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The importance of discourse and attitude in learning astronomy: A mixed methods approach to illuminate the results of the TIMSS 2011 survey

Abstract

The TIMSS (Trends in International Mathematics and Science Study) survey carried out in 2011 showed that Norwegian 8th graders reversed a declining trend in science achievement that had lasted almost two decades. However, the only sub-topic that contributed significantly to this turn-around was astronomy. The aim of this study is to explore factors that may have influenced the learning process and led to this high performance. We focused on the characteristics and influence of 1) attitudes towards astronomy and 2) practising astronomy discourse on 3) the conceptual understanding of astronomy. These three were investigated by questionnaire (n=200) and interview (n=32). The findings showed that these students' reported discourse practices had an influence on their attitudes and that attitude towards astronomy was important to their conceptual understanding of this topic. Students' attitudes reflected mostly interest and self-efficacy, and they reported practising astronomy discourse through media and discussions inside and outside of school.

INTRODUCTION AND RATIONALE

Norway has participated in all TIMSS (Trends in International Mathematics and Science Study) surveys since 1995, during which time there has been a steady decline in science performance among 8th graders (Martin, Mullis, & Foy, 2008). In the TIMSS 2011 survey, this negative trend reversed, but the only significant contribution to the enhanced science achievement was the performance in astronomy.

While 8th graders' performance in astronomy was higher in 2011 than in all previous TIMSS surveys, their performance in astronomy has been outstanding throughout all the TIMSS surveys when compared to all other sub-topics of physics (with electricity being the sub-topic with the lowest performance), and when compared to the performance of most other participating countries including top-performing Asian countries (Grønmo & Nilsen, 2013).

Astronomy is by TIMSS defined as a topic within the sub-domain of earth science (Martin, Mullis, Foy, & Stanco, 2012), while in Norway astronomy has traditionally been part of physics. Since Norwegian students have been, and are still struggling more with physics than any other science subject (Grønmo et al., 2012; Martin et al., 2008; Martin et al., 2012), it is especially interesting to explore factors that may have contributed to successful learning of astronomy. Exploring such factors may contribute to new insights into students' struggle with the other sub-topics of physics.

Performance in astronomy, as measured by TIMSS, for the most part reflects conceptual understanding. The test items are evenly distributed among three major cognitive abilities, in that the students are required to demonstrate factual knowledge about concepts, apply the knowledge about the concepts in different contexts and to reason by relating and synthesising knowledge in complex systems (Mullis, Martin, Ruddock, O'Sullivan, & Preuschoff, 2012). Mathematics is not required in astronomy at this level and TIMSS do not measure practical abilities required for e.g. experiments (ibid). The question is hence what factors may have contributed to conceptual understanding in astronomy.

Conceptual understanding and conceptual change was the major approach used in physics education research for decades to address the difficulties students had with this subject (Duit, Niedderer, & Schecker, 2007). However, an increasing amount of studies have emphasized the importance of learning "scientific language" (Lemke, 1990; Mortimer & Scott, 2003; Wellington, Osborne, & Wellington, 2001). This scientific language, or science discourse, may include e.g. symbols, models, representations and concepts, and mastering this discourse necessitates the ability to understand and use this language by reading, listening, talking and writing. Conceptual understanding entails learning a science discourse that is different from students' every-day language (Gee, 2010). Mortimer and Scott (2003) emphasized the importance of dialogue and *talking science* for practicing science discourse. Explaining science concepts to peers using their own words is an example of how students may practise science discourse. Moreover, according to Wellington and Osborne (2001), practicing science discourse may also include reading or listening. Hence, a student may practise science discourse by talking, listening, writing or reading science.

According to Eccles & Wigfield (2002), students' attitudes greatly influence their willingness to engage in tasks, such as practising science discourse. Indeed, attitude is another theme in science and physics education research, and several researchers underline the importance of attitude in learning science (see e.g. Duit et al., 2007; Krogh & Thomsen, 2005; Osborne, Simon, & Collins, 2003).

Even though previous and current research emphasize the significance of attitude and practising science discourse in the process of attaining conceptual understanding (Abell & Lederman, 2007; Osborne et al., 2003), there are few studies that integrate and explore the relation between these three. Our overarching aim is to shed light on students' performance in astronomy in the TIMSS 2011 survey by exploring the characteristics and importance of attitudes towards astronomy and students' reported astronomy discourse practices in attaining conceptual understanding in astronomy. This aim was addressed by asking the following research questions:

1. What characterizes 8th graders' attitudes towards astronomy and their astronomy discourse practices?
2. What is the relation between discourse practises, attitudes and conceptual understanding in astronomy?

Electricity is included in our survey for comparison, since this is the subject with the lowest scores in all TIMSS surveys (Grønmo & Nilsen, 2013). However, our main focus rests on astronomy.

THEORETICAL FRAMEWORK

Discourse

Due to the popularity of astronomy in media as well as its philosophical nature, we hypothesized that students practiced astronomy through discussions and by being exposed to media.

Discourse is generally defined as any written or spoken communication or debate, and has in previous reports been defined as “text in context” or “language in use” (e.g. Gee, 2010; Halliday & Webster, 2006). *Science* discourse was defined by James Paul Gee (2010) as a type of secondary discourse which is learned in social communities like school or work. Primary discourse, on the other hand, is the first discourse we learn at home; the every-day language which constitutes a base of prior understandings. This foundation, which varies from person to person, is the base upon which children build their secondary discourse.

One way of practising science discourse in classrooms is through dialogue, and by *talking science* (Mortimer & Scott, 2003). Through dialogue, students’ every-day language and conceptions are confronted with the teacher’s science discourse. This interaction constitutes the base for the conceptual understanding and learning of science according to Mortimer and Scott (ibid). Practising discourse with peers and family is also important, and children who practise secondary discourse with their parents are likely to do well in school (Hicks, 2008).

There are a number of semiotic modes (e.g. writing, reading, talking, listening) available to practise secondary discourse (Evagorou & Osborne, 2010). Science is a special subject in that students have to understand and be able to switch between a number of different representations of the same phenomenon (Angell, Kind, Henriksen, & Guttersrud, 2008; Dolin, 2001; Lemke, 1990). In astronomy, representations like pictures, models and animations are essential to illustrate various phenomena, such as the seasons, the tilt of the Earth’s axis, and solar and lunar eclipses. Media (e.g. the internet, newspapers, magazines and journals, and scientific programmes on TV) and books (including popular scientific literature) about astronomy offer a wide range of representations and semiotic modes, and the discourse therein may vary between primary and secondary discourse. Hence, being exposed to these sources may ease the path from primary to secondary discourse. Discussing science in classrooms, with peers and family, as well as using the internet and watching scientific programmes are all different ways of practising and learning science discourse.

Attitude

Students’ disenchantment with what are referred to as the STEM-subjects, i.e. science, technology, engineering and mathematics, has been an increasing concern in education policy and practice since the mid 1990’s (Bøe, Henriksen, Lyons, & Schreiner, 2011; Osborne et al., 2003), and many studies on attitudes towards science have been carried out. The positive correlation between attitude and performance has been documented in a number of studies according to Osborne and colleagues (2003).

Attitude has been defined differently across previous studies and may consist of a number of constructs depending on the aim of the study (Osborne et al., 2003). In the present study we hypothesized that intrinsic values (e.g. personal enjoyment) as well as extrinsic values (e.g. importance to society) may have played important roles in learning astronomy due to the exotic nature and popularity of this topic (Angell, Guttersrud, Henriksen, & Isnes, 2004; Sjøberg & Schreiner, 2006). Both intrinsic and extrinsic motivations as well as self-efficacy have been included as parts of students’ attitudes in previous studies (see e.g., Eccles & Wigfield, 2002; Mullis et al., 2012; Osborne et al., 2003; Simpson & Oliver, 1990). The extended emphasis on astronomy in the new curriculum in Norway followed by

the TIMSS 2011 participants (UDIR, 2012) could have provided the students with a further opportunity to learn and increased their self-efficacy in astronomy. Hence, we included the aspects of values and self-efficacy in our investigations of attitudes. These two aspects are also the main foci of Eccles' and Wigfield's (2002) expectancy-value model of achievement in which "Expectancies and values are assumed to directly influence performance, ..." (p. 118). Their model is well known and recognized (Bøe et al., 2011; Mullis et al., 2012; Osborne et al., 2003) and is based on empirical evidence (Eccles & Wigfield, 2002). Although the model is comprehensive and includes a number of other factors that are related to values and expectations of success, the latter two remains in focus and indeed a number of studies use this part of the model to investigate values and expectation of success in particular (Bøe et al., 2011; Jensen & Sjaastad, 2013; Schreiner, 2010).

Building on Bandura (1997), Eccles and Wigfield (2002) defined *Expectation of Success* as "individuals' beliefs about how well they will do on upcoming tasks, either in the immediate or long-term future" (p.119). Since Eccles and her colleagues (1983) found no empirical evidence that expectancy of success differ from self-efficacy (or beliefs about competence in a given domain) we will for simplicity refer to self-efficacy throughout the article. The other main component of their model is *Subject Task Value* which comprises interest (intrinsic motivation where enjoyment and interest is the driving force), attainment value (personal importance of doing well on a task), utility value (extrinsic reasons for engaging in a task, such as future career) and relative cost (negative aspects of engaging in a task, such as fear of failure). Eccles' and Wigfield's model served as our theoretical framework when constructing the written questionnaire and the interviews.

Conceptual understanding in astronomy

A cognitive dimension is embedded in the notion of conceptual understanding as it includes more than isolated knowledge and facts. Rather it entails a deep understanding of the meaning of concepts; including knowledge about concepts, the ability to use this knowledge in different contexts as well as in systems including relations to other concepts (Wellington et al., 2001).

Numerous studies have demonstrated how students have pre-instructional conceptions based upon their own experiences that are not in harmony with science views (Treagust & Duit, 2008). These pre-conceptions or alternative conceptions lead to a number of studies on conceptual change, in which various ways of changing students' pre-conception were explored (Duit et al., 2007; Treagust & Duit, 2008).

In spite of the numerous studies on conceptual understanding and conceptual change in physics education (Treagust & Duit, 2008), there has been relatively few studies within astronomy (Bailey & Slater, 2005; Duit et al., 2007). In astronomy pre-conception are especially prominent as this is an area where most students have previous experience. In a review of studies within astronomy education, Bailey and Slater (2005) found that most studies were related to students' preconceptions which would typically include e.g. the cause of seasons, lunar phases, and the day-night cycle (see e.g., Vosniadou & Brewer, 1994; Zeilik, Schau, & Mattern, 1998).

Conceptual understanding in astronomy hence entails both a cognitive aspect ranging from knowing to applying and reasoning, as well as a content aspect which includes the scientific understanding of key astronomy concepts. These two aspects should hence be considered when measuring conceptual understanding in astronomy.

METHODOLOGY

Study design and sample

In spring 2011, 200 8th grade students from two lower secondary schools, (School A and School B) completed a questionnaire. This questionnaire included test items as well as questions related to

attitudes and discourse practices in astronomy and electricity. As previously mentioned, electricity was included for the purpose of comparison. Four classes were sampled from School A which is situated in the capital city in the southern part of Norway, and four from School B situated in the very northern part of Norway.

About one day after completing the study questionnaire, a sub-group of 32 students also underwent a semi-structured interview about their attitudes and discourse practises in astronomy and electricity. Students had to volunteer for the interview to participate, and an equal numbers of boys and girls were selected from each class.

Both the questionnaire and the interview were piloted before the present study was implemented. A mixed-methods approach was then applied, using qualitative analysis for the interviews, and quantitative analysis for the written questionnaire.

The questionnaire

The test items on astronomy and electricity were selected from four TIMSS surveys (1995, 2003, 2007 and 2011) in order to include key concepts and test items concerning alternative conceptions according to research (Bailey & Slater, 2005). There were eight test items in astronomy and eight in electricity, including both multiple-choice and open-ended questions. Test items in astronomy included tasks related to eclipses, seasons and the tilt of the axis of the earth (Figure 1, example 2), lunar phases, diurnal motion and the day-night cycle, explanations for length of the year (Figure 1, example 1), and the orbits of planets and moons. The items on electricity included topics related to electric energy, electrical circuits, Ohms law, the differences between parallel and series circuits (see example 3, Figure 2), and electromagnets and magnets. The items were distributed among the three components of cognitive dimension: knowing, applying, and reasoning.

<p>Example 1:</p> <p><i>An earth year is the length of time it takes for:</i></p> <p>A) Earth to rotate once on its axis B) The Moon to revolve once around Earth C) The Sun to revolve once around Earth D) Earth to revolve once around the Sun.</p>	<p>Example 2</p> <p><i>The diagram above shows the Earth's path around the Sun and the tilt of Earth's axis. Which of the following patterns on Earth is caused by the tilt of Earth's axis?</i></p> <p>A) Seasons B) Day and night C) Years D) Time zones</p>
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Figure 1. Example test items on astronomy from the study questionnaire.

<p>Example 3:</p> <p><i>Homes are wired for electricity using parallel circuits not series circuits. What is the advantage of using parallel circuits in homes?</i></p>
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Figure 2. Example test item on electricity from the study questionnaire.

In order to relate performance in astronomy and electricity to attitudes and discourse practises, the questionnaire also included the following questions where the students could choose to agree or disagree.

Question 1. How do you feel about astronomy?

a) Astronomy is Difficult, b) Astronomy is boring, c) Astronomy is easy, d) Astronomy is exciting, e) Knowledge about astronomy is important to society, f) Knowledge about astronomy is important to me.

Question 2. How do you learn about astronomy?

a) In media (newspapers, TV, etc.), b) in books, c) by discussing with others, d) through Internet, f) other ways.

The same two questions were asked for electricity. We used a two point response scale for these constructs where agree was coded as one, and disagree was coded 0. These variables are hence categorical and dichotomous. In addition, the students were asked to comment each question. Question 1 was constructed so as to measure *Self-efficacy* and *Subject Task Value* as described in the theoretical section about Eccles' and Wigfield's model (2002), and as described in the next section. This question is inspired by, and similar to, questions provided in the TIMSS student questionnaire which also builds on the Eccles' and Wigfield's model (Martin et al., 2012).

Analysis of the study questionnaire

To study the impact of attitudes and discourse practices on performance in astronomy, we employed a Structural Equation Model (SEM) with Confirmatory Factor Analysis (CFA). Based on our theoretical framework, we used CFA to measure our latent (non-observable) variables *Attitudes* and *Discourse* as defined by the answers to the questions described in the previous section. SEM with CFA is a robust statistical technique that allows for investigation of latent variables (Hox, Maas, & Brinkhuis, 2010). The software used was Mplus which allows for computations of categorical variables (Muthén & Muthén, 1998-2010), and we used a weighted least squares approach (WLSMV), as this is recommended for dichotomous variables (Muthén & Muthén, 1998-2010).

In the first model built, Model 1, students' answers to how they would learn about astronomy (i.e. media, books, discuss with others, Internet, other) were used as indicators of the latent variable *Discourse*. We then investigated whether this latent variable *Discourse* influenced achievement in astronomy and then in electricity.

In the second model, Model 2, a higher order latent variable we called *Attitudes* was measured by the three latent variables *Interest*, *Self-efficacy* and *Utility*. The indicators for these three latent variables are included in Question 1 provided in the previous section. The latent variable *Interest* had two indicators, i.e. *Exciting* and *Boring*. Likewise, the indicators of *Self-efficacy* were *Difficult* and *Easy* and the indicators of *Utility* were *Important to me* and *Important to society*. We then investigated whether *Attitudes* influence achievement in astronomy and electricity (see figure 3). The last model, Model 3, was the same as the previous, except we also investigated whether *Discourse* affects *Attitudes*. The latent variable *Discourse* for the most part reflects use of media, (e.g. looking at spectacular pictures of the universe at the Internet) which we believed would have an impact on attitudes rather than the other way around. Simplified illustrations of the three models are provided in figure 4. Given that the indicators for the latent variables are dichotomous, the factor loadings provided by Mplus are logistic regression factors (Muthén & Muthén, 1998-2010).

Figure 3. A detailed illustration of Model 2, in which we investigate the impact of attitude on performance. The ovals represent the latent variables and the boxes represent indicators.

Model 1	Model 2	Model 3
The impact of Discourse on Performance	The impact of Attitudes on Performance	The impact of Attitudes on Performance and the impact of Discourse on Attitudes.

Figure 4. Simplified illustrations of the three models.

Interviews

The questions related to students’ attitudes towards astronomy were based on Eccles’ and Wigfield’s (2002) model and were focused on *Self-efficacy* and *Interest*. One major reason why students struggle with physics in Norway is related to difficulties with mathematics (Nilsen, Angell, & Grønmo, 2013). Since no mathematics competencies are required for 8th grade astronomy in Norway, we hypothesized that this may lead to high self-efficacy in astronomy. We hence probed students’ self-efficacy for science tasks requiring mathematics compared to tasks that do not. Furthermore, they were asked for the reasons behind their attitudes towards astronomy.

The students were also asked about how they practised astronomy discourse at home and with friends, the practice of astronomy discourse in the classroom compared to that of other science topics, and what opportunities they had to enhance their astronomy discourse through media and books. It should be noted however, that these question not necessarily reflect students discourse practises per se, but rather students *reported* discourse practises.

Analysis of the interviews

Interviews were audio taped and transcribed. The students' comments are reported herein verbatim, although they have been translated from Norwegian to English by the authors, and colloquial expressions have been modified for ease of comprehension.

Interview answers were reduced into natural meaning units in terms of concepts, expressions and words, described by Kvale and Brinkmann (2009) as meaning coding. These were gathered into subordinate categories. For instance, the words *exciting*, *interesting*, *curious* and *intriguing* were repeatedly used by the students in relation to astronomy, and were counted across questions and categorized into a subordinate category we called "interest for astronomy". The subordinate categories were made as they occurred naturally from the text and compared across questions, categories of questions and across the students. These categories were merged into super-ordinate categories. For instance, the category "interest for astronomy" and a category called "self-efficacy in astronomy" were merged into a super ordinate category called "attitudes towards astronomy". The concepts, expressions and words were individually categorized by two fellow researchers.

RELIABILITY AND VALIDITY

Regarding the questionnaire, the reliability and validity of the test items in astronomy and electricity have been thoroughly tested by TIMSS (Mullis et al., 2012), and were scored according to the TIMSS scoring guide (ibid). Moreover, by asking the students to comment on their answers related to attitudes and discourse in the questionnaire, valuable information was captured that may strengthen the validity. Using SEM with CFA strengthens the reliability and validity of the analysis of the questionnaire, since these methods are well suited to measure latent constructs such as attitudes and to measure dichotomous response items. Overall, the reliability and validity of the questionnaire should be acceptable.

Regarding the interviews, as mentioned above two researchers individually categorized the transcripts in order to enhance the reliability. There were few disagreements, and consensus was reached between the two researchers.

According to Tashakkori and Teddlie (2008) a mixed methods approach may enhance the validity and reliability of a study. For instance, Osborne (2003) described how constructs of attitudes in a written questionnaire are hard to make, and often perceived differently from one student to the next. In this study, we address this issue by exploring students' attitudes qualitatively as well as quantitatively. Neither of our methods alone solves the problem of reversed causality related to attitudes (whether positive attitudes lead to high performance or the other way around), however a mixed methods approach should help support our inferences (Tashakkori & Teddlie, 2008). Furthermore, the weakness of one method, such as interview bias, may be diminished by the other method (Johnson & Onwuegbuzie, 2004).

Our sample is of course not representative for the whole population, so we may not generalize our results. However, we argue that including well tested TIMSS items in our survey, using a mixed methods approach, applying a robust statistical technique (SEM), and aiming to enhance overall reliability, should increase the trustworthiness of our inferences.

RESULTS

Attitudes

Interest

The findings from the interviews strongly suggest that participating students' attitudes towards astronomy were indeed positive. The first question was very open; students were asked to describe

how they felt about astronomy. Most students referred to interest and enjoyment, and the two most frequently used words were: exciting (n=24) and fun (n=14). Other frequently used adjectives were fascinating and interesting.

Boy 10, School B: *"It is exciting to hear about it [astronomy]-to learn it; it is fun, more exciting than other science topics such as photosynthesis – that is terribly boring."*

Boy 10, School A: *"I think it is extremely fun. I like doing it because we made models of the universe and did role playing. I love doing astronomy, it is great fun."*

Furthermore, and without being asked, students elaborated on *why* they found astronomy exciting. They would then refer to curiosity about the unknown, e.g. life on other planets, and whether space has a limit or black holes:

Girl 15, School B: *"I think it [astronomy] is very exciting, and because there is so much we don't know, I want to know more."*

Girl 5, School A: *"It is very exciting because it is fun to find out where the other planets are, and whether there is life on other planets."*

Boy 8, School B: *"I think it is exciting-really- to speculate what might exist outside our universe. That is always fascinating."*

Girl 4, School B: *"It [astronomy] is kind of cool, I think black holes-that is extremely exciting. Also, if you think about it, if there had been life on other planets that would also have been pretty cool. And, I think it is pretty exciting."*

The students did not report the same attitudes towards electricity; very few students described electricity as exciting or fun. Instead they used words like *difficult*, *complicated*, *boring*, or *ok* to describe electricity:

Girl 1, School A: *"I do not believe it is the most exciting thing we can learn, because it is so complicated. It is technical stuff and so on. I do not think that is any fun."*

Boy 8, School B: *"I do not think electricity is as exciting, but it is necessary to learn about it."*

When asked specifically which subject, astronomy or electricity, they found more interesting; 25 students replied astronomy, one student found electricity more interesting, three students found both topics equally interesting and three students said they did not know.

These positive attitudes towards astronomy were confirmed by the results from the written questionnaire; while 157 students agreed that astronomy is exciting, 104 students replied the same for electricity. However, more students found electricity to be more important for society (171) as compared to astronomy (143).

Self-efficacy

According to Eccles and Wigfield (2002), in addition to interest and enjoyment, self-efficacy is also important to students' performance. The students were hence asked which topic they found easier, electricity or astronomy whereby 20 students replied astronomy. However, the students were asked a follow-up question to clarify what they meant by hard. Some students then explained that astronomy is a difficult field for researchers because there are so many unanswered questions, but an easy subject in school.

Another finding suggests the absence of mathematics might be an explanation for the high self-efficacy in astronomy observed in this study. There were 22 students who reported that all science tasks that require mathematics are more difficult than those that do not.

Girl 1, School A: *"A task where you have to use math is more difficult, because you are not only required to extract knowledge out of the subject, but you also have to use mathematics and then you have to merge two subjects-kind of, and then it is a little too much to keep track of."*

The high self-efficacy in astronomy was confirmed by the written questionnaire and there were large differences between astronomy and electricity. For instance, 140 students agreed that electricity is difficult, compared to 88 who found astronomy difficult. In line with the interviews, the comments provided by the students revealed that many students found astronomy to be an easy subject in school but a difficult field for researchers.

Relationships between attitude and learning

The students were then asked whether they thought their attitude was related to their learning of astronomy. Most students had a positive answer to this question, and many replied that a positive attitude towards astronomy either stimulated learning (n=19), or made them work harder:

Boy 10, School B: *"If I read something I am interested in, like, then it is easier to remember. And [astronomy] is indeed fun to read about. If I read something related to electricity, it kind of wouldn't have been so fun."*

Girl 5, School A: *"Yes, the stuff I find exciting makes me more curious to know more about it, and then I learn more about it."*

Girl 13, School A: *"Yes, I am sure of it. When I am not inspired I have a hard time working with it, but when we had astronomy, I worked and worked and I thought it was great fun to read about it."*

Discourse

Findings from the interviews indicated that some students (n=29) practised astronomy discourse with friends and family members who were interested in the topic. Furthermore, phenomena such as the Northern lights and seasons seemed to trigger these discussions.

Girl 13, School A: *"Yes, [I talk] very much with my family, around the breakfast table kind of. It [astronomy] is very interesting. Also a little with friends if I find something of interest."*

Girl 6, School B: *"Yes, I often ask my mum about different things, if, for instance-not long ago there was a major Northern lights display, so then I ask, like, why, and she told me it was because of solar flares/sun storms."*

Girl 13, School B *"My sister, and my mum think it [astronomy] is great fun, it is almost everyone in a way, so kind-of, if it is brought up, everyone wants to join and talk, discuss and listen."*

In addition to natural phenomena, astronomy classes also seemed to trigger discussion both after (n=24) and during (n=15) class, and many students contributed this to the nature of the topic (philosophical and exciting).

Girl 1, School A: *"Yes, more in astronomy than in other topics because astronomy is kind of a philosophical subject and then one may philosophise a little and so then it is easier to discuss it with others. It is not so easy to talk about the structure of an atom because that is facts. But in astronomy-nothing is certain and so there are more theories."*

The students were also asked what sources of information outside of school they thought enhanced their learning of astronomy. The majority of the students reported that they watched programmes about astronomy on TV (n=27), or looked up news and pictures on the internet (n=25) or read about astronomy in books (n=9) or newspapers (n=9). A few reported that they read about astronomy in journals, or listened to programmes about astronomy on the radio.

Boy 2, School B: *"I watch certain TV programmes about the Big Bang theory and about the birth of stars and a little about how time behaves and all that. I have a poster that I got when I was a child about our solar system, and I had a book that I have now lost which was a book for children about the universe. On my start page for internet there is a link called amazing pictures from space, I often look at that [internet page]."*

The findings from the interviews, regarding sources of information that may facilitate learning astronomy discourse, were confirmed in the written questionnaire. While 177 students reported reading

books about astronomy, only 66 students reported reading books about electricity outside of class. Furthermore, 154 students reported that they discussed astronomy with others, while 69 reported discussing electricity. Also, compared to electricity, more students reported looking up astronomy on the internet (174 in astronomy, 120 in electricity) or through other media (162 in astronomy, 141 in electricity).

Relationships and scores

The results of the survey show that our students' score on astronomy is much higher than that of electricity. In total, the students scored almost twice as high in astronomy than in electricity. The difference between the total score of the two schools was only about a third of the difference between the scores on electricity and astronomy.

Table 1. The table provides results from the SEM analysis. The coefficients are standardized and significances in the form of p-values are provided for each measure. The three model fits: χ^2 with degrees of freedom (df), RMSEA and CFI are reported for each model in the three most left columns.

	Discourse on achievement	Attitudes on achievement	Discourse on Attitudes	Chi ² Df	RMSEA	CFI
Model 1	0.059			6.51	0.00	1.00
Astronomy	(0.73)			Df = 10		
Model 1	0.086			8.62	0.02	0.98
Electricity	(0.40)			Df = 8		
Model 2		0.47		102.02	0.06	0.96
Astronomy		(0.00)		Df = 58		
Model 2		0.26		101.36	0.06	0.89
Electricity		(0.01)		Df = 57		
Model 3		0.43	0.65	90.39	0.06	0.97
Astronomy		(0.00)	(0.02)	Df = 54		
Model 3		0.28	0.52	98.38	0.07	0.89
Electricity		(0.00)	(0.00)	Df = 53		

Regarding the second research question about the relations between attitudes, discourse practises and scores on astronomy and electricity, the results from the SEM analysis is displayed in Table 1. In this table standardized results of the three models in astronomy and electricity from the SEM analysis are provided. The model fits are represented by χ^2 along with degrees of freedom (df), RMSEA and CFI, which according to Hox and Bechger (1998) make for a sufficient report of model fit. The model fits were all within acceptable limits (ibid).

In Model 1, there was no significant effect of the latent variable *Discourse* on astronomy or electricity achievement.

In Model 2, the latent variables *Attitudes* (towards astronomy) had a significant impact of 0.47 on astronomy achievement, as *Attitudes* (towards electricity) had a significant impact of 0.26 on electricity achievement. The CFA for the latent variable *Attitudes* towards astronomy provided satisfactory and significant ($p < 0.05$) factor loadings of 0.35 for the latent variable *Self-efficacy*, 0.70 for *Interest* and 0.85 for *Utility*. The factor loadings for the latent variable *Attitudes* towards electricity also provided satisfactory and significant ($p < 0.05$) factor loadings of 0.36 for the latent variable *Self-efficacy*, 0.59 for *Interest* and 0.71 for *Utility*.

In Model 3, Attitudes still had a significant effect on performance in astronomy (0.43) and electricity (0.28), and *Discourse* had a significant effect on *Attitudes* in astronomy (0.65) and electricity (0.52).

DISCUSSION

In this section, we follow the order of our research questions in that we first discuss the characteristics of attitudes and students' reported discourse practises, and then discuss the relation between these two and conceptual understanding.

Attitudes

Both the interviews and the questionnaire indicate that our Norwegian 8th graders have positive attitudes towards astronomy. These findings are supported by a previous study rooted in the ROSE (The Relevance of Science Education)-project (Sjøberg & Schreiner, 2006), which gathered information about affective factors relating to science in 2004. Their study showed that Norwegian students favoured astronomy over all other science topics (ibid). Other studies have shown that astronomy is a popular subject in many countries, e.g. in Sweden (Oscarsson, Jidesjö, Karlsson, & Strömdahl, 2009).

The characteristics of our students' attitudes are reflected in the findings of the qualitative analysis, and the most prominent finding concerns the "interest and enjoyment" component of the Eccles' and Wigfield's (2002) model. For instance, in the interviews, the words most often referred to in relation to astronomy were "exciting" and "fun", in direct contrast to "boring", which was the word most commonly used to describe the topic of electricity. The questionnaire supports this finding even though students considered the topic of electricity to be important for society. The latter refers to what Eccles and Wigfield called "utility value" (ibid). Furthermore, the students referred to the unknown when explaining their attitudes towards astronomy, referring to life on other planets, black holes and whether there is a limit to the universe. This fascination with the unknown in physics and astronomy has been underlined in previous studies (Angell et al., 2004; Sjøberg & Schreiner, 2006).

In addition to interest, these students' self-efficacy in astronomy was high compared to electricity, as indicated by both the study questionnaire and the interviews. The students explained this by emphasising how their interest in astronomy increased their willingness to learn. Furthermore, most students preferred science tasks with no mathematics competencies involved, and 8th grade astronomy requires no mathematics. This is supported by previous research, as students often struggle with applying mathematics in physics (Lie, Angell, & Rohatgi, 2010; Nilsen et al., 2013; Redish, 2006), and by Girl 1 from School A, who made reference to the problem of applying mathematics competencies to another subject (Rebello, Cui, Bennett, Zollman, & Ozimek, 2007).

During the interviews, it became clear that students who found astronomy to be difficult referred to the difficulty of the field of research, rather than the school subject. Several students also pointed this out in the study questionnaire. This underlines the difficulty of constructs measuring attitudes, and points to the value of qualitative studies in this field (Osborne et al., 2003).

Discourse Practices

In addition to attitudes, our results indicate that students' discourse practices may have played an important role in learning astronomy. Our 8th graders shared what they learned with friends and family, and according to Hicks (2008), practising secondary discourse at home has a positive influence on students' learning. One student claimed that astronomy "*is kind of a philosophical subject and then one may philosophise a little*". This may explain why electricity is not a favourite subject to bring up at dinner conversations. The threshold for engaging in astronomy discourse may be lower than in other physics topics due to its philosophical nature (Angell et al., 2004). Furthermore, it is easier to share learning if the community (in this case family and friends) is interested in participating, and most students had at least one member of their family with special interest in astronomy. Mixing primary and secondary discourse during conversations with family and friends may also ease the path towards secondary astronomy discourse (Hicks, 2008).

In our theoretical framework we describe why media is another way of practising astronomy discourse. Both our qualitative and quantitative analyses indicated that students used media to a larger extent in astronomy than in electricity. The students had books about astronomy from their childhood, used internet sources such as NASA and others, watched scientific programmes about astronomy, etc. The Norwegian government has provided extensive resources for recruiting students to scientific fields, increasing the number of internet resources, TV programmes, interactive learning sources and science centres over the last decade. Considerable shares of these resources are dedicated to astronomy, which has a more prominent place in the current Norwegian science curriculum compared to earlier versions. This curricular reform and the additional resources put in place may have provided the students with an additional opportunity to learn. Moreover, along with practicing discourse by discussions in and out of school, these factors may have boosted their interest. The relation between students' reported discourse practises and their attitudes is, however, described in the following section.

Relationships between attitudes, discourse and conceptual understanding

The second research question concerned the relationships between attitudes and discourse and conceptual understanding of astronomy and electricity (measured by the test items). Attitudes towards both astronomy and electricity had a significant and positive impact on performance in each topic respectively. However, attitudes towards astronomy had a stronger impact on astronomy performance which could indicate that attitudes play a more important role for performance in astronomy than in electricity. In both topics the factor loadings for self-efficacy were lower than interest and utility value. This could indicate that self-efficacy is a somewhat different dimension of attitudes than the other variables, which is also consistent with Eccles' and Wigfield's Model (2002).

Students' reported discourse practises did not directly affect performance in astronomy or electricity. However, *Discourse* did affect *Attitudes* which in turn had an impact on performance in both topics. In both Model 3 and Model 1, the impact of *Attitudes* on performance was stronger in astronomy than electricity. Furthermore, the impact of *Discourse* on *Attitudes* was stronger for astronomy than electricity. This may indicate that *Discourse* has an indirect effect on performance through *Attitudes*, and that this effect is somewhat stronger in astronomy. In other words, practicing discourse by reading, discussing and being exposed to media may lead to more positive attitudes in astronomy which in turn may have a positive effect on conceptual understanding in astronomy.

Previous research (see e.g., Mortimer & Scott, 2003) do indeed emphasise the importance of practising discourse for learning, and the qualitative and quantitative data indicate that our students practise astronomy discourse more than electricity, at the same time as the students scored much higher in astronomy.

IMPLICATIONS AND CONCLUDING REMARKS

Our research may provide valuable insights into reducing students' difficulties with other physics topics with regards to the value of attitudes and the value of practising physics discourse. Implications for education may include using astronomy (or other areas of interest) to approach other topics that are perhaps considered more boring by students. For instance teaching electricity using examples from the Northern lights or solar wind may evoke more positive attitudes and increased willingness to learn electricity.

Our research emphasises the importance of discourse practices for positive attitudes, and the importance of attitudes for conceptual understanding of astronomy. These factors may have contributed to positive results in astronomy, and hence to the enhanced science achievement seen in TIMSS 2011 survey. It could be that the geographical dispositions in Norway (e.g. Northern lights, the full range of contrasting seasons, and polar nights) may engender positive attitudes towards astronomy, whereas

other countries may engender interest in other sub-topics of physics. However, this would call for further research. What is important is taking the local interests into consideration, and encourage students to practise physics discourse, because together they may positively influence students' learning process.

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