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Skepticism and physics: epistemic beliefs of Norwegian physics students compared with other student groups

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Abstract

The purpose of this study is to examine how physics students position themselves compared to other student groups on various attitudes and opinions relevant to the tradition of "scientific skepticism". Previous research has shown physics students identifying and having mindsets in line with the epistemic ideas from this philosophical tradition, promoting disbelief in epistemically unfounded ideas, and skeptical inquiry as a tool for evaluating claims. In this, we employ quantitative constructs testing conspiracy beliefs and supernatural beliefs along with established psychological constructs for social dominance orientation, and the conspiracy mentality questionnaire that have previously been shown to have interconnectedness. After showing several direct comparisons between different student groups, the paper also examines other elements that can influence "scientific skepticism", like education level, education type, and gender via multivariate regression analysis. The results suggest physics students tend to position themselves to the end of the spectrum on several constructs connected to scientific skepticism, both compared to students from the humanities and social sciences, and students from other STEM (science, technology, engineering, and mathematics) fields, and the regression analysis finds being a physics student contributes a statistically significant contribution along the tested dimensions. The paper discusses possible reasons for this and what this tells us about physics students and physics education.

Keywords Skepticism · Physics students · Epistemic beliefs

1 Introduction

A previous qualitative research project has disclosed a group of master's physics students all describing becoming more skeptical and critical during their time as students [1], in line with the philosophical tradition of scientific skepticism or skeptical inquiry (the terms are used interchangeably) [2]. Many of the subjects of skepticism described by the students could be connected to the "International Skeptics Movement" [3]. An open question is however if this is connected to their role as physics students or if they simply reflect epistemic beliefs representative of students in general. Previous research on the connected topic of understanding of nature of science (NOS) concepts among different student groups are mixed. Students with backgrounds in science in general do not seem to have a better grasp of these concepts than other students [4–6]. It is thus not a given that an education in science also will give the best understanding of the epistemic values of science.

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Kurtz defines this skepticism as "a method of doubt that demands evidence and reasons for hypotheses" and as such "is willing to assert reflective unbelief about some claims that it finds lack adequate justification" [2]. In his book, Kurtz goes on to use this skepticism to dismiss paranormal claims, but also to critically engage in political and societal questions.

When considering supernatural beliefs, concepts that contradict the epistemic foundation of science will be considered [7]. Conspiracy theories are in general seen as unscientific, as they rely on anecdotal evidence, are not falsifiable [8], and stem from e.g. a range of biases and psychological factors rather than evidence [9]. Because of this, conspiracist ideation is an important predictor of rejection of science [10].

This project aims to test whether physics students' skepticism is representative quantitatively compared to other students, and attempts to answer the research question:

How does the skepticism of physics students compare to other student groups?

This paper will thus discuss the theoretical concept of "scientific skepticism" and examine it mainly through the dimensions of conspiracy belief and supernatural belief. Statistically confirmed constructs are used to compare physics students to other student groups at the same university.

1.1 Relevance/importance

In recent decades there has been an increasing emphasis put on educating students to be not only proficient agents within their fields but also to engage in society with their knowledge as engaged citizens and acquire knowledge and skills that enable them to do so [11, 12], often in line with ideas from the European tradition of Bildung [13]. These skills are seen as necessary in navigating a world of complexity in both problems, interests, change, and consequences [14].

Parts of the complexities in modern society are connected to the dissemination and endurability of epistemically unfounded beliefs [15]. Countering these falls within the scope of scientific skepticism as defined above. Traditional attempts to teach the philosophy of science to science students have been met with skepticism among the scientific communities (and hence, science students), and not entirely without reason [16]. Often these subjects are taught in separate courses [17], rather than being integrated into science courses, and it can be argued that much of the students' views on the more philosophical implications of science, are disseminated through science courses, and science professors, but unconsciously and organically as part of a 'hidden curriculum', where students are gradually included into the predominant culture of science [18].

A common idea from science education literature is evoking central tenets from NOS [19] and the scientific method to create critical thinking skills that can be employed in broader societal areas, and not just within science. One example of such use can be seeing critical thinking as a central skill in developing education for sustainability [20]. For physics students the latter could involve using their knowledge of science to dispel misconceptions about climate change, but also in having the skill set to understand and use e.g. life cycle assessment results to critically evaluate the sustainability of products or practices rather than employing popular but unsubstantiated assumptions.

In creating educational strategies that take considerations of teaching the epistemological foundations of science seriously and consciously, we must know where our students are situated to make conscious choices on how to include e.g., different epistemic and ontological concepts that shape students' worldviews into our education. Different student groups may be positioned differently in these epistemic areas and require different approaches e.g. different courses or forms of integration, which justifies a comparison between student groups. There are many perceivable differences within a student population. Some at the start of their program, others toward the end, there are gender differences, some are in shorter professional programs others in longer programs, some are in STEM, and others in social sciences or humanities. This study will examine how physics students position themselves compared to other student groups on various attitudes and opinions relevant to the "scientific skepticism" tradition along all these axes.

2 Ontological and epistemic beliefs, skepticism, and professional background

The foundational ontological and epistemic beliefs of physicists or physics students are not well-researched, but there is some data on common traits among physicists. An early 1993 US study showed physics students scoring high on general intelligence and spatial ability, but more mediocre on verbal abilities [21]. A British 1994 study of physicists found them more careful, controlled, and introverted compared with other groups. In related research, Sharon Traweek's seminal work on physicists' prevailing idea of existing within a "culture of no culture" gives us a glimpse into the way (some) physicists think [18].

On the wider area of STEM, a 2021 study concluded Openness and Agreeableness[1] as the best Big Five predictors of STEM preferences [23]. Similarly, a US 2012 study showed scientists scoring high on openness, intrinsic motivation, and tough-mindedness, and lower on assertiveness, conscientiousness, emotional stability, extraversion, optimism, and visionary style than the non-scientist control group [24].

It is important to note that these findings are not universal and can vary depending on the sample and the methods used in the study. Additionally, the personalities and beliefs of physicists and physics students will be shaped by their experiences and environment, rather than being simply inherent traits.

This study will concentrate on traits connected to the concept of "scientific skepticism" as described by Kurtz [2] and defined above, often connected with the so-called international skeptics' movement [3]. The scope and degree of plurality within this movement is not the topic of this paper but can be found by reading select texts from within the movement [25, 26]. In brief, it is concentrated on skepticism towards claims in areas like alternative medicine, conspiracy theories, and similar epistemically unfounded beliefs. It resonates with current discussions about fostering 'critical thinking skills' [27], discussions that have been amplified in recent years by challenges around e.g. 'fake news' [28] and conspiracy beliefs [29]. This is coupled with promoting science as the method(s) for understanding the natural world. As such, skepticism has a historical connection with the natural sciences, including physics [30].

Much previous research shows close correlations between different forms of alternative and pseudoscientific beliefs, including conspiracism and supernatural beliefs [31–33]. Bensley et.al [34] have explicitly shown how scientific skepticism has a distinct negative correlation with both paranormal and conspiracy theory beliefs. Given that a survey of i.a. conspiracism and supernatural beliefs among other student groups from the same university had recently been done [35], this survey will test conspiracism and some supernatural spiritual beliefs among a group of physics students both at first-year and master levels for comparison.

There are of course also other factors than field of study that can influence the skepticism we are discussing in this paper. Previous research e.g., suggests gender is important for specific forms of skepticism, but not necessarily skepticism in general (e.g. [36, 37]). One potential factor can be a known general higher religiosity among women [38].

2.1 Conspiracism

There is to my knowledge little quantitative research directly comparing areas of study in general, or on physicists, and belief in conspiracy theories. There are however studies examining adjacent topics.

A 2019 study from Spain found that both beliefs in conspiracy theories, paranormal beliefs, and other unwarranted beliefs interact poorly with scientific literacy, scientific knowledge, and trust in science [39]. In general, it is a common feature of conspiracy theories that they contest the epistemic authority of science [40] as such it is to be expected that a connection, or a wish to connect to this epistemic authority, e.g., a physics student, would be inversely correlated to belief in such theories.

The direct contrast between scientific knowledge and conspiracy theories can be seen in fields like electromagnetism/5G [41], flat earth conspiracies [42], Moon landing [43] climate change denial [44, 45] vaccine hesitancy, and COVID conspiracies [46] or chemtrails [47]. Several of these should be of particular interest to physics students. Knowledge of the connection between photon energy and the frequency of electromagnetic radiation should help dismiss ideas of health risks from low-frequency radiation. Similarly, knowledge of atmospheric physics or simply the mechanisms of absorption and re-emission of radiation by molecules that lie behind the greenhouse effect should engage physics students against many of the ideas in climate change denial. Physics students are also well positioned to understand the mechanisms included in advanced climate models, like the ones who won the Nobel Prize in physics in 2021.

Other conspiracy theories are, however, more unrelated to the natural sciences, like those around the deaths of celebrities, or those of a more political nature (e.g., "false flag"-speculations). However, the well-established propensity to believe in other conspiracy theories if you believe in one [see e.g.15], along with findings on education, in general, being inversely correlated with belief in conspiracy theories [48], might suggest science students, including physics students, also have a low belief in conspiracy theories in general.

[1] Interestingly also the two traits most commonly associated with liberal political views [22].

A 2001 study examining i.a. paranormal beliefs in pre-service teachers however found considerable cultural differences between Finnish, Estonian, and American participants [49], suggesting that documented geographical differences [50] also exists across a student population in the same field of study.

2.2 Supernatural phenomena and religion

The relationship between skepticism, science and spirituality and religiosity is complex. Historically science has been promoted as both supporting religious beliefs, as opposed to them, and as belonging to non-overlapping spheres [51].

A classic study found that successful natural scientists, including physicists, tended to atheism [52]. This was confirmed in a 1998 study [53]. A 2011 study of US students found that most of them held a non-conflict view on the relationship between religion and science. Among the students who held a conflict view, mathematics, engineering, and natural science students were the ones who sided the most with science [54]. These groups did however not have a larger overall conflict view.

A 2016 study from Finland, found that supernatural beliefs were strongly correlated to low skills, knowledge, and interest in physics [55].

A global study spanning eight regions found large regional differences in scientists' religious practices and beliefs, although they, except Hong Kong and Taiwan, identified as less religious than the general population [56]. Most scientists across regions however, like the US students, had a non-conflict view on the relationship between science and religion and saw them as belonging to independent spheres.

To test skepticism we will thus base our analysis of skepticism within the area of spirituality on the idea of independent spheres, or "non-overlapping magisteria" [57], and connect the term with disbelief in spiritual ideas that conflict with the epistemological foundation of science, methodological naturalism [7, 58], like belief in healing, black magic or clairvoyance, and not with religiosity in itself.

This will in sum allow us to test skepticism along two dimensions—conspiracism and supernatural spirituality, comparing physics students with other students.

3 Constructs and comparisons/methods

For this survey, a range of different questions were put to physics students on a seven-point Likert scale. The survey was distributed on paper questionnaires to students during lectures and the results were subsequently extracted into SPSS for analysis. The questionnaire is based on a previous survey done by Dyrendal, Kennair, and Bendiksen [59]. Some questions and question sets are omitted as they are less relevant to this project. I have with appreciation been allowed to use the dataset from this previous survey, to compare the responses of other student groups with physics students to see how physics students position themselves, and if they differ considerably from other groups.

3.1 Confirmatory factor analysis

The questions in the survey are mostly previously developed and tested. They consist of the following: Gender (one item, two-point scale), 17 items on different aspects of supernatural beliefs originally assembled by A. Dyrendal (Sup) [35], 5 items from the Conspiracy Mentality Questionnaire [60], with one additional item added by Dyrendal [59] (CMQ6), 16 items on social dominance orientation [61] (SDO16), 4 items testing rational suspicion [62] (RatS), 10 out of 16 items testing conspiracy belief (Con10), with two items testing documented conspiracies (Real Conspiracy) [59], all 7-point Likert scales. Finally 8 of the 17 supernatural items that most clearly conflict with the epistemological foundation of science, methodological naturalism [7, 58], like belief in healing, black magic, or clairvoyance was singled out as a separate construct (Sup8).

Of the items from the sample of physics students, the following were identical in the data from other students: All the 17 items from the *Sup* variable, all 6 items from the *CMQ6* variable, all the 16 items from the *SDO16* variable, 10 of the 16 items from the *Conspiracist* variable and the two real conspiracies. A detailed description of the items in the different constructs can be found in Appendix A.

We will not do an exploratory factor analysis as this study is based on previously tested theoretical constructs, but we will do a confirmatory analysis to examine how these constructs work as factors in this student group, with minor adjustments done for this study (Table 1). For this comparison, we validate the constructs with all the items similar between the physics and the non-physics students and validate a Conspiracy belief variable (*Con10*) from the 10 identical items for both physics and non-physics students. Similarly, we extract 8 items from the *Sup* variable that most clearly conflict with methodological naturalism into a variable *Sup8* and are thus able to compare scientific skepticism between different groups of students along two dimensions.

The items are put through a reliability test and confirmatory factor analysis in SPSS. All factors are tested for skewness and kurtosis.

We employ the lack of belief in conspiracy theories in the *Con10* scale, and the lack of supernatural beliefs in the *Sup8* construct, as two dimensions that indicate skepticism.

To compare skepticism between physics students and different groups of non-physics students we can however also argue that for testing critical thinking skills, the difference between the Con10 and the "Real conspiracy" score is relevant. Disbelief in conspiracy theories might not be seen as a critical attitude if it is combined with a lack of belief in actual documented conspiracies. We will thus also use this difference for simple comparisons, bearing in mind however that it is not a confirmed factor.

The novelty in this paper is not the constructs, but rather employing and testing them on physics students as a group and comparing them with other student groups to explore the concept of scientific skepticism in an educational context. The results of this factor analysis are presented in Table 1.

3.2 Comparing physics students with other students

The survey among Norwegian physics students had a total of 177 respondents. 138 were students recruited from a course mandatory for all 1st-year students (of a total of 241 registered). Additionally, 39 master's students were selected from 3 different master-level courses to get a spread of respondents (from a total of 145 enrolled master's physics students). Of a total of N = 891 non-physics students from a survey made by from Dyrendal, Kennair, and Bendixen [59], 869 answered the question of their faculty belonging. 126 were from the humanist faculty, 32 from the medical faculty, 72 from IT, mathematics, and electronics, 37 from engineering science, 56 from natural science, 277 from social science, 137 from health and social science, 39 from teachers' ed, and 93 from technology.

Using data only from the items that are identical between the two surveys, we can see how physics students position themselves relative to other student groups, and also attempt to answer the question of whether physics students are more skeptical along the tested dimensions than other students.

The total of these non-physics-respondents is used to represent a generic "non-physics student". This is not an average student, but the sample is composed of a wide variety of student groups. We first compare physics students with both this set of all non-physics students, a set of all Humanities/Social science students, and non-physics STEM students to see whether we can discern differences in the constructs between different fields of study. We also separate these results based on gender, as previous research has shown gender differences in several constructs, and there are discernable gender differences between fields of study as well. The results from this comparison are presented in Table 2.

There are however many other different axes to regard fields of study along other than hard/soft, e.g. applied/theoretical, professional/disciplinarian, or shorter/longer. A more detailed comparison on the faculty level might disclose if such variables are relevant, so we will do this comparison as well. This survey was conducted in the middle of a reorganization, where a university college with mainly shorter profession-oriented study programs was merged into the university but at the time of the survey, still in separate faculties. (These latter will be termed "ex coll." In Table 3.) In sum, this yields a robust mix of both "soft" and "hard" sciences, and more theoretically and more professionally oriented study programs that can be employed for comparison. This comparison can be seen in Table 3.

Having looked at the data through comparison, we can identify potential bivariates that can contribute to our discussed dimensions of "skepticism". We thus finally do a multiple regression on factors that might contribute to skepticism on the variables *Con10* and *Sup8* as described by Ringdal [63] and Field [64]. These factors are Physics student or non-physics student, STEM student or non-STEM student, University or College study program, Gender, and master's vs. bachelor student. The results from this analysis are presented in Table 4.

4 Results

In the following, we will evaluate our factors though a confirmatory factor analysis and attempt to compare our analysis of physics students with the larger dataset of other student groups.

4.1 Confirmatory factor and reliability analysis

The proportion of missing values was 1.9%. Missing values were solved by excluding respondents with no. missing values > 20 and substituting the remaining missing values with the mean within the student group (physics/non-physics). The items with the most missing values had 8.4% and 5.7% and were the real conspiracies—one can assume some students found these items difficult, not having the historical knowledge. Some factors are skewed toward low values as is represented in the results (low belief in conspiracy theories etc.), but there is no heavy kurtosis.

The results from the confirmatory factor and reliability analysis of the variables common between physics and non-physics students can be found in Table 1.

The *Sup* variable has one primary factor dominating, and the factor loadings are mostly good. An item asking about living in the end times has low factor loading. Oblimin rotation however gives two other factors with relatively more comparable sums of square loadings (4.239 vs. 3.023 and 2.519) and may disclose different aspects of spirituality. Going into this is however beyond the scope of this study. For a discussion of supernatural beliefs in general, the results show that this variable fits well as a factor.

The CMQ6 also works well with good factor loadings on all items and one factor above Kaisers. We get a correlation between the first factor and the others with an absolute value between 0.37 and 0.63.

SDO16 has a dominant factor in the unrotated solution, but with oblimin rotation, we get a much more balanced result with 4 factors with RSSL between 3.2 and 4.6.

The Con10 works well as a factor, and the 10 item-variable explains a significant percentage of the total variance.

The Sup8 has a slightly lower Alpha than the Sup variable, but with fewer items, it still yields an acceptable internal consistency. No items would yield a higher Alpha if deleted and the item with the lowest correlation was also the least explicitly connected to a break with scientific epistemology (on intuition and ancient wisdom). The factor analysis gives one dominant factor with good factor loadings. The other factor is barely above Kaiser's (1.1012) and is hard to interpret considering the items, other than that the sign of the factor loadings correlates with the items being reverse scored.

4.2 Comparison between Physics, HumSoc, and STEM students

To disclose differences between fields of science the faculties of social sciences and humanities—fields some physics students regarded as "less scientific" than physics [1], are singled out (N = 403, M = 128, F = 274). To evaluate diversity within the STEM fields, data from Non-Physics STEM students are also separated and compared (N = 258, M = 173, F = 83). Average sum scores and standard deviation are calculated for the different groups (Table 2).

Table 1 Reliability and factor analysis. Column 1: Variables analyzed, 2: Number of items in each variable, 3: Cronbach's Alpha for each variable, 4: Item within each variable with lowest Corrected Item-Total Correlation, 5: Initial Eigenvalue of the primary factor to come out of the factor analysis, 6: The % of variance explained by that primary factor, 7: Number of factors above Kaiser's criteria from factor analysis, 8: The % of variance explained by all factors above Kaiser's criteria

Variable	Items	Cronbach's Alpha	Lowest Corrected Item-Total Correlation	Initial Eigenvalue primary factor	% of variance primary factor	Factors above Kaisers	% of variance all factors
Sup	17	.855	.266	5.478	32.222	4	42.127
CMQ6	6	.865	.616	3.620	60.333	1	–
SDO6	16	.892	.468	6.382	39.889	4	53.276
Con10	10	.861	.468	4.574	45.737	1	–
Real conspiracy	2	.404	.253	1.253	62.641	1	–
Sup8	8	.789	.375	3.336	41.703	2	54.347

"Real conspiracy" is not intended as a factor on its own, but is included to test against the "Conspiracist" variable. % of variance all factors is reported from extraction sums of square loadings and only for variables with more than one factor

Table 2 Simple comparison on variables between physics (M = 93, F = 77) and non-physics students (M = 340, F = 548), students from the Humanities and Social Sciences (F = 274, M = 128) and non-physics students from STEM fields (M = 173, F = 83):

	Physics students		All non-physics students		HumSoc students		Non-physics STEM	
Variable Gender	Scale mean (1–7 scale)	Std. deviation	Scale mean (1–7 scale)	Std. deviation	Scale mean (1–7 scale)	Std. deviation	Scale mean (1–7 scale)	Std. deviation
Sup	2.0482	.8528	2.3783	.9404	2.3599	.92382	2.1664	.91900
M	1.9901	.81822	2.0994	.89812	2.0747	.87833	2.0809	.90863
F	2.1081	.89675	2.5526	.92402	2.4886	.91517	2.3627	.91963
Sup8	1.8265	.96464	2.4071	1.12227	2.4269	1.13452	2.0889	1.02862
M	1.7473	.94670	2.0051	1.01882	2.0394	1.04718	1.9489	.987432
F	1.9126	.98629	2.6603	1.11274	2.6062	1.13216	2.3946	1.06129
CMQ6	3.1537	1.1655	3.2058	1.2273	3.2770	1.24695	3.3032	1.22967
M	3.1326	1.11250	3.3876	1.25429	3.4968	1.36884	3.3980	1.17860
F	3.1873	1.24627	3.0951	1.19650	3.1704	1.17467	3.1347	1.30875
SDO6	1.9605	.8881	2.2077	.9426	2.0605	.91137	2.3675	.97431
M	2.1906	.89017	2.4533	1.07270	2.2996	1.07479	2.5618	1.04104
F	1.6929	.82065	2.0518	.81338	1.9401	.78970	1.9693	.67807
Con10	1.691	.8010	1.871	.8926	1.7975	.82887	1.8813	.99598
M	1.6041	.76685	1.8863	1.02918	1.8585	.95761	1.9237	1.06829
F	1.7910	.84079	1.8573	.79222	1.7602	.74885	1.7887	.82977
Real con	3.7395	1.0418	3.267	1.2500	3.2714	1.27964	3.4039	1.31987
M	3.8325	1.06122	3.5858	3.5858	3.7116	1.41801	3.5653	1.34182
F	3.6207	1.02575	3.0700	1.13408	3.0650	1.15844	3.0799	1.22955

In some areas we can see physics students differ from non-physics students. They score slightly lower on Conspiracism (*Con10*) (ca. 0.2 of the Standard deviation of physics students), on Supernatural beliefs (ca. 0.4 Standard deviations on the *Sup* variable and 0.6 standard deviations on *Sup8*), and Social dominance orientation (*SDO16*) (ca. 0.3 standard deviations).

An interesting result from the SDO16 score is that non-physics STEM students score highest, while physics students score lowest. To avoid the known and confirmed effect of gender on SDO, comparing only males we here get a Cohen's d of 0.37, representing a small to medium effect size. We can merely speculate as to the reasons for this discrepancy, but as different kinds of engineering students are composing a large part of the STEM selection it is in line with previous research which has suggested engineers being overrepresented within psychological "need for cognitive closure", which again predicts a larger SDO [65].

The physics students score the lowest in conspiracy beliefs (*Con10*), but the difference is small, and the variance is correspondingly large. Utilizing Cohen's d we get only small effect sizes of around 0.2.

Comparing the ability to spot the difference between conspiracy theories and real conspiracies while keeping in mind that the *Real conspiracy* variable is not a reliably confirmed factor, and we should only employ it for simple comparisons and not a detailed analysis, we see that the difference between the Conspiracist score and our test of two real conspiracies is larger among the physics students, than the non-physics students (2.0 vs 1.4), corresponding to a Cohen's d of 0.53, representing a medium effect size.

For the 8-item set of unscientific spiritual beliefs, *Sup8*, physics students are also the group with the least belief in the variable we might epistemologically correctly term supernatural. The difference between physics students and the mean of all other students corresponds with a Cohen's d of 0.53, which again represents a medium effect size. We however also see that the *Sup8* factor is heavily gendered yielding an overall Cohens d of 0.57. The effect of being a physics student here is thus of similar size as the gender effect.

4.3 Comparison of students by faculty

To investigate this further, we separate each of the faculties from the data (Table 3) and compare the difference between conspiracist belief and belief in actual conspiracies (*DeltaCon*), along with Conspiracy beliefs (Con10) and supernatural beliefs (*Sup8*).

This table nuances the image above. We see physics students scoring only second lowest on the *Con10* variable, though the engineering faculty students have a low N.

We see a difference in both *Con10* and *DeltaCon* not only between different fields of study but also between different types of education. The ones marked "ex coll." are shorter professional studies from a college recently merged into the university, and they score lower with regards to skepticism than the traditional university study programs (apart from Medicine for the *DeltaCon*, but here N is also very low). Comparing the college programs with the rest yields 1,1859 vs. 1.6234 for *DeltaCon* and gives a Cohens d of 0.35 representing a low to medium effect size.

For the supernatural (*Sup8*) scale we again see physics students score the lowest and the non-STEM college programs the highest. The college vs. university difference may play in also here, but the engineering students from the technology faculty are relatively more similar to the physics students on this variable.

4.3.1 Multivariate regression analysis on conspiracism and supernatural beliefs

To gain a deeper insight into factors that contribute to differences in skepticism along our two dimensions, we do a multivariate regression analysis on the variables we have seen that can influence skepticism (physics, STEM, university vs. college, gender, master's vs. bachelor).

For analysis of both *Con10* and *Sup8* collinearity diagnostics show four predictors with variance inflation factors slightly above 10, and subsequently one dimension with a condition index above 16, which would indicate a possible collinearity problem, although just above the cut-off value of 15. However, for all three cases, the variance proportions show only one value above 0.9 (others are on 0.5 or below), which indicates no strong linear dependence between the variables.

A certain collinearity should be expected since physics students are also a part of the group of STEM students, but as we wish to see whether being a physics student in particular contributes to this analysis it would nevertheless be counterproductive to remove it for this study.

For *Con10* the adjusted R squared is 0.810, almost identical to the unadjusted (0.811), indicating a very good cross-validity of a model explaining most of the variation. For *Sup8* we get an adjusted R squared of 0.831 (equal to the unadjusted), with similarly good cross-validity and most of the variance explained by the model [64].

For *Con10* the overall regression model was significant $F\ (5, 1026) = 879$, $p < 0.001$, $R^2 = 0.811$.

Table 3 Belief in conspiracy theories (Con10), the difference between belief in conspiracy theories and real conspiracies (DeltaCon), and score on unscientific spiritual beliefs (Sup8) separated by faculty plus physics students

Faculty	N	Con10 Mean	Std deviation	DeltaCon Mean	Std deviation	Sup8 Mean	Std. deviation
Humanist (HF)	126	1.9108	.90494	1.6418	1.24794	2.5580	1.27440
Medicine (DMF)	32	1.9281	.92151	1.2601	1.01950	2.4271	1.30257
Information Technology (IME)	72	1.7937	.80273	1.6633	1.39724	2.1768	.96860
Engineering (IVT)	37	1.5547	.74641	1.8934	1.39248	2.1060	.86604
Natural science (NT)	56	1.8237	1.17185	1.3919	1.37445	2.0718	1.27333
Social science (SVT)	277	1.7459	.78819	1.3976	1.23934	2.3672	1.06197
Health and social science (ex coll.)	137	1.8991	.80274	1.1266	1.08504	2.7151	.94693
Teacher ed (ex coll.)	39	2.3564	.87953	1.0159	1.08630	3.2372	1.29135
Technology (ex coll.)	93	2.1139	1.06264	1.3447	1.29392	2.0242	.97891
Physics students	172	1.6913	.80096	2.0483	1.14928	1.8265	.96464
Total	1042	1.8383	.87718	1.5105	1.25769	2.3113	1.11837

Similarly for *Sup8*, with F (5, 1026) = 1014, $p < 0.001$, $R^2 = 0.832$. The analysis itself is thus significant and explains a large part of the variance for the two constructs *Sup8* and *Con10*, as seen in more detail in Table 4.

Independently in the bivariate analysis, we see in Table 4 that all our variables pass the p-test, and have substantial Beta-values, so it makes sense to include them in our multivariate analysis.

For the variables in the multivariant analysis, we get mixed results. We see that for the *Con10* variable, being a STEM student is not significant ($p < 0.05$). For the *Sup8* variable master's vs. bachelor students are not significant, but both being a STEM student and a physics student are significant.

Overall, we see from our analysis that for both *Con10* and *Sup8*, identifying a student as a physics student, explains a statistically significant amount of unique variance. The value for Beta is similar along both dimensions (0.256 vs. 0.286), while e.g. the gender effect varies considerably (0.508 vs. 0.131). So does the difference between master's and bachelor students, being not significant for *Sup8*, but significant with a medium effect size for *Con10*.

Along with being a physics student, the difference between students in university programs and college programs has a consistent and significant influence along both dimensions of skepticism of similar size as being a physics student.

5 Discussion

Overall, we see a continuum in our data where physics students are at one extreme. Physics students seem to have among the lowest conspiracy beliefs, the lowest supernatural spirituality beliefs and to be better at separating real conspiracies from conspiracy theories. Physics students were the only group to have a difference in score above 2 points between belief in the actual and unfounded conspiracy theories. The data thus does support, though not strongly, that physics students might be more skeptical along the lines we have defined the term, than non-physics students.

However, as most physics students tested are 1st semester students this does not seem to be a result of higher education in physics, but rather a factor of preselection. In line with previous research, one might argue that it forms part of the identity of physics students(see e.g. [66]). The regression analysis partially supports this, showing limited effect along the master's vs. bachelor variable.

HumSoc students position themselves closer to the physics students on the tested factors for "skepticism" than the average of all tested non-physics students. This is perhaps not surprising taking into account previous research showing science majors having a poorer grasp of NOS concepts [5], and one could argue that students with a background in humanities and social sciences could have a better understanding of social, psychological, or philosophical concepts that help them understand how thinking can go wrong, thus gaining a "skeptical" score along the lines defined in this paper.

The documented variation in NOS understanding for science students compared with others [4–6] however, seemingly contradicts physics students' clear identification with the epistemic values of science represented by their adherence to skepticism. This can suggest taking issues connected to these epistemic values as a starting point in discussing NOS could improve physics students' engagement with NOS concepts. This is an area that could benefit from further exploration.

Table 4 R squared-, F- and p-value for the overall model for regression on the Spri8 and Con10 variable respectively, with p- and Beta values for the respective independent variables

			Regression on Sup8				Regression on Con10	
Adjusted R squared			.831				.810	
F			1014				879	
p-value			.000				.000	
Variables	Bivariate, p	B	Multivar. p	B	Bivariate, p	B	Multivar. p	B
Physics student or not	.000	.961	.016	.256	.000	1.233	.001	.286
STEM student or not	.000	1.061	.001	.281	.000	1.377	.785	.020
University or College	.000	1.333	.002	.240	.000	1.674	.000	.312
Gender (M = 1, F = 2)	.000	1.058	.000	.508	.000	1.384	.024	.131
Master's vs. bachelor	.000	.947	.074	.150	.000	1.197	.000	.346

We also see from the comparisons that the forms of skepticism we have tested here are gendered, where males score higher on skepticism, though the regression analysis nuances this. The large variation in gender differences between the two dimensions of the analysis is in line with the discussed research suggesting gender is important for specific forms of skepticism rather than skepticism in general [e.g. 36, 37]. The larger difference in the Sup8 variable is also in line with the general higher religiosity among women [38]. Looking at Table 2, we also see that female physics students overall respond more similarly to male physics students than to female non-physics students.

The connection between skepticism and physics nevertheless is in line with research that shows physics being associated with masculinity [67–69], given that skepticism itself also has such an association [70]. On the other hand, we see physics students scoring low in social dominance orientation (Table 2), where a high score is male-oriented. In total, it suggests physics students as a group have an identity drawing on both traditionally masculine and feminine values. This can be considered hopeful for educators attempting to recruit physics students from a broader base and create an inclusive physics culture.

The lower score from college programs might be interpreted by university programs being more laden in areas of the general theory of science and similar topics, both in content and in the preselection of students than shorter more profession-oriented college programs, but based on this data, this will be speculations and would be a suggestion for further research. The length of the programs might have an effect, but as we can see from the mixed effect of the master's/bachelor-variable in the multivariate regression analysis, and the physics students being mostly 1st year, the difference between different study programs can as easily be that they recruit different student groups than that the study programs themselves have this effect.

In sum, physics students have a very strong adherence to the epistemic values of science, also compared to other student groups. Previous research however indicates that how consciously these values are taught varies significantly [5]. A more conscious approach to teaching these values in physics education could unlock the potential in these values to fight epistemically unfunded beliefs, i.e. "fake news", while at the same time avoiding the downsides of some forms of scientific skepticism, like unreflected dismissal [71] and "scientism" [13].

5.1 Limitations and suggestions

This study has been undertaken at a certain time, at one university in one country, on questions we know are culturally dependent [49]. Elements like social background have neither been tested in this study, although previous research from Norway shows this is correlated with the choice of study programs [72]. Neither does this study include data on the students' grades, or the qualifications needed to gain access to the different study programs. This is also selection criteria that may influence how students score. Further studies combining e.g. the variables in this study with comparing universities in different parts of the world, and other variables from more detailed surveys of students' backgrounds would increase our understanding of how different elements influence these epistemic beliefs among students.

6 Conclusion

The data from this study overall supports the idea that physics students are more skeptical, in the tradition of scientific skepticism/scientific inquiry than other students, with results varying between fields of study in a continuum with physics students at one extreme.

The answer to the research question of whether physics students are more skeptical than other students is therefore a conditioned yes. All although there are examples of individual student groups scoring better than physics students on individual indicators, i.e., students from the engineering faculty on the Con10 variable, the physics students had the highest ability to separate real and fake conspiracies.

The regression analysis further suggests being a physics student yields a statistically significant amount of unique variance along both the examined dimensions of skepticism.

This study cannot answer the question of why the physics students are more skeptical, but the composition of the student group, and the small overall effect from the bachelor/master variable, suggests it is not primarily a *result* of studying physics in university. It however shows a strong connection between physics students and the epistemic values of science that should be consciously employed in education.

Declarations

Author contributions As this is a single-author paper, the author, R.K., is responsible for the entirety of the paper.

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Data availability Data on physics students can be made available by contacting the author.

Code availability Not applicable.

Ethics approval This individual study does not require ethics approval as per Norwegian guidelines, as the study does not collect identifiable personal data. The project the study is a part of has however been approved by the Norwegian Centre for Research Data (NSD) with reference number 187759. All data has been anonymized and stored according to current regulations.

Consent to participate The purpose of data collection was made clear to all participants and participation was completely voluntary to ensure principles of informed consent were applied.

Competing interests The Author has no financial or non-financial interests that are directly or indirectly related to the work submitted for publication.

References

1. Kjelsberg R. The Skeptics - Experiences of Bildung in University Level Physics. In: Levrini O, Tasquier G, editors. The Beauty and Pleasure of Understanding: Engaging with Contemporary Challenges Through Science Education (Proceedings of ESERA 2019). Bologna: ESERA; 2020.
2. Kurtz P. The new skepticism : inquiry and reliable knowledge. Buffalo: Prometheus Books; 1992. p. 371.
3. Skoglund A. Falsk eller ekte skeptiker? Inngrupper og utgrupper på Skepsisforumet. Humanist - Tidsskrift for livssynsdebatt. 2012;2012(4).
4. Irez S. Are we prepared? An assessment of preservice science teacher educators' beliefs about nature of science. Sci Educ. 2006;90(6):1113–43.
5. Akgun S, Kaya E. How do university students perceive the nature of science? Sci Educ. 2020;29(2):299–330.
6. Emran A, Spektor-levy O, Paz Tal O, Ben Zvi Assaraf O. Understanding students' perceptions of the nature of science in the context of their gender and their parents' occupation. Sci Educ. 2020;29(2):237–61.
7. Novella S. Your deceptive mind: a scientific guide to critical thinking skills course guidebook. Chantilly: The Teaching Company; 2012.
8. Keeley B. Of conspiracy theories. J Philos. 1999;96(3):109–26.
9. Lewandowsky S, Oberauer K. Motivated rejection of science. Curr Dir Psychol Sci. 2016;25(4):217–22.
10. Lewandowsky S, Gignac GE, Oberauer K. The role of conspiracist ideation and worldviews in predicting rejection of science. PLoS ONE. 2013;8(10): e75637.
11. Committee on Yale College Education. Report on Yale College Education. New Haven, Yale; 2003.
12. CDIO. Optional standard 1: sustainable development. CDIO optional standards 30: CDIO; 2022.
13. Hellesnes J. Ein utdana mann og eit dana menneske. In: Dale EL, editor. Pedagogisk filosofi. Oslo: Ad Notam Gyldendal; 1992. p. 79–104.
14. Elmose S, Roth WM. Allgemeinbildung: readiness for living in risk society. J Curric Stud. 2005;37(1):11–34.
15. Garrett RK, Weeks BE. Epistemic beliefs' role in promoting misperceptions and conspiracist ideation. PLoS ONE. 2017;12(9): e0184733.
16. Fjelland R. Teaching philosophy of science to science students: an alternative approach. Stud Philos Educ. 2022;41(2):243–58.
17. Grüne-Yanoff T. Teaching philosophy of science to scientists: why, what and how. Eur J Philos Sci. 2014;4(1):115–34.
18. Traweek S. Beamtimes and lifetimes: the world of high energy physicists. Cambridge: Harvard University Press; 1988. xv, 187 p. p.
19. Lederman NG. Syntax of nature of science within inquiry and science instruction. In: Flick L, Lederman NG, editors. Scientific inquiry and nature of science: implications for teaching, learning, and teacher education. Dordrecht: Springer; 2006. p. 301–17.
20. Thomas I. Critical thinking, transformative learning, sustainable education, and problem-based learning in universities. J Transform Educ. 2009;7(3):245–64.
21. Humphreys LG, Lubinski D, Yao G. Utility of predicting group membership and the role of spatial visualization in becoming an engineer, physical scientist, or artist. J Appl Psychol. 1993;78:250–61.
22. Gerber AS, Huber GA, Doherty D, Dowling CM. The big five personality traits in the political arena. Annu Rev Polit Sci. 2011;14(1):265–87.
23. Coenen J, Borghans L, Diris R. Personality traits, preferences and educational choices: a focus on STEM. J Econ Psychol. 2021;84: 102361.
24. Lounsbury JW, Foster N, Patel H, Carmody P, Gibson LW, Stairs DR. An investigation of the personality traits of scientists versus nonscientists and their relationship with career satisfaction. R&D Manag. 2012;42(1):47–59.
25. Lindsay RA. Why skepticism? Skeptical Inquirer. 2017;41(2).

26. Novella S. NeuroLogica Blog [Internet]. Novella S, editor: NeuroLogica Blog. 2015. [https://theness.com/neurologicablog/index.php/rethinking-the-skeptical-movement/. Accessed 2020.
27. Wartono W, Hudha MN, Batlolona JR. How are the physics critical thinking skills of the students taught by using inquiry-discovery through empirical and theorethical overview? Eurasia J Maths Sci Technol Educ. 2018;14(2):691–7.
28. Lazer DMJ, Baum MA, Benkler Y, Berinsky AJ, Greenhill KM, Menczer F, et al. The science of fake news. Science. 2018;359(6380):1094–6.
29. Douglas KM, Uscinski JE, Sutton RM, Cichocka A, Nefes T, Ang CS, et al. Understanding conspiracy theories. Polit Psychol. 2019;40(S1):3–35.
30. Rothman MA. A physicist's guide to Skepticism Buffalo. New York: Prometheus Books; 1988.
31. Lamberty P, Imhoff R. Powerful pharma and its marginalized alternatives? Effects of individual differences in conspiracy mentality on attitudes toward medical approaches. Soc Psychol. 2018;49(5):255–70.
32. Stone A, McDermott MR, Abdi A, Cornwell B, Matyas Z, Reed R, et al. Development and validation of the multi-dimensional questionnaire of scientifically unsubstantiated beliefs. Personal Individ Differ. 2018;128:146–56.
33. Lobato E, Mendoza J, Sims V, Chin M. Examining the relationship between conspiracy theories, paranormal beliefs, and pseudoscience acceptance among a university population. Appl Cogn Psychol. 2014;28(5):617–25.
34. Bensley DA, Watkins C, Lilienfeld SO, Masciocchi C, Murtagh MP, Rowan K. Skepticism, cynicism, and cognitive style predictors of the generality of unsubstantiated belief. Appl Cogn Psychol. 2022;36(1):83–99.
35. Dyrendal A, Kennair LEO. Personlighet, religion og politikk. unpublished2016.
36. Darwin H, Neave N, Holmes J. Belief in conspiracy theories. The role of paranormal belief, paranoid ideation and schizotypy. Pers Individ Dif. 2011;50(8):1289–93.
37. Lindeman M. Biases in intuitive reasoning and belief in complementary and alternative medicine. Psychol Health. 2011;26(3):371–82.
38. Trzebiatowska M, Bruce S. Why are women more religious than men? OUP Oxford; 2012.
39. Fasce A, Picó A. Science as a vaccine. Sci Educ. 2019;28(1):109–25.
40. Harambam J, Aupers S. Contesting epistemic authority: conspiracy theories on the boundaries of science. Public Underst Sci. 2014;24(4):466–80.
41. Krawczyk A, Korzeniewska E, Stańdo J, editors. Electromagnetic field in social perception—myths and conspiracy theories. 2020 IEEE problems of automated electrodrive theory and practice (PAEP); 2020 21–25 Sept. 2020.
42. Fernbach PM, Bogard JE. Conspiracy theory as individual and group behavior: observations from the Flat Earth International Conference. Topics in Cognitive Science.n/a(n/a).
43. Eversberg T. Stars are Missing in the Sky. The Moon Hoax? Conspiracy Theories on Trial. Cham: Springer International Publishing; 2019. p. 23–30.
44. Leiser D, Wagner-Egger P. Determinants of belief-and unbelief–in climate change. In: Siegmann A, editor. Climate of the middle understanding climate change as a common challenge. Cham: Springer; 2022. p. 23.
45. Uscinski JE, Douglas K, Lewandowsky S. Climate change conspiracy theories. Oxford research encyclopedia of climate science 2017. https://doi.org/10.1093/acrefore/9780190228620.013.328
46. Siani A, Carter I, Moulton F. Political views and science literacy as indicators of vaccine confidence and COVID-19 concern. J Prev Med Hyg. 2022;63(2):E257–69.
47. Xiao S, Cheshire C, Bruckman A. Sensemaking and the chemtrail conspiracy on the internet: insights from believers and ex-believers. Proc ACM Hum-Comput Interact. 2021;5(CSCW2):Article 454.
48. Drochon H. Who believes in conspiracy theories in great Britain and Europe? In: Uscinski JE, editor. Conspiracy theories and the people who believe them. New York: Oxford University Press; 2019. p. 337–46.
49. Keranto T. The perceived credibility of scientific claims, paranormal phenomena, and miracles among primary teacher students: a comparative study. Sci Educ. 2001;10(5):493–511.
50. Imhoff R, Zimmer F, Klein O, António JHC, Babinska M, Bangerter A, et al. Conspiracy mentality and political orientation across 26 countries. Nat Hum Behav. 2022;6(3):392–403.
51. Edis T. Atheism and the rise of science. In: Bullivant S, Ruse M, editors. The Oxford Handbook of Atheism. Oxford: Oxford University Press; 2013.
52. Leuba JH. Religious beliefs of American scientists. Harper's Magazine. 1934;169:291–300.
53. Larson EJ, Witham L. Leading scientists still reject God. Nature. 1998;394(6691):313.
54. Scheitle CPUS. College students' perception of religion and science: conflict, collaboration, or independence? A research note. J Sci Study Relig. 2011;50(1):175–86.
55. Lindeman M, Svedholm-Häkkinen AM. Does poor understanding of physical world predict religious and paranormal beliefs? Appl Cogn Psychol. 2016;30(5):736–42.
56. Ecklund EH, Johnson DR, Scheitle CP, Matthews KRW, Lewis SW. Religion among scientists in international context: a new study of scientists in eight regions. Socius. 2016;2:2378023116664353.
57. Gould SJ. Leonardo's mountain of clams and the Diet of Worms : essays on natural history. 1st Harvard University Press ed. Cambridge: Belknap Press of Harvard University Press; 2011. 422 p.
58. Schafersman SD. Naturalism is today an essential part of science. Conference on Naturalism, Theism and the Scientific Enterprise; Texas: Department of Philosophy, The University of Texas; 1997.
59. Dyrendal A, Kennair LEO, Bendixen M. Predictors of belief in conspiracy theory: the role of individual differences in schizotypal traits, paranormal beliefs, social dominance orientation, right wing authoritarianism and conspiracy mentality. Personal Individ Differ. 2021;173: 110645.
60. Bruder M, Haffke P, Neave N, Nouripanah N, Imhoff R. Measuring individual differences in generic beliefs in conspiracy theories across cultures: conspiracy mentality questionnaire. Front Psychol. 2013;4:225.
61. Pratto F, Sidanius J, Stallworth LM, Malle BF. Social dominance orientation: a personality variable predicting social and political attitudes. J Pers Soc Psychol. 1994;67(4):741–63.
62. Stojanov A, Halberstadt J. The conspiracy mentality scale: distinguishing between irrational and rational suspicion. Soc Psychol. 2019;50(4):215–32.

63. Ringdal K. Enhet og mangfold Samfunnsvitenskapelig forskning og kvantitativ metode 4. utgave. Bergen: Fagbokforlaget; 2018.
64. Field AP. Discovering statistics using IBM SPSS statistics. 5th edition, North American edition. ed. Thousand Oaks: Sage Publications Inc.; 2018. xxv, 775 pages p.
65. Gambetta D, Hertog S. Engineers of jihad : the curious connection between violent extremism and education. Princeton: Princeton University Press; 2016. xv, 192 pages p.
66. Johansson A. Analyzing discourse and identity in physics education: methodological considerations. Phys Educ Res Conf. 2016:180–3.
67. Francis B, Archer L, Moote J, DeWitt J, MacLeod E, Yeomans L. The construction of physics as a quintessentially masculine subject: young people's perceptions of gender issues in access to physics. Sex Roles. 2017;76(3):156–74.
68. Archer L, Dawson E, DeWitt J, Seakins A, Wong B. "Science capital": a conceptual, methodological, and empirical argument for extending bourdieusian notions of capital beyond the arts. J Res Sci Teach. 2015;52(7):922–48.
69. Gonsalves AJ. "Physics and the girly girl—there is a contradiction somewhere": doctoral students' positioning around discourses of gender and competence in physics. Cult Sci Edu. 2014;9(2):503–21.
70. Vuolanto P, Kolehmainen M. Gendered boundary-work within the finnish skepticism movement. Sci Technol Human Values. 2021;46(4):789–814.
71. Hammer O. New age religion and the sceptics. In: Hammer O, Lewis J, Kemp D, editors. Handbook of New Age. Leiden: Brill; 2007. p. 375–404.
72. Hjellbrekke J, Korsnes O. Intergenerasjonell mobilitet og sirkulasjon i norske elitar og profesjonar. In: Korsnes O, Hansen MN, Hjellbrekke J, editors. Elite og klasse i et egalitært samfunn. Oslo: Universitetsforlaget; 2014. p. 54–92.

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