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Research Article

Skeptics - Experiences of Bildung from university-level physics students

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ABSTRACT

This study explores transformative experiences in university physics education and their potential to contribute to Bildung through a case study based on interview data of six Norwegian master's physics students. The results show that the students experience becoming more skeptical and critical in different ways, and while not solely ascribing this to studying in general, or studying physics in particular, they also ascribe their change to their experiences as physics students. This is connected to the term 'scientific skepticism'. This is evaluated and compared with forms of scientific skepticism from the literature. The students' forms of skepticism are evaluated critically against a definition of Bildung by Hellesnes and within a theoretical tradition from Humboldt and Klafki. The results are mixed and also support the idea of Bildung as a social process. These questions are important to be able to understand and to have a conscious attitude toward, what knowledge and attitudes students are left with after graduating. Do we have a conscious attitude toward the epistemic values we teach our students, and are they being prepared to use their knowledge to engage critically in society?

Keywords: Bildung, scientific skepticism, physics education

INTRODUCTION

> If I hadn't had a physics education or an education in research, I would have thought 'OK, fine, organic foods are good', for example. But when I actually have that, what shall we say, that critical way of thinking I can see 'OK, why do they recommend it', and one for example finds out that 'OK, fine, that is not really sustainable'. (Student S2)

This excerpt comes from an interview with a Master's physics student, who was asked whether studying physics had transformed or changed her. The response was similar to that of other students, pointing to acquiring a sense of skepticism and critical thinking skills. This project had an ambition of examining what transformative experiences students had in education, that could be interpreted as Bildung. The skepticism described was not the project's starting point, but came out of the data as an obvious result, and subsequently became a central theme. This paper thus intends to examine whether these experiences of becoming skeptical can be considered a form of Bildung.

Scholarship on education from many different perspectives promotes the transformative nature of education (Heddy & Pugh, 2015; Yacek, 2020). Education not only teaches you a subject but changes you as a human being. Building on this notion of personal development, the purpose of university education is not only to qualify young people for work-life but also to see 'oneself as a member of a larger community' and in such a societal view to use one's powers 'for the larger good' (Committee on Yale College Education, 2003). This idea also sums up a common notion of Bildung and is in line with current trends showing renewed interest in the democratic role of science education (Gornitzka & Maassen, 2022).

Skepticism in the sense discussed in this paper, must not be confused with the philosophical tradition of classical skepticism. The word is in this context used in a more colloquial sense (Dyrendal, 2010) and in the more modern tradition of 'scientific skepticism' (Skoglund, 2012), which is not skepticism towards science, but rather employing science as a tool to dispel epistemically unfounded claims (Skoglund, 2012). Kurtz (1992) critiques forms of classical skepticism as no longer viable given developments in human knowledge in diverse fields (p. 77) and counters them with an argument for a critical realism (p. 87), and the need for a new skepticism, a skeptical inquiry, that entails a "limited and focused, selective and positive" quest for knowledge (p. 72).

This form of scientific skepticism is a recent development. It was institutionalized in the latter half of the 20th century via skepticism towards "extraordinary claims at the fringes of science". It arose as a response to newer cultish milieus purporting paranormal claims during the 70s (Hammer, 2001, p. 251), and spread to Norway towards the nineties (Eggen, 2012).

Within science education transformative experiences can be defined as e.g. "actively use science concepts to see and experience their everyday world in a meaningful, new way" (Pugh et al., 2010, p. 2). I will however use a wider definition more in the tradition of Bildung - whether they experience being changed as a person (Schwanitz, 1999, p. 482) during their physics education. Based on the results, this is then seen in light of different aspects associated with skepticism. I will then discuss whether these results can be connected to Bildung, employing a definition by Hellesnes that entails connecting one's knowledge to the 'everyday world' – the world outside the scientific domain (Hellesnes, 1992).

Framing the Study

Bildung has been a central topic in European educational debates, predominantly within primary and secondary education (Telhaug, 2011). A clear definition is often considered impossible (Straume, 2013), however, it commonly entails an individual developing not simply as a professional but as a human being, enabling becoming an engaged citizen in society. Science and technology are commonly seen as less relevant to questions of Bildung than other fields of research (Schwanitz, 1999; Sjöström et al., 2017). The validity of such claims is however heavily disputed.

Hessen (2011) and Sjøberg (2009) claim that i.a. the methods, and the cognitive values of science can contribute to Bildung. Through the concept of scientific literacy, being able to employ scientific knowledge as well as understanding scientific connectivity to society, connects elements of science to Bildung (Aikenhead, 2006; Sjöström & Eilks, 2018). Elements within this tradition also emphasize developing a critical understanding of current social problems with a scientific component, employing the methods and epistemic values of science (Stuckey et al., 2013). This also resonates with international discussions about fostering 'critical thinking skills' (Wartono et al., 2018), discussions that have been amplified in recent years by challenges around e.g. 'fake news', science denial (Lazer et al., 2018; Oreskes, 2021; Sinatra & Hofer, 2021), and conspiracy beliefs (Douglas et al., 2019) as threats to democracy, and which are normative ideals also at the core of the philosophical tradition of 'scientific skepticism' or 'skeptical inquiry' (Kurtz, 1992).

To my knowledge, there is little to no research on the concept of scientific skepticism in physics education in particular, or science education in general. There is much research on the mentioned concept of 'critical thinking', but this is a more limited concept. Defined as "the use of cognitive skills or strategies to describe the thoughts involved in solving problems, formulating conclusions, determining possibilities, making decisions, reasoning and arguing" (Firmansyah & Suhandi, 2021), it is a central tool in scientific skepticism but it does not have the same societal ambitions. This can also be seen in how talk about a 'critical thinking movement' points to a movement within education science (Davies, 2015). The "skeptical movement" on the other hand consists of a loose collaboration between organizations like "The Skeptics Society", "The Committee for Skeptical Inquiry" and many others (Center for Inquiry, 2023), along with individuals or more or less loosely organized social media groups working actively to reduce the spread of epistemically unsubstantiated beliefs, albeit with very diverging methods and attitudes (Grams, 2021).

Some aspects of both the natural sciences and by extension skepticism have also been seen as representing the opposite of Bildung (Sjöström et al., 2017), dismissing other realms of knowledge and closing itself off against the outside world. The contribution of this paper will thus be to examine this conflicted

relationship between skepticism and Bildung among physics students and attempt to answer the question of how these students' experiences of becoming skeptical can be interpreted in the context of Bildung.

PHYSICS, BILDUNG, AND SCIENTIFIC SKEPTICISM

The main concepts in this paper will be physics education, Bildung, and scientific skepticism. Initially, the historical and theoretical connectedness between these concepts will be explored.

Bildung

The field of Bildung is complex and attempts to define Bildung in any specific sense have been considered futile by many. Max Horkheimer famously declared, "Don't expect me to define it [Bildung]. There are areas in which clear and simple definitions are more than to the purpose, and the role of definitions in knowledge should not be underestimated in any way" (Siljander & Sutinen, 2012, p. 2), arguing that clear boundaries of concepts are not always necessary.

The term is commonly attributed to Wilhelm von Humboldt, who emphasized the development of an individual's potential and the cultivation of moral as well as intellectual faculties (Humboldt, 1903), which emphasize different aspects of the concept (Sjöström et al., 2017).

Although the field of Bildung is chaotic and diverse, we can choose a useful operative definition of Bildung for this study: Bildung is a process of making an educated person able to operate within the 'the everyday world' and the 'everyday language', as opposed to the separation of science into its own world and language (Hellesnes, 1992, p. 84). In a broad sense, Bildung connects science to society. This definition is also similar to the idea of Bildung as a process enabling you to become a *citizen* – an active participant in society, and not simply an instrumental practitioner of a craft. This idea is found in both the tradition of classical Bildung in the tradition of Humboldt and the Anglo-American tradition of liberal education (Adler, 1952; Hancock, 1987; Paxson, 1985). While the concept of Bildung has developed in a German and Scandinavian context, it has also been employed in context with critical and emancipatory pedagogy from the global south (Schröder, 2021). Similar to both science and education, Bildung as a process and product has a social dimension, and already Humboldt also saw the process of Bildung as a deeply collective endeavor (Klafki, 2016, p. 41), a process that challenges and nuances the more traditional, individualized image of self-Bildung (Hellesnes, 1992).

Bildung in Natural Science

With a view of Bildung as opening science to society, science education research identifies several relevant aspects of science. We might separate Bildung aspects of science into two parts; elements that can be *useful in society* as a whole, like cognitive skills and values of science (Dagher & Erduran, 2014) or scientific literacy (Sjöström & Eilks, 2018), and aspects of science that *themselves show* sciences interconnectedness with society, like elements of the Family Resemblance Approach to NOS, such as Social certifications and dissemination, Scientific ethos, Social Values and Professional activities (Dagher & Erduran, 2014).

In a Norwegian context, it has been pointed out how the natural sciences, not only their products but also their methods, ideals, and values are an important part of our cultural inheritance (Hessen, 2011; Sjøberg, 2009). Hessen (2011) points out how '*realization and cognizance in a broad sense, about the human being itself, and our place in it all*', makes knowledge about the natural world central to culture and Bildung.

Bildung is also connected to scientific literacy. Sjöström and Eilks (2018), building on previous work (Aikenhead, 2006; Hodson, 2011; Liu, 2013; Roberts & Bybee, 2014) show how a 'Vision III' of scientific literacy (where the first two visions are learning scientific content and processes, and understanding usefulness of science in society respectively) directed towards '*critical scientific literacy*' and '*knowing-in-action*' can be connected to the Bildung tradition. In addition, a fourth element is incorporated, demanding '*socio-political action*' based on scientific knowledge (Sjöström & Eilks, 2018).

It is not hard to connect this to Hellesnes' definition. This brings the understanding of Bildung very close to an understanding of scientific literacy as a critical and political concept.

Some traditions within scientific literacy also point toward the aforementioned idea of critical thinking, an aspect of the epistemic values of science, as a central component. Roberts (1988) makes to '*develop a critical*

understanding of current social problems which have a significant scientific component in terms of their cause and/or their solution' a central component of science education (Stuckey et al., 2013). Similar connections between critical thinking and Bildung have been made by Harvey Siegel (2003) pointing out both critical thinking's role in rational traditions in educational activities, including science, and simultaneously how a sufficiently critical citizenry is a prerequisite for democracy. The latter understanding is pulling the critical thinking concept closer toward both scientific skepticism and Bildung than its traditional educational use.

Can Scientific Skepticism be Seen as Bildung?

Scientific skepticism in the sense discussed in this paper is defined in line with the 'new skepticism' envisioned by Kurtz (1992). This skepticism has historically been concentrated on skepticism towards claims in areas like alternative medicine, conspiracy theories, and similar topics, while shifting attention over the years depending on which (supernatural) subjects are in the public focus (Hammer, 2001; Lindsay, 2017; Novella, 2015), coupled with promoting science as the method(s) for understanding the natural world. As such, skepticism has a direct connection with the natural sciences, including physics (Rothman, 1988).

There are recent papers suggesting employing scientific skepticism in science education to dispel unwarranted beliefs e.g. in health (Tiller & Phillips, 2023). A 2022 Stanford University report suggests strengthening students' skills in line with the ideals of scientific skepticism to combat misinformation students meet online (Osborne et al., 2022). For physics students, one could point to relevant areas like electromagnetism/5G (Fernbach & Bogard, 2024; Krawczyk et al., 2020), Moon landing (Eversberg, 2019) climate change denial (Leiser & Wagner-Egger, 2022; Uscinski et al., 2017) where conspiracy theories are abundant, skepticism is paramount, and where physics can play a key factor in dismissing misinformation. Understanding the relationship between photon energy and electromagnetic frequency can e.g. debunk health risk myths about low-frequency radiation. Similarly, knowledge of atmospheric physics and the greenhouse effect helps counter climate change denial. Physics students are also well-equipped to grasp advanced climate models.

On a theoretical level, skepticism falls within the form of cognitive skills mentioned by Dagher and Erduran (2014), which are relevant to Bildung. Skepticism does not in itself necessarily imply interconnectedness with society, but it can be useful in society, and it is commonly applied there. Students employing their knowledge of the scientific method and its epistemic values on various phenomena they meet in society could be exactly bringing their knowledge into the everyday world, acting as engaged citizens in society.

An alternative view could be that viewing all phenomena through the lens of the natural sciences can become the 'scientism' Hellesnes warns of (Hellesnes, 1992). Being convinced of one's rationality, coming from a 'culture of no culture' (Traweek, 1988), can also lead to the so-called 'bias blind spot' where you become blind to your preconceptions (Pronin et al., 2002), which if caused by naïve realism runs contrary to the idea of Bildung. Examples of such anti-Bildung skepticism can be when skeptics are dismissive of other fields of study with little actual knowledge of them, of which there are multiple examples (Pigliucci, 2019). One could argue that several of these rather extreme pathways of development of thought, stem from attempts to use 'skepticism' or the epistemic ideas and values of the natural sciences in areas where they do not apply. This can again be connected to a lack of understanding of fields outside of natural science. In Wolfgang Klafki's tradition of categorical Bildung, Bildung happens when the student and the subject matter simultaneously open up to one another, the former gaining categories to understand the world in the process (Klafki, 1964). Employing this framework, we could say the understanding of the necessary categories is missing in these cases (Christensen et al., 2006; Klafki, 2001).

To consider whether forms of scientific skepticism can be connected to Bildung, it is thus necessary to evaluate the different forms scientific skepticism takes and to see whether they engage critically with the world outside science, or whether they take the form of unreflected dismissal of areas outside the domain of natural science.

Forms of Skepticism

The skeptical movement has been connected to atheism and higher education and is traditionally a male-dominated movement (Dyrendal, 2010), but increased diversity in the 'skeptics movement' has both increased the span of opinion and caused internal conflicts (LeDrew, 2015; Oppenheimer, 2014).

The relationship between skepticism and science on one hand and spirituality and religiosity on the other is complex (Edis, 2013), and a divide in the skeptical movement (Skoglund, 2012) has been between exactly hardline atheists who believe religion and science are incompatible (Dawkins, 2006), and those who believe religion and similar questions of faith are outside the domain of skepticism as 'non-overlapping magisteria' (Gould, 2011).

This disagreement reflects more fundamental disagreements on NOS on whether (natural) scientific descriptions are all-encompassing or whether other fields like humanities, history – and religion – can offer insight into e.g. more value-laden realms (Cimino & Smith, 2015; LeDrew, 2015; Sterelny, 2007).

With a definition of Bildung that entails connecting science to the world outside science, it is reasonable to interpret attitudes that are dismissive of entire realms of this world, outside the chosen definition of Bildung. This also parallels the difference Olav Hammer (2007) describes between "dry skeptics", not engaging very deeply but compensating this with a strategy of ridicule, and "wet skeptics" promoting engaging actively and critically with the arguments and evidence of their opponents. Internally this also reflects conflicts where "dry" skeptics have been accused of anti-intellectualism and "pseudoskepticism" by skeptics adhering to the normative ideals of skepticism (Mayer, 2023).

METHODOLOGY, INTERVIEWS, AND ANALYSIS

This study is a case study based on six individual semi-structured interviews with master's physics students on Bildung aspects of their physics education. They were recruited by email to all master's students and posters in student areas. The six respondents in this study were all the students who volunteered to participate in this recruitment process. After assuring these respondents represented a diversity in gender and study program, no respondents were excluded, nor was there made additional attempts to recruit more respondents. For the study programs as a whole, the gender distribution is about 70/30, with a male majority.

The recruitment process declared that the project was about Bildung, and the students were presented with the overarching question of whether studying physics had contributed to personal development. The students were asked open questions about transformative experiences in their education and about whether their studies had changed their worldview, in interviews of length from half an hour to an hour and 15 minutes.

Participant background:

- **S1** male, 2nd year of a 2-year master in physics program, native Norwegian
- **S2** female, 4th year of a 5-year technical physics program, native Norwegian
- **S3** female, 1st year of a 2-year master in physics program, non-native Norwegian
- **S4** female, 2nd year of a 2-year master in physics program, native Norwegian
- **S5** male, 5th year of a 5-year technical physics program, native Norwegian
- **S6** male, 5th year of a 5-year technical physics program, native Norwegian

All master program students come from a bachelor program in physics (required), and all students had their most recent pre-university education from Norway.

Interview guide:

(1) Open questions about physics and the education the student has taken.
(2) Of all those who start physics in the first year, some do not pursue a master's thesis. What is your impression of those of your fellow students who quit? When did they quit and why do you think they quit?
(3) Transformative experiences - is there anything about physics education that has been sort of 'wow' - that has changed you or the way you see things?
(4)
   a. What about your worldview? Is there anything about your education that has influenced how you look at the world beyond physics itself? Are there any areas you have changed views on?
   b. Elaborative/follow-up questions in specific areas - politics – view of science - ontological/epistemological questions, the view of other disciplines (hard/soft science), etc., depending on the response to previous questions.

(5) Is there anything you think physics education should have had more or less of in light of what you have said until now? Does it have the right focus? Would it have been more inspiring and exciting if something had been done differently? If so, what? Is there anything you think of as 'physics' you wish you had learned more about?

A natural starting point in the process of sorting has been to be on the lookout for recurring content, and sorting this content thematically (Rennstam & Wästerfors, 2015), in line with thematic analysis as described by Braun and Clarke (2006).

This process has been oriented toward identifying larger meaning units, or Concept Codes in the terminology of Saldaña (2016). I have attempted to look at the material as freely as possible from forgiven prepositions and expectations (Rennstam & Wästerfors, 2015), in a '*more naïve, pretheoretical way*' (Giorgi, 2009, p. 135). In line with this, the present study was undertaken by going through interview transcripts, identifying such meaning units, critically re-reading them, and evaluating recurring themes. While the term 'Bildung' guided some questions for the interview guide and as such the study, the use of the concept of 'skepticism' and the theoretical interpretation of it came inductively out of the interpretation of the data.

Because of the focused research objectives of this case study, I have chosen "a more detailed and nuanced account of one particular theme" related to "a specific question or area of interest within the data which gives specific phenomena of interest" (Braun & Clarke, 2006, p. 83). This has guided the identification of a central theme (Robson & McCartan, 2016), and opened the way for a reduction of the material by excluding other themes (Rennstam & Wästerfors, 2015). In addition, illustrative examples were identified, in which elements of the data that particularly shed light on the central themes are included. Illustrative quotes were then put through a process of meaning condensation (Giorgi, 2009) (for results, see **Table 1**). Some common themes (e.g. connected to physics itself), were thus excluded from the analysis as they fell outside the research objective of Bildung which forms the basis for this study.

Limitations

This is a qualitative case study, and can as such not be used to make quantitative claims. In addition, the paper describes the students' own experiences, and cannot say whether the students own impressions of becoming more skeptical from studying physics are correct. Although the methodological choice of coding free from presuppositions has been attempted through several critical re-readings of the interviews, an author can never completely free oneself from all biases. Finally, the study was conducted on students from one northern European university and involved questions that may not be culturally neutral. The findings may thus also be different than they would be within another cultural context.

RESULTS

Initially, the students' reflections on their chosen study and pathways leading to this study, suggest that their interest in physics came from a fascination with the 'big questions' like astrophysics, which is common (Henriksen & Bøe, 2018; Nilsen, 2013). They had often read popular science growing up and were curious to understand how the world worked. In addition, their perceived talents and a certain number of coincidences had led them to study university-level physics. In the following, we will turn to the students' reflections on their own transformative experiences during their physics education.

Students' Experiences of Skepticism

The most common Bildung-oriented theme was that all the students in one way or another described how they during their education had become more skeptical and critical in different ways (**Table 1**). The students had all volunteered these perspectives on open questions in a way that was hard to identify among other themes.

Table 1. Analysis of forms of skepticism from students S1-S6. Column 1: Student, Column 2: Condensed quote from the interview, Column 3: Examples of subjects of skepticism gathered from the entire interview, Column 4: Short interpretation of 'form of skepticism'

Student	Condensation	(Additional) mentioned subjects for 'skepticism'	Interpretation
S1	S1 states that he has learned to think independently, and thinks e.g. alternative treatment should be prohibited.	- alternative treatment - organic food - humanities (money spent on)	Combines elements from scientific skep with skepticism towards not humanities but their priority in society relative to na sciences.
S2	S2 states that she has become more skeptical, wants to get to the bottom of things and be precise.	- tabloid news media -dietary advice - pedagogy and psychology (as science) - homeopathy	Combines elements from scientific skep with skepticism toward the scientific rig pedagogy and psychology.
S3	S3 states that she has become more self-critical, and thinks of what a critical outside reader would think.	- climate denial - own preexisting views on abortion - pedagogy and social science (as science) - general lack of skepticism in society	General disapproval of lack of skepticisr society combined with skepticism towar climate denial.
S4	S4 states that she looks upon the world in a more reflected way, believes in popular enlightenment, and is provoked by e.g. flat earthers.	- flat earthers - climate denial - resistance against nuclear technology - gender biases - religion	Combines elements from scientific skep with skepticism towards gender biases.
S5	S5 states that he has become more objective and less emotional. Critical towards organic foods, etc.	- organic foods - resistance against genetic technology - emotions in politics	All elements fit into scientific skepticism
S6	S6 states that he has become more skeptical towards cocksureness and feels discussions about e.g. nuclear power are too emotionally driven.	- resistance to nuclear technology - CERN (money spent on) - lack of scientific rigor in evolutionary psychology, pedagogy and humanities, and social sciences in general.	Combines elements of scientific skeptici with skepticism towards priorities of exp parts of physics itself, and the scientific humanities and social sciences.

The students' experiences seem to revolve around aspects of criticism (incl. self-criticism), skepticism, independence of thought, rationality, etc. I label these ideas 'skepticism' in this analysis, also on the background of the examples the students contribute (**Table 1**, Column 3). Illustrative condensations from the interviews, along with categories constructed during the analysis are presented in **Table 1**.

As we can see from **Table 1** all but one student (S6) explicitly comments on topics common in the discourse of 'scientific skepticism' like alternative treatment, but these are combined with skepticism towards a variety of social and political topics. We also see a considerable thematic overlap between this study of physics students and studies specifically sampling skeptics (Simmons, 2018).

A good example of this variation can be seen when e.g. student S4's skepticism (**Table 1**, Row 4), is directed both at a classical 'scientific skepticism' subject, like the flat earth movement, but also climate change denial and toward dated and prejudiced notions on gender difference, as the following excerpt indirectly illustrates:

> S4: I have met several people who have been very loud about "girls aren't made for science" [...] – to my face. [...] So I read up and realized the research they were referring to was 60 years old, so perhaps people should update their attitudes instead?

In this excerpt, we can see delving into the science on a (non-physics) topic, is the tool S4 uses to dispel outdated notions about women and science and assert her self-worth as a female scientist.

Similarly, the assertiveness of individuals with little to no knowledge of climate was a source of frustration for S4 who had spent 2-3 years working on climate physics.

> S4: When people have no background knowledge about it [...] and they are the ones who shout the loudest. These things are ... sad...

Here her direct knowledge of physics acts as motivation for societal engagement on climate issues.

In Norway, the recent phenomenon that has gained the most public attention and that can be seen to be inspired by this school of thought is the TV program 'Folkeopplysningen' (Popular Enlightenment) hosted by physicist Andreas Wahl. Among issues this program has raised and that the students in this study also mention (**Table 1**) as examples of subjects of their skepticism are organic foods, dietary advice, nuclear technology, climate denial, alternative medicine, and genetically modified food (NRK, 2018). Students S4 and S5 also explicitly mention this program.

When student S3 expresses a general disappointment over the lack of knowledge about how science works and the effects this has on the public debate on climate change, she also directly employs the epistemic values of science in current political debate.

> S3: Yes, the method, or - because there are too many, I believe, that have a far too simplified view of how research is being done. They like, in the United States, where 'they all lie', for example. You cannot believe that if you understand a little more about how climate research is being done.

In general, as seen in **Table 1**, several of the students' responses fit with the idea of taking one's scientific knowledge and bringing that into society, being skeptical of obvious falsehoods, and potentially contributing to a discussion on more open issues.

Students' Development toward Skepticism

The students had slightly varied views on the causes of their skepticism. It was not necessarily just their education that led them to become skeptical, but it helped. While S6 describes how modern physics was an eye-opener to how things you have taken for granted may be wrong and S5 and S1 describe how studying physics has contributed to "a more objective approach to things" and "learn[ing] to think on one's own" respectively, S4 describes how education in general and not just physics have made her "more reflected" in her worldview. S2 describes how her growing older during her time at university can also be a contributing factor. S3 describes uncertainty of whether she chose physics because she had a critical worldview or she became this way from studying physics but concludes studying physics had also contributed. In her response, we can also see traces of how Bildung also can be a collective process (Klafki, 2016, p. 41), where one is formed by one's co-students, as complementary to the more common image of self-Bildung.

> S3: I have always liked to be critical, of myself as well. But I also believe that I've become more like this as a result of studying physics, and also because I've gotten to know other people who are also critical. So, I think that has helped quite a lot. The conversations you are having with others, not just about physics, but about politics, for example.

Student S3 also hypothesizes how being practiced in discussing physics, where most people have less strong preconceived positions, gives one a better starting point for self-criticism and more open discussions on other subjects, like politics.

> S3: It is because you talk to people who are also studying physics. It's because you've taught yourself to go on even though things get difficult. That you've learned to be skeptical - all of those things. But I do not feel that knowing those things have changed me. It is more the path towards knowing those things.

Students' Connectedness to the World Outside Science

The students interviewed do in general not fit an anti-religious image, except S4 who had become more anti-religious due to an experience with a childhood friend who had become very religiously conservative. S1 volunteered religiosity (the students were not asked explicitly about this) and saw no problem combining this with a general scientific worldview, but if there was to be a conflict, physics would take priority.

On the topic of other scholarly areas, student S2 purports an increased skepticism to 'what I accept as a science and not' and mentions pedagogics and psychology.

> S2: In a way, it becomes just assumptions, and people can assume a lot of things, but it can be really destructive to believe something, just because somebody has assumed their way to a viewpoint.

Here we can see S2 being quite dismissive about fields she has not studied. Student S3 has similar experiences.

> S3: It's really very different. I got a shock. I took PPU (a one-year course in practical-pedagogical education, auth. remark), then it's like – what they call research, has nothing to do with what we call research.

However, student S3 like most of the students is not entirely dismissive. They however do not see these fields as science.

> S3: But that does not mean, I mean – we need it. So, not like – just science. But it would have been nice if those who did that stuff had also [been a bit more] scientific.

S3 is not quite sure how to interpret this perceived lack of science in some non-STEM fields and find them both relevant and useful. A majority of the students (S2, S4, S5, and S6) also volunteered interest toward parts of the humanities, and S2 in particular found parts of a compulsory introductory philosophy course interesting while confirming it has a bad reputation among science students. She mentioned a student choir serving alcoholic shots to students ahead of the entrance to the lecture hall to help them survive the (presumably boring) lectures.

DISCUSSION: THE RELATIONSHIP BETWEEN SKEPTICISM, PHYSICS, AND BILDUNG

How do these students position themselves in a landscape of skepticism? What forms does the students' skepticism take, and does it make sense to label these forms of skepticism 'Bildung'?

Skepticism and Physics

As this study is about physics students, it is relevant to look at some connections between physics and skepticism. The data suggests that the students partially see the cognitive skills acquired through studying physics as a reason for their skepticism. As we have discussed scientific skepticism highlights the scientific methods that underpin the epistemic values of the scientific community these students are attempting to enter, so this is perhaps not surprising. Cultural similarities between skeptical communities and physics communities can reinforce this positive attitude to skepticism from a physics standpoint.

Previous research has shown how important identity is for the choice of education (Schreiner & Sjøberg, 2007). There may therefore also be other more cultural factors, factors of identity that attract physics students to skepticism, or skeptics towards physics as student S3 alludes to. If we look at these communities, we can find several commonalities with physics. They are both traditionally white and male-dominated fields and more so within the more 'hard-line' (e.g. New Atheism) parts of skepticism cf. previously discussed splits within the movement (Cragun, 2015; Eaton et al., 2020). The idea of 'a culture of no culture' (Traweek, 1988) is prominent in parts of both communities. Skepticism thus resonates with physics both within the cognitive values they both promote, but also on a socio-cultural level of identity which may manifest itself more subconsciously.

This gives two possible complementary paths for physics students into scientific skepticism, one more connected to the subject of physics, and one more connected to culture. We can find support for both in the students' interviews.

Does these Students' Skepticism Entail Bildung?

Does it, based on the criteria discussed and the results presented previously, make sense to label the forms of skepticism these students describe as a form of Bildung? Looking at the chosen definition of Bildung of connecting the world of science to the everyday world, the world of politics, some of the presented examples of skepticism from **Table 1** fit this definition quite well. Using the cognitive skills they have learned in science education on areas like alternative medicine, tabloid news media, climate denial, fear of nuclear technology, etc. as we can see in **Table 1**, means engaging in hotly debated topics in political debate. Here the students are evoking central tenants from the nature of science (Lederman, 2006) and the scientific method on broader societal areas, including climate change, thus using critical thinking as a central skill in education for sustainability as suggested by Thomas (2009). If we accept the students' descriptions of these cognitive skills being (partly) a result of studying physics, it thus makes sense to see this experience as a form of Bildung as we have defined it.

In evaluating whether all the students' skepticism can be viewed as Bildung, however, we should have a closer look at the students' views along the discussed lines of critical engagement vs. unreflected dismissal. On the more contentious topics of religion and the non-natural sciences, the results in this regard are more mixed, and the students themselves express difficulty with these questions during the interviews.

Forms of Skepticism in Students' Responses

Students' views on religion are relevant to describe the *type* of skepticism they experience, and in extension, whether this skepticism can be seen as Bildung. The most common view of religion among the students seems to be one not of personal religiosity but neither anti-religion. This is a view more similar to Stephen Jay Gould's 'non-overlapping magisteria' (Gould, 2011, p. 269).

A similar varied, but not directly rejective view can be seen of fields of research within the humanities and social science. We do find viewpoints that point in a direction as critical of their scientific rigor. Some of the student's comments, like S2's on psychology and pedagogics, would be considered arrogant by practitioners in these fields. These attitudes seem to be based on a narrow view of what science is (*science=natural science*), and perhaps a lack of insight into the epistemology of social science and the humanities. Similarly, the condescending and unscientific perspectives on women's inferior role in science, which student S4 reports having been confronted with, could be attributed to a lack of knowledge of the sociocultural dependence of social science, or misguided perceptions of the value-neutral "culture of no culture" of the natural sciences which pave the way for verbal harassment dressed up as rational arguments – none of which contribute to a constructive connection between the world of science and the everyday world of politics.

In the spectrum discussed previously, however, the students in general position themselves away from the dismissive position. Though some students are skeptical of some aspects of social sciences and the humanities, they also see their importance, and neither does this skepticism apply to all students.

Overall, we can interpret the students' skepticism as mixed when it comes to fitting into our chosen definition of Bildung. While the overall responses are not dismissive of non-science fields, they nevertheless struggle to understand these fields and fit them into their epistemic categories. This thus is an area in desperate need of more categorical Bildung.

The bad reputation of the introductory philosophy course among science students is also interesting as it is the course where the philosophy of science and critical thinking should be introduced. Studies have shown that critical thinking classes do reduce the degree of epistemically unwarranted beliefs (i.e. increased 'skepticism') among students (Barberia et al., 2018; Dyer & Hall, 2019; Wilson, 2018). One could perceive a possible contradiction between the down-prioritizing of these philosophy classes among science students and the idea that science students are particularly skeptical. This reputation however fits with a more dismissive view of the humanities. It also fits well with research showing science majors have a poorer grasp of NOS concepts (Akgun & Kaya, 2020). This could thus contribute to the students' skepticism becoming more superficial and less grounded in the epistemic values of science, and thus to less Bildung.

Are we Forming the Students we Want to Bild?

Although results from a case study cannot be generalized, they shed light on the contradictions known from existing scholarship we have previously described and can thus support a more conscious approach to teaching the values of science.

Fostering cognitive skills like critical thinking has been seen as a desired outcome in science education in general, and physics education in particular for many decades (Bernal, 1940; Burke, 1949). With this in mind, fostering skepticism of the kind we have discussed is a welcome Bildung effect of physics education. On the other hand, based on a perspective on Bildung connecting physics to society, we can see in some of the student's quotes a form of 'skepticism' closing them off to the outside world. A lack of diversity (Wade, 2019) can reinforce a reproduction of practice (Lave & Wenger, 1991) that creates this closedness. If we wish to increase the diversity in physics to counter this effect, bonding to a community like the skeptical movement, with the same diversity problems might be counterproductive. When two communities with similar problems of diversity are connected, the problems may be mutually reinforced. If we believe the cognitive values in themselves are sound, they should however not be dismissed on these grounds, and the students' responses did not in general correspond with the more hardline skeptical positions with the largest diversity problems.

There is also a very timely argument for fostering the critical thinking skills associated with scientific skepticism. Recent years have shown an increasing amount of false information spread online, and research shows false news reached more people than the truth (Vosoughi et al., 2018). Fostering skepticism in students can be one important contribution to empowering individuals to withstand false information. There have been attempts to insert critical thinking actively in schools, however, the effects, particularly over time are uncertain (Lazer et al., 2018). On this basis, one can easily argue that a Bildung approach where these values are entrenched in the culture of an institution and are conveyed through a gradual collective process of personal development has a more promising starting point.

From the students' reflections, we can see examples of how e.g. student S4 uses her skepticism and science literacy to engage in political questions like gender equality and climate change, in addition to frustration about flat-earthers and other more classical vendors of pseudoscience. This is at the core of Bildung as we have described it. In contrast students also, e.g. S2 turn to dismissing pedagogics and psychology in a way not dissimilar to the people S4 was frustrated about in climate science. There is thus a wide scope of use (or misuse) of the students' skepticism.

This begs the question of whether one needs a more active approach where this form of Bildung should be promoted within university-level physics education to encourage students to engage themselves more in society, both on a personal level where skepticism can act as a protection against deception, but also for the possible positive effects such an engagement might have on society. If you don't let yourself be fooled, you will be less likely to contribute to fooling other people (Buchanan, 2020). In such a case one should however take care not to limit the scope of said skepticism to current hegemonic societal ideas (Stølen, 2022), and discourage the unreflected dismissal we can see in some students' attitudes.

A conscious approach, where learning goals that build on the ideas of scientific skepticism, like critical thinking, are integrated into the study programs and are taught consciously instead of being part of a "hidden curriculum" (Orón Semper & Blasco, 2018), can both employ and strengthen the positive Bildung-oriented elements of this tradition seen in students' critical engagement in societal topics, but also reduce the epistemically unfounded unreflected dismissal we can sometimes also see.

CONCLUSION

The data suggests that the interviewed physics students have an experience of going through a process of personal change during their time at university.

We predominantly see that the students all express becoming more critical and skeptical during their student years and that the topics of this skepticism make it relevant to partially connect this to the concept of scientific skepticism. If this development can be connected to Bildung, it will be a form somewhat different from the one traditionally connected with the humanities and that is closely connected to the students' knowledge of and dedication to the scientific method from natural science. The data show examples of how

a product of science education can be useful in, and create engagement with wider society in general, and political questions in particular thus being in line with the concept of Bildung we have discussed. It however also shows that the predominant culture in physics can be dismissive of other areas of research and other worldviews, which can create a distance and barrier to societal engagement. To which extent students' skepticism can be considered Bildung, will thus depend on their positioning within a perceived 'space of skepticism' moving from the critical but open toward the closed.

In the space of attitudes within this skeptical movement we have examined (religion and views of HumSoc fields) a typical physics student from this sample presents a more moderate form of skepticism that has critical but nuanced views about social sciences and the humanities and with one notable exception a view on religion and science more as 'non-overlapping magisteria'. The difficulty several students have in positioning e.g. social sciences in relation to their understanding of 'science', however, suggests that they lack the necessary categories to position some other realms of knowledge, again suggesting a lack of both understanding of NOS and Bildung, leaving the overall results mixed.

A more conscious attitude toward teaching NOS aspects and their limitations in physics courses may unlock more of the potential for Bildung that exists within science, than the more organic and random dissemination of skeptical ideas these interviews describe.

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