interview

Researcher:	We could study a series of models, piece by piece. Which one would you introduce in class to figure out its worth? If this is our initial model, an animation, could you weigh its advantages against its disadvantages when it comes to use in class? I can see you nod.
Teacher 10:	Yes, the Earth's axis has been positioned differently.
	[confirmation, a.o. by teacher 11]
Teacher 20:	I use this in class, too, but I often keep it hidden. You could switch it off, you know.
Teacher 16	Right, just the fleeting image.
Teacher 20:	Indeed, and at the same time you can notice the lighting.
Teacher 16:	So can I.
Teacher 20:	I consider it confusing that the Earth's axis is not positioned alike invariably, or doesn't remain unmodified.

Researcher:	And have you noticed this confusion within your student public too?
Teacher 20:	I have.
Researcher:	Anyone sharing this conviction?
Teacher 19:	I haven't utilized this model yet.
Researcher:	Not utilized…
Teacher 19:	…and it hadn't occurred to me, but I can imagine this being the case for students, indeed.

During the interviews with the teacher managers, three out of four recognized the problem, while one teacher manager had never thought about the problem. This person even asked whether teachers were aware of it or not (Transcript excerpt 9). However, even the managers who knew there was a problem could not always describe the mental model of students. They mentioned the fact that the figure was seen from different perspectives, which made it difficult for students to understand but never said the students might think the axis is wobbling during the motion of the Earth around the Sun (Transcript excerpt 10). One manager, who was aware of the prevalence of this misconception, even said that there were also teachers who did not fully understand the concept of the tilted axis themselves. This teacher manager also got questions from teachers about how the seasons and especially the parallel moving tilted axis could be explained in a proper way in class.

Transcript excerpt 9. An excerpt from the semi-structured individual interview with teacher manager 4

Researcher:	I am prepared to be in for this. Take model 1, an animation, enabling you to make the Earth orbit the Sun. In this manner, you can install this so called 'Earth profiled' in order to observe where the Sun hits the Earth perpendicularly. If you keep a close eye upon the Earth's axis, it turns out to be slanted, while obviously remaining parallel to itself while orbiting the Sun.
	[assenting noises]
Researcher:	One of the erroneous conceptions living among student is…
Teacher manager 4:	That the Earth spins this way
Researcher:	Indeed, that the Earth's axis…
Teacher manager 4:	…wobbles…
Researcher:	Indeed, wobbles, a wobbling Earth's axis, one of the misconceptions.

Teacher manager 4:	Are teacher aware of this?
Researcher:	Ehm. In most focus group interviews, this was proffered.
Teacher manager 4:	Why indeed do they point this axis to this side?
Researcher:	Coming to think of it, I could … the animators…
Teacher manager 4:	Just for the fun of it? Them remarking it is innovative.
Researcher:	I haven't got a clue as to why they have done this, but it turns out to be quite mind blowing to students, whereas just the angle of approach is different.
Teacher manager 4:	Weird, but you have a point, here.

Transcript excerpt 10. An excerpt from the semi-structured interview with teacher manager 3

Researcher:	What might go astray; or where could students lose track?
Teacher manager 3:	Indeed, one gets two different issues, at least, not exactly two different issues, but the perspective changes, no? Here an Earth pointed that way, be it as it may, you need to be allowed a view of this too, don't you?
Researcher:	It may just not catch on, right?
Teacher manager 3:	Correct. I fear this might be a hitch. You get this image simultaneously.

Thus, a more diverse pattern was identified here. On the one hand, there were teachers who were aware of the existence of the wobbly tilt model in students, but on the other hand, there were also teachers who hadn't even thought about it, or never experienced a problem related to this misconception. From those who were aware, there were also teachers who undertook action to prevent it. These teachers still seemed to be the exceptions in the group. Nevertheless, while having the discussion about figures, teachers agreed that the use of misleading figures and applications might be a cause for this existing misconception.

Length of day in the polar region

In all focus groups, the teachers mentioned the fact that it seemed difficult for students to understand how day and night changes throughout a year in the polar region. However, in one focus group, the teachers described mental models of students, for example, some students thought the polar night lasted for six months in the whole polar region (Transcript excerpt 11), or students believed that 24 hours of darkness and 24 hours of light

could only happen at the poles. Also, ideas about the relation between the temperature at the Earth surface and the duration of the Sun above the horizon was mentioned as a difficulty (Transcript excerpt 12). But, the reasoning behind those was not clear. Further research is necessary to find out the ideas of students in more detail, also because the geography teachers managers did not mention the occurrence of this kind of problems.

While not every teacher could describe the mental models of students, they all tried different strategies to make the content clear to students: Programs as Stellarium (Version 0. 12.0; Stellarium Development Team, 2013), Google Earth™ (Version 7.1.2.2041; Google Inc., 2013) and different applets were used to illustrate the cycle, but a lot of teachers also used a globe and a strong light to visualize day and night at different locations on Earth.

Transcript excerpt 11. An excerpt from the first focus group interview.

Teacher 8: […] What I hear a lot, when I am explaining the duration of the polar night, is that a student says 'Oh, yes polar night, six months light and six months dark...'

Transcript excerpt 12. An excerpt from the first focus group interview.

Teacher 7: They expect it to be warmer out there when the Sun is above the horizon all day.
Teacher 1: Yes, if there is 24 hours of light.
Teacher 7: There is light, so it means that it should be warmer there.

Despite different teaching strategies, most teachers did mention a variety of difficulties regarding the length of day in the polar region, without succeeding in explaining the full mental model of the students. Some of them were able to tell parts of the students' ideas, but in general, it became clear that most teachers did not challenge their students thoroughly to describe their thoughts.

Dealing with student ideas by teachers

All teachers in the focus groups agreed that higher learning gains could be attained if teachers started from the prior knowledge of students. However, most teachers only seemed to assess the preconceptions of the students by asking questions in an educational conversation. Some teachers admitted that they only focused on the correct answers of students during these conversations. Others also paid attention to the wrong answers, but some of these teachers admitted to adjusting the answer by giving the correct answer themselves. Only two teachers out of 27 said they started with a

short list of questions to gain more information on the students' prior knowledge.

From the interviews, it was clear that most teachers did not construct a reasoning together with the students by adding and rejecting arguments, and correct or adjust the preconceptions of students. At least two teachers seemed to be aware of this and a lack of time was given as a reason. The other teachers agreed (Transcript excerpt 13). Another problem mentioned by the teachers was the huge difference in prior knowledge of students (Transcript excerpt 14). In two of the three focus groups, teachers had the experience that this difference in prior knowledge was greater for the lessons on astronomy compared to other themes. None of the teachers seemed to apply (effective) methods of differentiation in class.

Transcript excerpt 13. An excerpt from the second focus group interview.

Teacher 11:	The trainee supervisors I have had over the past few years often remarked that trainee – student interaction needed improvement. Considering this, and speaking for myself, I can imagine that we as teachers don't question our students enough or don't encourage them enough to make surface intrinsic knowledge.
Teacher 16:	Could also be due to lack of time, no?
Teacher 14:	Lack of time, definitely.
Teacher 15:	We always have to rush to ensure all the compulsory learning content is getting taught.

Transcript excerpt 14. An excerpt from the first focus group interview.

Researcher:	Will learning effect increase when you start from a deliberate misconception, which subsequently becomes rectified for example through calculation?
Teacher 2:	Maybe this is the case, though not all students need to have the same deviating mental model.
Researcher:	True. How can this be solved?
Teacher 2:	Which wrong mental model could be departed from in class? […] It's not easy to differentiate when it comes to speed of comprehension.
Researcher:	Certainly not.
Teacher 3:	That one misconception about the distance to the Sun is easy to bring to light, though most of the time we tend to feed on correct student answers.
Teacher 10:	Yes, that's because we only have one or two hours' teaching time a week per class.

Teacher 2: True, once again.

Also three of the four interviewed managers of geography teachers believed that teachers should start more from the prior knowledge of students. When they were asked how the teachers should do this, the answer was always to ask more and more profound questions during the educational conversations with students. One of the managers was convinced that teachers already started from this prior knowledge and couldn't imagine teachers could teach in a different way (Transcript excerpt 15).

Transcript excerpt 15: An excerpt from the semi-structured individual interview with teacher manager 4.

Researcher:	Do you expect the learning effect to increase if teachers appeal to occasionally fallacious prior knowledge.
Teacher manager 4:	Invariably so. I can't imagine teaching in another way.
Researcher:	How could teachers concretely address prior knowledge, which after all seems to be a kind of generic theme around here?
Teacher manager 4:	In a specific domain of study, with apt pupils and functional learning tracks, prior knowledge always becomes activated. You just presuppose them to have mastered certain fields of knowledge if they fare well in class.
Researcher:	Ok, but needn't this prior knowledge be refreshed for a start?
Teacher manager 4:	Definitely so. This is pure didactics.
Researcher:	And how are they supposed to do so? Or, how can they be enabled to act this way?
Teacher manager 4:	There are plenty of ways. It can be achieved via a traditional teaching method, or other activating means. I just can't imagine a teacher not being in for this.

In conclusion, it could be stated that asking questions in educational conversations was the most used technique to uncover the prior knowledge of the students. According to the teachers, this was due to practical limitations such as the available time frame and the differences in students' prior knowledge. Although, it could be argued that a lack of awareness on existing naïve models played a role in it too.

DISCUSSION

The extent of awareness and consequences

Regarding the specific misconceptions in the theme of astronomy, very different levels of awareness were found. Some misconceptions as described in the literature were known by almost all teachers, and others were not known at all. An example of a well-known misconception was that students thought the distance from the Sun to the Earth caused the seasons. A misconception not known at all was the fact that the elliptical orbit was often seen as too elliptical, while actually it is almost a circle. Surprisingly, the teachers in the focus groups mentioned an astronomy misconception, which seemed to be lacking in literature. This misconception concerned the difficulty that students had with the duration of day and night in the polar region. Finally, there seemed to be teachers who had misconceptions themselves, which could explain their unawareness of it as was already confirmed by the research of Halim and Meerah (2002).

When teachers were fully aware of misconceptions, they acknowledged the importance of these preconceptions and they sometimes developed strategies to achieve conceptual change. On the other hand, it was apparent that they did not try to investigate to what extent students had misconceptions. In their teaching practice, teachers did not often start from the preconceptions students had, or did not try to let the students find out why (part of) their preconceptions were wrong and what was the correct scientific model. These results were consistent with the research of Gomez-Zwiep (2008) and Morrison and Lederman (2003) who concluded that teachers all mentioned the importance of knowing the preconceptions of students, but only used low-level recall questions to estimate the prior knowledge of students. Moreover, some teachers were really convinced that misconceptions disappeared after their class by telling the correct scientific model to students. This was similar to the conclusion by Lightman & Sadler, who stated that "teachers vastly overestimated the gain in knowledge their students would achieve after their astronomy course" (Lightman & Sadler, 1993, p.164; Sadler et al., 2009).

Although we did not observe classroom practice of the teachers, our findings indicated something about the teachers' view about this. To a certain extent, the teachers did agree that they did not go into depth when they questioned the students. Some of them argued that this was due to two reasons. Firstly, almost all teachers experienced a lack of time. In Flanders, the Geography course was generally scheduled for one hour a week in the last two years of high school. The second reason, clearly mentioned in two of the three focus groups, was the difference in prior knowledge between students. Teachers hardly applied effective methods of differentiation to cater for this large variation between students.

Especially the theme of astronomy appeared to be difficult in this context. The teachers were really convinced it was more efficient to teach the new learning content without integrating too much of the prior knowledge. They seemed to assume the new learning content would replace the current misconceptions of students after having heard it once. Therefore, one conclusion that could be drawn from this research was that teachers strongly underestimate the persistence of misconceptions and that they lacked the knowledge about conceptual change in general. Only very few teachers recognized the fact that misconceptions could still exist when students left the classroom. The awareness of most teachers concerning the importance of preconceptions, often also misconceptions, was not big enough at this moment to use explicit strategies to handle it and to change their teaching method.

Limitations of the study

Despite the effort to reflect the variety in population of geography teachers as strongly as possible, only 27 teachers participated in the focus group interviews. Therefore, drawing general conclusions about the awareness of geography teachers on misconceptions should be undertaken with care. The impact of the moderator on the development of the conversation was inherent for the method of focus group interviews. To limit this influence, several actions were undertaken e.g. a detailed manual and timeframe were used as described in the methodological section; an experienced female moderator was chosen, which was generally preferred by male and female participants (Vogt, King, & King, 2004). Nevertheless, this research method allowed greater depth, when asking teachers to describe the mental model of students for example. The effect of the group, which created reactions on the ideas of others, also contributed to the profundity of the conversation and the insights that emerged. These kinds of understanding was much harder to achieve, if not impossible, when using questionnaires for example.

Recommendations

It was important to increase the teachers' awareness of student ideas and provide them with strategies to cope with the problem. First, this topic could be more emphasized in teacher training programs for pre-service teachers and in professional development activities for in-service teachers and teacher managers. An example of such an activity could be the development of professional learning communities, which come together on a regular basis to talk about similar topics. These might be led by persons who are actively engaged in discipline-based educational research. Also the managers of teachers might help to raise awareness and offer solutions for themes, where such problems might show up. However, to

achieve a higher awareness and a proper training and coaching of the teachers, it is important that these teacher managers and teachers trainers become more aware of the misconceptions that exist, how they develop, how persistent they are, and how teachers can support conceptual change. This showed the need for more discipline based educational research and efficient communication about it. Finally, also textbook authors should be aware of these misconceptions and take them into account in the design of learning materials. More attention should be paid to the development of correct figures (Pena & Gil Quilez, 2001; Testa, Leccia, & Puddu, 2014) and to adequately writing texts.

CONCLUSION

In general, it seemed rather difficult for teachers to describe their students' incorrect mental models. Often they could identify students' difficulties, however, without a detailed description of the underlying mental models. Nevertheless, there were some exceptions that were known by most teachers, for example the distance model. Even for these known misconceptions, however, their persistence was largely underestimated. A more or less similar pattern was found with the teacher managers, which was alarming, since they have a certain responsibility towards the geography teachers. If they are more aware of misconceptions and have a deeper understanding of possible strategies to deal with them, they can play a key-role in the improvement of teachers' pedagogical content knowledge.

Although the teachers were aware of some difficulties and acknowledged the importance of the activation of prior knowledge, it seemed very difficult for teachers to undertake action. Often they did not start from the mental models of the students to build up on their reasoning, nor did they actively investigate the prior knowledge of students. The main reasons mentioned were a lack of time and the big differences in prior knowledge between students. This level of understanding of students' misconceptions and the lack of strategies indicate that the quality of the pedagogical content knowledge can still improve.

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