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# University students' beliefs about science and their relationship with knowledge about science

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## Abstract

Science and personal experiences in some cases seem to be two different ways of knowledge justification. The current "post-truth" era is characterized by a rise of personal beliefs and justifications. In order to address these phenomena from a perspective of beliefs, several constructs may be considered: Beliefs about the utility of science and of personal experiences, trust in science, and epistemic beliefs. Despite some research addressing each belief's independent relation to information seeking behavior, we do not know much about the interrelationship of these beliefs. To address this research gap and to explore whether knowledge about how science works is related to these beliefs, a paper–pencil study with 315 university students of psychology, education, and teacher education was conducted. There was a high positive relationship of trust in science with justification-by-authority beliefs, and medium negative relationships of trust in science with uncertainty beliefs and personal-justification beliefs. Trust in science was positively related to the perceived utility of science. Epistemic beliefs were also related to utility beliefs. The number of methods courses taken and knowledge about how science works was related to trust in science and epistemic beliefs, but not to utility of science or utility of personal experiences. It is concluded that we should revisit our conceptualization of epistemic beliefs in the context of "post-truth".

**Keywords** Science · Trust · Utility · Epistemic beliefs · Knowledge

## Introduction

In the current society, science and personal experiences are in some cases two opposing ways of justifying knowledge and actions or behavior. Some examples are the usefulness of homeopathy or other alternative medicine, climate change, vaccination, working from home, gender-sensitive language, alcohol consumption, weight loss, dietary supplement, or healthy nutrition in general. In many of these examples, the scientific evidence is quite

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clear (e.g., negative health effects of alcohol consumption), while people continue to rely on practices that are at odds with this evidence (e.g., continue to consume significant amounts of alcohol), sometimes claiming personal experiences (or the lack thereof) as justification (e.g., somebody's uncle drank a glass of wine per day and died a natural death aged 104).

Although there are certainly several psychological mechanisms operating when it comes to the sketched importance of personal experiences, beliefs about knowledge creation, about science, and about personal experiences may be part of the picture. Thus, learning more about these beliefs seems important. There are several lines of research on constructs that are of interest in this context: epistemic beliefs (beliefs about the nature of knowledge and knowing; e.g., Hofer & Pintrich, 1997), trust in science (the assumption that science and scientists provide true or valid knowledge that is of benefit for the society: Hendriks et al., 2016; Wintterlin et al., 2022), and utility beliefs about science and personal experiences (the value that is ascribed to scientific findings and personal experiences, respectively, to inform decisions; see Parr & Timperley, 2008). All of them have been shown to have a decisive impact on information seeking and decisions for personal and societal life (e.g., Barzilai & Eshet-Alkalai, 2015; Kiemer & Kollar, 2021; Sailer et al., 2022; Schoor et al., 2023a). Although utility beliefs at first sight seem very close to the current societal phenomenon and have a high face validity for capturing it, epistemic beliefs are the best-researched among these constructs. Thus, the relationship of beliefs is worthy to be considered both from an analytical and an empirical perspective.

Knowing more about the interrelation of beliefs may help understand their respective development and find starting points for belief change, with all due caution regarding correlation and causality. There is reason to assume relationships of epistemic beliefs with utility beliefs and trust in science: Since epistemic beliefs are beliefs about knowledge (created by science) and the knowledge creation process (in science), they may directly influence utility perceptions and trustworthiness judgments of science. That is, beliefs about how we can know things (epistemic beliefs) may influence preferences for or against personal experiences and scientific evidence (Barzilai & Chinn, 2020). Yet, there is so far only indirect evidence for this assumption (e.g., Strømsø et al., 2011). Moreover, methodological knowledge about science may also relate to these beliefs. Methodological knowledge about science, in this context, means knowledge about how scientists create scientific knowledge (Miller, 1983; OECD, 2016). It can relatively easily be addressed by instruction. If there is a relationship between beliefs and knowledge, it could be researched in a second step whether the instruction of methodological knowledge may positively influence beliefs.

The present paper has two major aims: 1) To analyze the relationship of utility beliefs and trust in science with epistemic beliefs and 2) to test whether methodological knowledge about science, as it is conveyed in psychological and educational university classes, is related to these beliefs. Thus, it can contribute to a more comprehensive view of students' different personal beliefs regarding science and shed more light on university instruction and methodological knowledge as potential means for supporting positive beliefs about science (i.e., considering science useful and trustworthy).

In the following, we first sketch the context and motivation for the present research. Then, we elaborate on the perceived utility of science and of personal experiences, on trust in science and scientists, and on epistemic beliefs. We will argue that beliefs about knowledge creation (i.e., epistemic beliefs) and beliefs about the utility and trustworthiness of science and of personal experiences are related in a meaningful way. Moreover, we will argue that methodological knowledge about how science works is positively related to trust in science, utility of science, and epistemic beliefs.

## Context and motivation for the present research: Aspects of the epistemic situation in the society in the beginning of the twenty-first century

The epistemic landscape in our societies seems to be characterized by a huge success of science (e.g., the rapid development of vaccines against COVID-19) and a high trust in science (e.g., Bromme et al., 2022; Vetenskap & Allmänhet 2015; Wissenschaft im Dialog, 2017) on the one hand and the rise of science scepticism and "post-truth" on the other hand. We will first briefly sketch what we mean by "science" and "post-truth" before we outline our motivation for researching the constructs used in the present study.

### What do we mean by „science "?

The COVID-19 pandemic has shown quite vividly what an important and powerful tool science can be for informing decisions. Not only in a pandemic, but also in other contexts, science can provide valuable information, for example with regard to the climate crisis or locally relevant issues. These issues are often termed "socio-scientific issues" (e.g., Sadler, 2004), since this kind of questions often involves both scientific-empirical and other normative / value aspects. Thus, in socio-scientific issues, scientific findings can provide information, but decisions cannot be based on science alone and need to be taken by balancing scientific findings with other norms and values of individuals and the society. These other norms may, of course, also be based on personal beliefs and/or experiences. Thus, by arguing for the value of science we do not argue for a simple scientocracy.

"Science" in this context mostly means the natural and social sciences. As argued by Kind and Osborne (2017), there is no uniform scientific method, but the sciences are characterized by several "styles of scientific reasoning", such as mathematical deduction, experimental evaluation or hypothetical modeling. Across different disciplines, the emphasis on one or several of these styles differs. In the following, the terms "science" and "scientific" refer to "Wissenschaft" in the general sense (Bromme et al., 2022, p. 1), which encompasses not only the natural science but also social sciences and humanities, although the term "scientific evidence" refers to empirical evidence that mostly stems from natural and social sciences.

### Post-truth and the desire for personal experiences

"Post-truth" is a label that has been given to circumstances "in which objective facts are less influential in shaping political debate or public opinion than appeals to emotion and personal belief" (Oxford English Dictionary, n.d.). The current "post-truth" era is characterized by a conglomerate of unsettling phenomena. Instead of trusting institutions such as science and the kind of facts that they can provide, a relevant proportion of the society appears to prefer emotional value and/or own experiences as "truth" (e.g., Barzilai & Chinn, 2020; Kienhues et al., 2020). Thus, personal experiences are often valued higher than scientific evidence (e.g., Barzilai & Chinn, 2020; Kiemer & Kollar, 2021). Yet, "post-truth" concerns not only science or institutions of knowledge, but it can be considered an epistemic crisis in which societies lose consensus about how valid knowledge can be generated (e.g., Chinn et al., 2020).

Thus, the "post-truth" condition should be reflected in beliefs such as (lower) trust in science, (lower) perceived utility of science, and (higher) perceived utility of personal experiences. Beliefs like these can have a decisive impact on behavior (Fishbein & Ajzen, 2010) that is potentially harmful to the individual and/or the society as a whole. For example, a greater belief in science was related to more (self-reported) mask wearing during the COVID-19 pandemic in the United States (Stosic et al., 2021), and a higher trust in science was related to more compliance with and acceptance of COVID-19 measures during the pandemic (e.g., Pagliaro et al., 2021; Sailer et al., 2022). Yet, beliefs about science are also related to information seeking and processing (e.g., Kiemer & Kollar, 2021; Mahlow et al., 2022; Schoor et al., 2023a, 2023b) and may thus both be a symptom of "post-truth" and – on the long run – contribute to enhancing "post-truth" beliefs.

### Perceived utility of science and of personal experiences

Perceived utility is a value that is ascribed to an object or an action, more concretely how useful this object or action is for reaching a specific goal and how well it relates to current and future goals (Eccles & Wigfield, 2002). Following this definition, perceived utility of science is the value that is ascribed to scientific findings to inform decisions both in the professional and the private context (see Parr & Timperley, 2008). Analogically, the perceived utility of personal experiences is the value that is attributed to personal experiences with the question at hand to inform decisions.

Utility value has been suggested to be potentially related to actual behavior and decision-making (see Eccles & Wigfield, 2020; Fishbein & Ajzen, 2010). In the situated expectancy-value theory (e.g., Eccles & Wigfield, 2020), utility value is conceptualized as a subcomponent of the value aspect, together with intrinsic value, attainment value, and cost. In this context, it has been shown that the utility value that is ascribed to the respective task is related to achievement and achievement-related behavior, for example in college-level mathematics courses (Husman & Hilpert, 2007), low-stakes tests (Cole et al., 2008), or reading (Schoor, 2016).

With respect to science and scientific findings, the perceived utility of science has been suggested as a belief of teacher education students concerning research on learning and instruction (Kiemer & Kollar, 2018; Parr & Timperley, 2008). The general idea is that teaching should be based on scientific evidence, but often teachers use their personal theories or experiences and intuition as a guideline for teaching decisions (Bråten & Ferguson, 2015; Landrum et al., 2002; Parr & Timperley, 2008; see also Pajares, 1992). Consequently, teacher education students often consider the utility of personal theories or experiences higher than the utility of science (e.g., Bråten & Ferguson, 2015; Kiemer & Kollar, 2021).

The perceived utility of science and of personal experiences also play a role for the kind of sources that students select when searching for information on the internet (Schoor et al., 2023b). Schoor et al. (2023b) found that university students were less likely to select sources with only personal experiences as compared to sources with scientific expertise for further reading when they reported a higher perceived utility of science. In contrast, students were more likely to select personal-experiences sources when they reported a higher perceived utility of personal experiences.

### Trust in science and scientists

Trust is a complex construct that has many aspects (Nadelson et al., 2014). In the present study, we view trust from the perspective of trust in science and scientists and the public's understanding of science with a psychological focus. While there is also research on trust in science for specific topics, the present study focuses on the more general and social aspect of trust in science and scientists.

Trust in science and scientists is of key importance not only for those practicing science, but also for the general public's (bounded) understanding of science (Bromme & Gierth, 2021; Hendriks & Kienhues, 2020). Given their limited possibilities to understand science and scientific findings, laypersons have to trust in the providers of scientific knowledge, that is the scientists and science as a system (Bromme & Gierth, 2021; Hendriks & Kienhues, 2020). Wintterlin et al. (2022) suggest that the perceived epistemic trustworthiness of scientists is a precursor of trust in science. In their study, they measured trust in science with a single item ("How high is your trust in science in general?", Wintterlin et al., 2022, Supplemental Appendix SA2, p. 3). For epistemic trustworthiness, they followed prior research conceptualizing the characteristics that determine the trustworthiness of a source of science information as expertise, integrity, and benevolence (Hendriks et al., 2015). As expected, Wintterlin et al. (2022) found a positive relationship of perceived epistemic trustworthiness of scientists and trust in science.

Bromme et al. (2022) compared data from the German Science Barometer of September 2019, April 2020, May 2020, and November 2020. These representative data suggest a rise of trust in science in the German population immediately after the outbreak of the pandemic that was followed by a decline. Yet, trust in science in November 2020 (i.e., about 8 months into the pandemic) remained higher than trust in science in September 2019 (i.e., before the pandemic). Bromme et al. (2022) also found that education was a predicting factor not only for trust in science but also for the increase of trust in science with the onset of the pandemic. They argue that a better education helped people understand the complex issues around the pandemic, and a feeling of understanding increased trust in science.

As described above, trust in science is an important predictor for the behavior of people, for example for compliance with COVID-19 measures (Pagliaro et al., 2021; Sailer et al., 2022). We argue that trust in science and scientist is also related to perceiving science as useful, because trust in science may influence the perceived utility of science, but also because the perceived utility of science may influence trust. First, trust may be a necessary condition for considering science useful, since you can only fully benefit from the expertise of others if you trust the people who have it (Brockmeier, 2017, p. 2). Thus, scientific findings can be considered useful when these findings or reports thereof are considered valid and true findings (Schoor & Schütz, 2021). On the other hand, pragmatic theories of truth argue for the opposite direction: Useful information is considered true information (e.g., Capps, 2019), thus perceived utility would lead to trust.

### Epistemic beliefs: Beliefs about the nature of knowledge and knowing

Epistemic beliefs answer the question how knowledge is characterized and how knowledge can be created (e.g., Hofer & Pintrich, 1997). Epistemic beliefs are sometimes also researched under the labels "epistemic cognition" (e.g., Bråten et al., 2014) or "epistemic thinking" (e.g., Barzilai & Eshet-Alkalai, 2015).

From an analytical point of view, post-truth age loses the societal consensus that the best way of knowledge creation is to systematically use scientific styles of reasoning (Barzilai & Chinn, 2020), which is an epistemic belief. Instead, people seem to fall back to their own experiences (another epistemic belief). This reliance on own experiences may result from lack of trust in institutions in general and in science in special. Thus, epistemic beliefs appear to be the first address both for analyzing beliefs about science (i.e., current post-truth phenomena) and to relate them to trust in science and perceived utility of science.

Conceptualizations of epistemic beliefs can be differentiated into developmental models and dimensional models (Greene et al., 2008). In the present study, we take a dimensional approach (for an overview see, e.g., Conley et al., 2004). Hofer and Pintrich (1997) suggested the dimensions "certainty of knowledge", "simplicity of knowledge", "justification for knowing", and "source of knowledge". Certainty of knowledge refers to the degree to which knowledge is considered fixed and certain versus tentative and evolving, while positions believing knowledge to be less certain are considered more sophisticated. The simplicity dimension refers to knowledge being considered an accumulation of facts versus highly interrelated. Justification for knowing includes reasons for beliefs and covers beliefs in authority, experts, and evidence. Source of knowledge refers to the degree to which the source of knowledge is considered external (e.g., an authority, an expert), from where it is transmitted, or internal to the self who constructs it.

Greene et al. (2008) suggested to further differentiate the dimension "justification for knowing", which had also an overlap with the "source of knowledge". Based on these considerations, Ferguson et al. (2013) argued for three justification dimensions: personal justification (knowledge is characterized by personal opinion), justification by authority (knowledge comes from an external authority or expert), and justification by multiple sources (knowledge has to be corroborated across several sources).

Justification by authority seems closely related to trust in science. Trust in science (i.e., the perceived trustworthiness of persons and the system) is probably at least in part a prerequisite for justification by authority (i.e., the trustworthiness of knowledge conveyed by scientific authorities) (see Wintterlin et al., 2022). However, there are only few studies that address the relationship of trust in science and epistemic beliefs.

Post et al. (2021) found in a large cross-sectional study with German citizens in April 2020 that the belief that scientific knowledge was stable was positively related to the wish that scientists dominate policy. Merk and Rosman (2019) used a developmental approach to epistemic beliefs and related them to the trustworthiness of scientists in terms of expertise, integrity, and benevolence. Their results were inconsistent: In a first exploratory study they found that the further developed epistemic beliefs were (as measured by an overall index), the higher participants rated expertise, integrity and benevolence of scientists. In their second, confirmatory study Merk and Rosman (2019) could not replicate this finding.

Hendriks et al. (2020) conducted an experiment on the effect of the information about successful replications of a study about a health-related topic on ratings of the credibility of this study's results and the trustworthiness of the researcher responsible for this study. Exploratorily, Hendriks et al. (2020) researched whether beliefs about the certainty and stability of medical knowledge would affect credibility and trustworthiness ratings. Participants rated the study results to be less credible when they believed that medical knowledge was uncertain. Moreover, they judged the researchers' expertise, integrity, and benevolence (i.e., their trustworthiness) lower when they believed medical knowledge to be uncertain.

The reported empirical studies suggest that beliefs about the uncertainty and stability/simplicity of knowledge are related to trustworthiness ratings and trust in science (Hendriks et al., 2020; Post et al., 2021). Yet, whether this is a positive or negative relationship remains unclear. Empirically, it seems as if in a dimensional perspective, more sophisticated epistemic beliefs (i.e., higher beliefs in uncertainty and lower beliefs in stability/simplicity of knowledge) were related to less trust in science (Hendriks et al., 2020; Post et al., 2021), whereas from a developmental perspective more sohisticated beliefs could be associated with more trust in science (Merk & Rosman, 2019). There is no specific theory from which we could derive predictions, but both directions seem plausible: People who know about the uncertainty and instability of knowledge may also know that we need to trust experts (e.g., Bromme & Gierth, 2021), but these people may also understand that even experts can fail such that a blind trust in experts is also not advisable.

## University education, knowledge about how science works, and beliefs about science

There is evidence that university-level education and knowledge about how science works are related to beliefs about science. By "knowledge about how science works" we mean objectively measured knowledge based on test items that can be scored right and wrong about general principles and measures used in empirically-working science, such as generalizability or experimental research design. Thus, it is knowledge about "how scientific knowledge is produced" (Wintterlin et al., 2022, p. 1). Together with knowledge about scientific concepts (i.e., content knowledge; e.g., Miller, 1983; OECD, 2016), knowledge about societal and policy issues related to science (e.g., Miller, 1983), and epistemic knowledge about the values, norms, and assumptions in science (e.g., OECD, 2016), knowledge about how science works constitutes scientific literacy (e.g., Miller, 1983; OECD, 2016).

In research on scientific literacy and the public's understanding of science and trust in science, often scientific content knowledge (i.e., factual knowledge) has been assessed (Retzbach et al., 2015), although knowledge about how science works may be more relevant for predicting beliefs about science (see Weisberg et al., 2020). It may not be the knowledge of scientific facts (or of scientific consensus), but knowledge about the processes in science with which knowledge is generated, that influences whether people trust this knowledge and the producers of this knowledge. In recent years some studies have addressed knowledge about how science works (e.g., Čavojová et al., 2022; Drummond & Fischhoff, 2017). In the context of scientific reasoning, more knowledge about how science works has been found associated with less coronavirus conspiracy beliefs, less other unfounded health-related beliefs, less anti-vaccination attitudes (Čavojová et al., 2022), less epistemically suspect beliefs (e.g., pseudoscientific beliefs, other conspiracy theories; Čavojová et al., 2020), and more beliefs that are scientific consensus (Drummond & Fischhoff, 2017).

In these studies, knowledge about how science works predicted beliefs about scientific *content*. With regard to epistemic beliefs, utility of science, and trust in science as dependent variables, less is known. Epistemic beliefs have been shown to develop with exposure to a disciplinary context (Rosman et al., 2017). In this study, the epistemic beliefs of students of psychology versus computer science developed differentially across a three-semester study period. In contrast to psychology students, computer-science students developed more absolutist epistemic beliefs across time. In a study on multiple document comprehension about the topic of depression, Schoor et al. (2019) reported moderate relationships of epistemic beliefs with prior content knowledge: The more central concepts the university students could come up with in the pretest, the more they believed knowledge to be unstructured and the more they believed knowledge to be variable.

Conflicting information about a topic has often been used for changing epistemic beliefs (e.g., Kienhues et al., 2008; e.g., Rosman et al., 2019), because it is supposed to cast epistemic doubt (e.g., Rule & Bendixen, 2010). Whereas content knowledge (conflicting information) or enculturation into a discipline have been widely addressed within epistemic beliefs research, we do not know of any study relating methodological knowledge about science with epistemic beliefs. Yet, enculturation into a discipline such as psychology may include to a major part the enculturation into a specific way of scientific thinking, which is closely connected to methodological knowledge. Thus, teaching university students about scientific methodology may impact their epistemic beliefs.

Analogously to epistemic beliefs, also beliefs about the utility of science may be influenced by what students know about how science works. Regarding content knowledge, there is a relationship of knowledge and utility. For example, physicians who know more about a drug also perceive it more useful (Denig et al., 1990). In an analogous way, students who know more about how science works may consider science more useful. In a correlational study with university students, Schoor and Schütz (2021) found a small to moderate relationship of knowledge about how science works with utility of science.

For the relationship of knowledge about how science works and trust in science and scientists, research is also scarce. Nadelson et al. (2014) found that trust in science and scientists was positively related to the number of college-level science courses and the number of years of college. Schoor and Schütz (2021) found no significant relationship of trust in science and scientists with knowledge about how science works.

## The present study

In the present study, we asked university students to report their beliefs about the utility of science and of personal experiences, their trust in science and scientists, and their epistemic beliefs. We told them to think of science in the general sense including the natural and social sciences and the humanities (Bromme et al., 2022). With regard to utility, we asked them to think of utility of science and of personal experiences for personal decisions. Epistemic beliefs were also assessed with regard to scientific knowledge in general. Moreover, we tested the students' knowledge about how science works, that is their methodological knowledge in the context of natural and social sciences as it is needed to understand scientific evidence in the context of socio-scientific issues (e.g., Sadler, 2004).

We related beliefs about the utility of science and of personal experiences to trust in science and scientists, epistemic beliefs, and knowledge about how science works. All research questions were exploratory in nature, since the literature does not provide enough support for robust hypotheses, although we had some expectations.

First, we expected that trust in science and scientists would be related to perceiving science as useful (Brockmeier, 2017; Schoor & Schütz, 2021). We did not have a specific hypothesis for the relationship of trust in science and perceived utility of personal experiences, since there is no prior research – at least to our knowledge – and one could argue both for no relationship (if personal experiences are considered an independent source of knowledge not related to science) and a negative relationship (if personal experiences are considered an alternative to scientific knowledge).

RQ 1(Trust and utility beliefs): Is trust in science related to utility beliefs?

In addition, we expected that epistemic beliefs are related to trust in science. Based on prior research (Hendriks et al., 2020; Post et al., 2021), we expected that beliefs about the uncertainty and simplicity of knowledge would be related to trust in science. As for the direction of the relationship, prior research suggests a negative relationship for uncertainty beliefs and a positive relationship for simplicity beliefs with trust in science. In a more exploratory way we researched the relationship of trust in science and justification beliefs, and the relationship of epistemic beliefs with utility beliefs, although we expected the belief in personal justification to be related to the perceived utility of personal experiences.

RQ 2 (Epistemic beliefs and trust in science):

2.1 Are uncertainty and simplicity beliefs related to trust in science?
2.2 Is trust in science related to justification beliefs?

RQ 3 (Epistemic beliefs and utility beliefs): Are epistemic beliefs related to utility beliefs?

Based on prior argumentation and research, we expected that a better knowledge about how science works would be related to epistemic beliefs, trust in science, and perceived utility of science and of personal experiences.

RQ 4 (Knowledge about how science works and beliefs about science)

4.1Are university-level methods courses and knowledge about how science works related to utility beliefs?
4.2Are university-level methods courses and knowledge about how science works related to trust in science and scientists?
4.3Are university-level methods courses and knowledge about how science works related to epistemic beliefs?

# Method

## Sample

Participants were 315 university students from the faculty of human sciences and education of a German university. Accordingly, they were enrolled in a Bachelor's ($n=192$) or Master's ($n=22$) program of mainly educational science ($n=150$) or psychology ($n=56$) or enrolled in teacher education ($n=96$). They were 18 to 51 years old ($M=22.0$, $SD=3.53$, 82.2% female). Participation was voluntary and in accordance with APA principles regarding informed consent. The research project has been approved by the university's ethics committee.

## Design and procedure

The design was cross-sectional and correlational. The participants were recruited in several courses on psychology, educational science, and teacher education, thus potentially creating variance with regard to the knowledge about how science works, since these subjects differ with regard to how much of this knowledge is explicitly taught in classes. Students who were willing to participate received a paper-based questionnaire and could fill it in at the end of or after the class. The questionnaire was the same for every participant. They did not receive any compensation. Filling in the questionnaire took about 20 to 30 min. The data were collected before the COVID-19 pandemic.

## Material and instruments

### Utility of science and personal experiences in the context of socio-scientific issues

The perceived utility of science and personal experiences was measured with eight items of Schoor and Schütz (2021), which cover the utility of science (four items) and of personal experiences (four items) in the context of socio-scientific issues. In previous studies, these scales showed meaningful relations for example with an indirect measure of utility of science (Schoor & Schütz, 2021), multiple document comprehension (Schoor et al., 2023a), and selection of documents for further reading (Schoor et al., 2023b). Sample items can be found in Table 1. The items were measured on a 5-point Likert scale. A confirmatory factor analysis (CFA) showed an acceptable fit ($\chi^2 = 58.87$, $df = 19$, $p < 0.001$; RMSEA = 0.08; CFI = 0.92; SRMR = 0.06). The internal consistencies of the scales were also acceptable (McDonald's ω[1]: utility of science: 0.77; utility of personal experiences: 0.75).

### Trust in science and scientists

Trust in science and scientists was measured on a 5-point Likert scale with a German short version (Schoor & Schütz, 2021) of Nadelson et al. (2014). A general trust scale was chosen to measure the level of trust in science independent of specific individuals, as opposed to measures such as the Muenster Epistemic Trustworthiness Inventory (METI: Hendriks et al., 2015), which focuses on several dimensions of trustworthiness of particular persons. In previous studies, the trust in science and scientists scale showed meaningful relations for example with multiple document comprehension (Schoor et al., 2023a), and selection of documents for further reading (Schoor et al., 2023b). A sample item is displayed in Table 1. The eight items showed a good internal consistency (McDonald's ω=0.84). When allowing two items with almost identical wording to correlate, the fit was good ($\chi^2 = 48.54$, $df = 19$, $p < 0.001$, RMSEA = 0.07, CFI = 0.95, SRMR = 0.04).

### Epistemic beliefs

Epistemic beliefs were measured by means of 26 items in five scales (Mahlow et al., 2022):

- Uncertainty: the belief that knowledge is uncertain and tentative (in contrast to knowledge being certain and absolute).
- Simplicity: the belief that knowledge consists of simple and isolated facts (in contrast to knowledge being complex and interconnected).
- Personal justification: the belief that knowledge can be justified by personal opinion.
- Justification by authority: the belief that knowledge can be justified by referring to an authority such as an expert.
- Justification by multiple sources: the belief that knowledge has to be justified by considering multiple sources (in contrast to the belief that one source is enough).

The items for uncertainty and simplicity were translated from Bråten and Strømsø (2010). The items for the three justification scales were translated from Ferguson et al.

[1] McDonald's ω is an alternative to Cronbach's α that accounts for many problems of Cronbach's α (McNeish, 2017). It was calculated as ω total with the R package *psych* (Revelle, 2020).

**Table 1** Descriptive values and sample items of variables

| | Mean | SD | Scale range | ω | Sample item |
|---|---|---|---|---|---|
| Utility of science | 3.51 | 0.63 | 1–5 | .77 | "Scientific knowledge is useful for personal decisions." (Schoor & Schütz, 2021, Appendix p. 4) |
| Utility of personal experiences | 3.77 | 0.62 | 1–5 | .75 | "Personal decisions should be mainly based on one's own or others' experiences." (Schoor & Schütz, 2021, Appendix p. 4) |
| Trust in science | 3.15 | 0.61 | 1–5 | .84 | "We can trust scientists to share their discoveries even if they don't like their findings" (Nadelson et al., 2014, p. 86) |
| Uncertainty | 3.69 | 0.45 | 1–5 | .70 | "What is considered to be certain scientific knowledge today, may be considered to be false tomorrow." (see Bråten & Strømsø, 2010, p. 30) |
| Simplicity | 2.57 | 0.51 | 1–5 | .66 | "There are only a few connections among different scientific issues." (see Bråten & Strømsø, 2010, p. 31) |
| Personal justification | 2.37 | 0.68 | 1–5 | .68 | "What is a fact in science depends only on personal views." (see Ferguson et al., 2013, p. 105) |
| Justification by authority | 3.14 | 0.59 | 1–5 | .87 | "When a professor says something is correct in his or her area of expertise, I believe it." (see Ferguson et al., 2013, p. 105) |
| Justification by multiple sources | 4.03 | 0.50 | 1–5 | .70 | "In order to trust statements about scientific topics, I have to check various sources of knowledge." (see Ferguson et al., 2013, p. 105) |
| Knowledge about how science works | 4.86 | 1.92 | 0–9 | – | |
| Courses | 4.32 | 4.03 | 0-∞ | – | |

No internal consistency was calculated for courses because this was just the number of courses taken, nor for knowledge, because it was not expected that a heterogeneous knowledge test has high internal consistency (Taber, 2018)

**Table 2** Latent Intercorrelations of Epistemic Beliefs. 95% confidence intervals in brackets

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| (1) Uncertainty | | | | |
| (2) Simplicity | -.37 *** [-.56; -.19] | | | |
| (3) Personal justification | .10 [-.08; .27] | .66*** [.52; .81] | | |
| (4) Justification by authority | -.34*** [-.50; -.19] | .04 [-.14; .22] | -.34*** [-.48; -.20] | |
| (5) Justification by multiple sources | .47*** [.32; .62] | -.39*** [-.57; -.22] | -.04 [-.21; .13] | -.17* [-.32; -.02] |

*** $p<.001$; * $p<.05$

(2013). Instead of a specific content domain, all items were phrased such that they referred to science in general (see Karimi & Richter, 2021). Sample items can be found in Table 1. In the Mahlow et al. (2022) study, the epistemic beliefs scales (referring to a specific domain) showed meaningful relations to multiple document comprehension overall and with regard to specific cognitive requirements.

The fit of the CFA ($\chi^2=639.38$, $df=289$, $p<0.001$, RMSEA = 0.06, CFI = 0.76, SRMR = 0.08) was acceptable except for the CFI. However, as argued by Kenny (2020) and Kamata and Liang (2018), the CFI can be low in a well-fitting model if the model fit of the baseline model was already not bad. Kenny (2020) suggests to not interpret the CFI if the RMSEA of the baseline model was lower than 0.158. The RMSEA of the present baseline model was 0.119, which is why we consider the model fit acceptable despite a low CFI. The internal consistencies were acceptable. They can be found in Table 1. The latent intercorrelation of the five scales can be found in Table 2.

### Knowledge about how science works

Knowledge about how science works was assessed in a scenario-based test with nine items (Schoor & Schütz, 2021) that covered scenarios a scientist could find themself in with regard to, for example, control group design, probability, or generalizability. For each scenario, the participant had to choose how science works out of four alternatives (single choice). The scenarios were designed in a way that no specific training in research methods was necessary to solve them. The number of correctly solved items was counted, thus resulting in a maximum score of 9.

### Number of methods courses taken

In the questionnaire, for each of the three study programs of the participants (i.e., teacher education, educational science, psychology) the methods courses and exams specified in the respective module handbook were listed. The participants were asked to tick all courses and exams that they already had passed, including prior studies. They were asked to list methods courses they had taken at another university or in another study program in an open field. The overall number of methods courses and exams passed was summed up. This measure is only a rough proxy for exposure to instruction about science in the respective study programs, since especially in teacher education, methodological knowledge is mainly taught in classes not explicitly devoted to methods.

### Data analysis

For analyzing all research questions, a model was specified in Mplus 8.6 in which utility beliefs, trust in science, and epistemic beliefs were included as latent variables, and knowledge about how science works and the number of methods courses taken as manifest variables (see Fig. 1). A latent approach was chosen for the belief variables because it was assumed that an existing (latent) belief would influence the answering of the indicator items and because the latent modeling allows to account for measurement error. This reasoning does not equally apply to the number of courses and knowledge. The number of courses was a single variable. Knowledge was assumed to be better represented by a sum score, since knowledge of one aspect in the test does not necessarily imply knowledge of another aspect (see Taber, 2018).

All variables were allowed to correlate. Missing data were rare (0.3%) and treated with Mplus' default procedure (full information maximum likelihood: Muthén & Muthén, 1998–2017). The model was specified before the analysis (but not before the study) and not optimized further.

### Transparency and openness

We report how we determined our samples size, all data exclusions (if any), all manipulations, and all measures in the study, and we follow Journal Article Reporting Standards (Kazak, 2018). The data that support the findings of this study have been deposited in the Open Science Framework with the https://doi.org/10.17605/OSF.IO/TSH2J. Materials and analysis code for this study are available by emailing the corresponding author. The data were analyzed using R, version 4.0.4 (R Core Team, 2021) and the package *psych,* version 2.0.12 (Revelle, 2020), and Mplus 8.6.

## Results

The descriptive results can be found in Table 1. Bivariate correlations of all manifest variables are displayed in Table 3. For researching RQ 1–4, an overall latent model was specified. The model had a good model fit ($\chi^2 = 1479.60$, $df = 858$, $p < 0.001$, RMSEA = 0.05, CFI = 0.79,[2] SRMR = 0.07).

### Research Question 1: Trust in science and utility beliefs

The results for Research Question 1 can be found in the first line of Table 4. As expected, trust in science was significantly related to utility of science ($r = 0.25$, $p < 0.001$), but not to utility of personal experiences ($r = 0.00$, $p = 0.952$).

[2] The CFI is not interpreted because the RMSEA of the baseline model is .10, thus below .157 (Kenny, 2020).

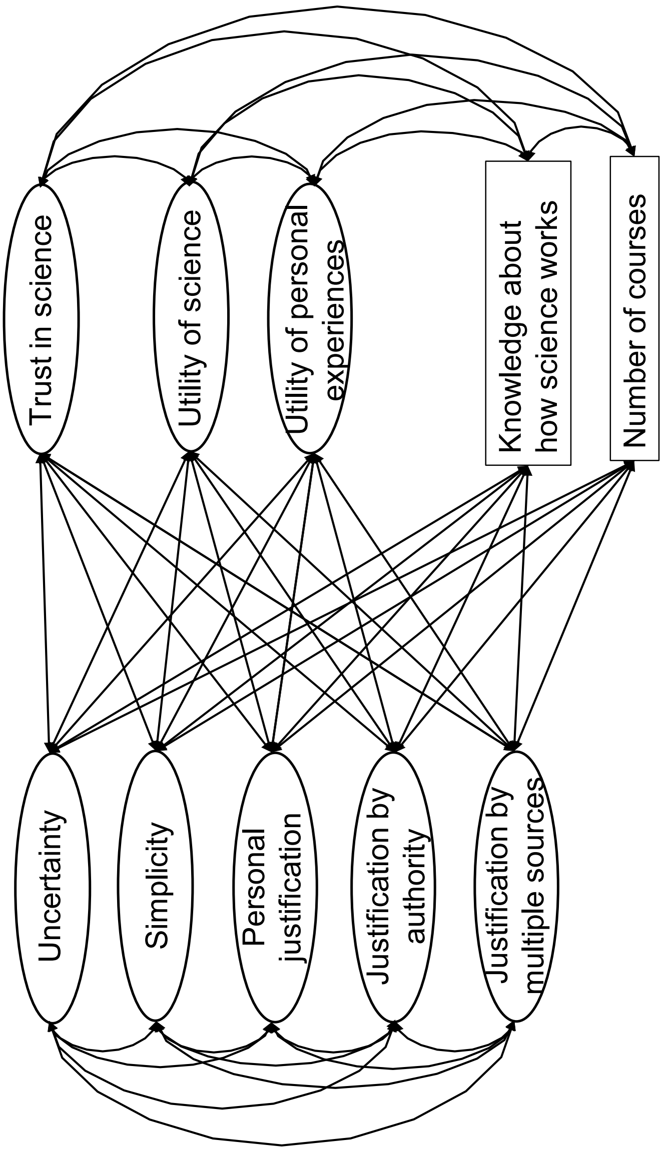


**Fig. 1** Specified model. Manifest indicators of latent variables are not depicted for the sake of clarity and readability

**Table 3** Bivariate Correlations of Manifest Variables

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| (1) Utility of science | | | | | | | | | |
| (2) Utility of personal experiences | .02 [-.09; .13] | | | | | | | | |
| (3) Trust in science | .16$^{**}$ [.05; .27] | -.01 [-.12; .11] | | | | | | | |
| (4) Uncertainty | .07 [-.04; .18] | .17$^{**}$ [.06; .27] | -.25$^{***}$ [-.35;-.14] | | | | | | |
| (5) Simplicity | -.16$^{**}$ [-.27; -.05] | -.12$^{*}$ [-.23; -.00] | .07 [-.04; .18] | -.10 [-.21; .01] | | | | | |
| (6) Personal justification | -.19$^{***}$ [-.30; -.08] | .05 [-.06; .16] | -.21$^{***}$ [-.31; -.10] | .24$^{***}$ [.14; .35] | .37$^{***}$ [.27; .46] | | | | |
| (7) Justification by authority | .06 [-.06; .17] | -.05 [-.16; .06] | .54$^{***}$ [.45; .61] | -.30$^{***}$ [-.40; -.20] | .09 [-.02; .20] | -.25$^{***}$ [-.35; -.14] | | | |
| (8) Justification by multiple sources | .14$^{*}$ [.03; .25] | .16$^{**}$ [.05;.26] | -.06 [-.17; .05] | .27$^{***}$ [.16; .37] | -.18$^{**}$ [-.29; -.07] | .02 [-.10; .13] | -.13$^{*}$ [-.24; -.02] | | |
| (9) Knowledge about how science works | .08 [-.03; .19] | -.06 [-.17; .05] | .11 [-.00; .22] | .05 [-.06; .16] | -.37$^{***}$ [-.46; -.27] | -.26$^{***}$ [-.36; -.15] | .11 [-.00; .22] | .07 [-.04; .18] | |
| (10) Courses | .03 [-.08; .14] | -.02 [-.13; .09] | -.02 [-.13; .10] | .01 [-.10; .12] | -.18$^{**}$ [-.28; -.07] | -.03 [-.15; .08] | -.02 [-.13; .10] | .09 [-.02; .20] | .16$^{**}$ [.06; .27] |

$^{***}$ $p < .001$; $^{**}$ $p < .01$; $^{*}$ $p < .05$. For (1) – (8), a mean score was built

**Table 4** Model results regarding relationships of beliefs (RQ 1–3). 95% confidence intervals in brackets

| | Trust in science | Utility of science | Utility of personal experiences |
|---|---|---|---|
| Trust in science | | .25*** [.11; .39] | .00 [-.14; .15] |
| Uncertainty | -.18* [-.34; -.02] | .26** [.10; .42] | .25** [.09; .41] |
| Simplicity | -.02 [-.20; .15] | -.27** [-.44; -.10] | -.22* [-.39; -.05] |
| Personal justification | -.27*** [-.41; -.12] | -.29*** [-.44; -.14] | .01 [-.14; .17] |
| Justification by authority | .67*** [.58; .77] | .08 [-.07; .22] | -.06 [-.20; .08] |
| Justification by multiple sources | -.08 [-.23; .07] | .20* [.04; .35] | .21** [.06; .36] |

*** $p<.001$; ** $p<.01$; * $p<.05$

### Research Question 2: Epistemic beliefs and trust in science

The results for RQ 2.1 and 2.2 can be found in the first column of Table 4. The uncertainty of knowledge was negatively related to trust in science ($r$ = -0.18, $p$ = 0.026), that is students believing scientific knowledge to be uncertain trusted science and scientists less. Simplicity beliefs were not significantly related to trust in science ($r$ = -0.02, $p$ = 0.799).

As expected, trust in science was positively related to justification by authority ($r$ = 0.67, $p$ < 0.001). Moreover, trust in science was negatively related to personal justification beliefs ($r$ = -0.27, $p$ < 0.001).

### Research Question 3: Epistemic beliefs and utility beliefs

In a more exploratory way, the relationship of epistemic beliefs with utility beliefs was researched. The results for this research question can be found in Table 4. Beliefs in the uncertainty of knowledge were positively related to both utility of science ($r$ = 0.26, $p$ = 0.002) and of personal experiences ($r$ = 0.25, $p$ = 0.002), while the belief in the simplicity of knowledge was negatively related to both utility beliefs (utility of science: $r$ = -0.27, $p$ = 0.002; utility of personal experiences: $r$ = -0.22, $p$ = 0.010). Moreover, personal justification beliefs were negatively related to the perceived utility of science ($r$ = -0.20, $p$ < 0.001), and beliefs in the justification by multiple sources was positively related to both utility of science ($r$ = 0.20, $p$ = 0.014) and of personal experiences ($r$ = 0.21, $p$ = 0.006).

### Research Question 4: Knowledge about how science works and beliefs about science

For analyzing Research Question 4, the same overall model was used as for the other research questions. The results for Research Question 4 can be found in Table 5. Knowledge about how science works and the number of methods courses taken were not significantly related to utility beliefs (RQ 4.1). Knowledge about how science works was positively related to trust in science ($r$ = 0.13, $p$ = 0.030). Moreover, knowledge about how science works was significantly related to uncertainty ($r$ = 0.18, $p$ = 0.014), simplicity

**Table 5** Model results regarding relationships of beliefs with knowledge about how science works, and number of methods courses taken. 95% confidence intervals in brackets

| | Knowledge | Courses |
|---|---|---|
| Utility of science | .08 [-.05; .21] | .04 [-.09; .17] |
| Utility of personal experiences | -.06 [-.19; .06] | -.02 [-.14; .11] |
| Trust in science | .13* [.01; .26] | -.04 [-.16; .09] |
| Uncertainty | .18*[.04; .32] | .04 [-.10; .18] |
| Simplicity | -.51*** [-.63; -.38] | -.25** [-.39; -.11] |
| Personal justification | -.33*** [-.45; -.21] | -.05 [-.18; .09] |
| Justification by authority | .12 [-.01; .24] | -.02 [-.15; .10] |
| Justification by multiple sources | .12 [-.02; .25] | .13 [-.00; .27] |

*** $p < .001$; ** $p < .01$; * $p < .05$

($r$ = -0.51, $p < 0.001$), and personal justification beliefs ($r$ = -0.33, $p < 0.001$). The number of methods courses was additionally related only to simplicity beliefs ($r$ = -0.25, $p$ = 0.001).

## Discussion

In the present study, the science-related beliefs of university students (i.e., students of psychology, education, and teacher education) were researched and related to their knowledge about how science works and to the number of university-level methods courses they had taken. Thus, two aims were pursued: The relationship of beliefs about the utility of science and of personal experiences with trust in science and epistemic beliefs was researched, because we consider these beliefs important for explaining current "post-truth" phenomena such as relying more on personal experiences than on scientific evidence. Moreover, university-level education and knowledge about how science works were researched as a possible predictor of these beliefs.

We found that trust in science was positively related to the perceived utility of science but not to the utility of personal experiences. Epistemic beliefs were partly related to trust in science: Uncertainty and personal justification beliefs were negatively related to trust in science. There was a high relation of trust in science with justification-by-authority beliefs. Uncertainty beliefs were positively related to utility beliefs (both of science and of personal experiences), and simplicity beliefs were negatively related to both utility beliefs. Moreover, personal justification beliefs were negatively related to the perceived utility of science.

Knowledge about how science works was positively related to uncertainty beliefs and negatively to simplicity and personal-justification beliefs. University-level methods courses taken were additionally and negatively related to simplicity beliefs.

### The relationships of perceived utility of science and of personal experiences, trust in science, and epistemic beliefs

The mostly moderate correlations of epistemic beliefs, perceived utility of science, and trust in science in the present study show that these constructs cover rather different aspects of beliefs about science. Thus, it might be worthwhile to consider all of them for studies that deal with understanding of scientific findings, for example in research on multiple document comprehension of science-related topics (e.g., Bråten & Strømsø, 2010; Schoor et al., 2019). Another body of research that may be interesting in this context is research on people's understanding of the nature of science (e.g., Lederman et al., 2015; McComas, 2020). Future research may consider, for example, how students' actual epistemic beliefs are related to their knowledge about the epistemic assumptions of science.

Moreover, the present results provide some interesting insights about the interrelationship of utility beliefs, epistemic beliefs, and trust in science. First, our study provides additional support for the assumption that trust in science may be a necessary but not sufficient condition for considering science useful (Schoor & Schütz, 2021). Yet, in our study the relationship was not very high ($r = 0.25$), and the direction of the relationship also may be reverse, since the present study was a cross-sectional correlational study. Further research is needed to a) replicate the results and b) establish the assumed direction of the relationship between the two belief constructs. Moreover, it would be interesting to follow up on sufficient conditions for considering science useful, that is potential moderators of the trust – utility relationship. We speculate that in addition to trust in science, people may need some epistemic belief that the scientific approach is a method for the creation of valid and useful knowledge, but to our knowledge no such conceptualization or measure exists.

Second, we found a relatively high relationship of trust in science and justification-by-authority beliefs ($r = 0.67$). At first sight, this may be considered worrying. Justification-by-authority beliefs are often considered less advisable or less sophisticated epistemic beliefs (Greene et al., 2008). This consideration is based on the thinking that people should not trust blindly in authorities, but that all knowledge claims have to be justified by evidence and/or multiple sources. Whereas this may be true and especially relevant for authorities that do not have the expertise, we actually wish people to trust in expert authorities such as scientists.

Moreover, original literature suggests a dichotomy for the epistemic belief dimension source of knowledge ranging from an external source (e.g., expert, authority) to an internal source, that is the self constructing knowledge (Hofer & Pintrich, 1997). Yet, given the specialization of knowledge in our societies, it is utterly impossible for an individual to understand everything in the world on their own, but we have to rely on experts (Kienhues et al., 2020). The reliance on oneself, in contrast, seems one of the bases for the post-truth emphasis on personal experiences.

Thus, the evaluation of justification-by-authority beliefs needs to be reconsidered. Justification-by-authority beliefs are not in all cases less advisable epistemic beliefs, especially not in the case when we measure justification-by-authority beliefs with regard to authorities such as scientists, as was the case in the scale we used in the present study. Thus, a high positive correlation is expectable and sensible. As a consequence, also justification-by-authority beliefs may be considered more sophisticated, or at least not negative.

With regard to the relationship of trust in science with simplicity and uncertainty beliefs, our results are in line with Hendriks et al. (2020)'s findings who reported a negative relationship of uncertainty beliefs and, in their case, trustworthiness ratings. Interestingly, the sign of the direction (positive/negative) of uncertainty and simplicity on the one hand and utility beliefs on the other was the same for both utility beliefs. That is who believes knowledge to be uncertain considers both science and personal experiences useful – maybe to counter an uncertain world? And who believes knowledge to be simple considers both science and personal experiences less useful – maybe because they are able to explain a simple world on their own and do not need neither science nor experiences? Of course, these are speculations.

### Beliefs about science and knowledge about how science works

The second aim of the present study was to explore whether university-level methods education and knowledge about how science works are related to university students ' beliefs about science. While our cross-sectional study design does not allow causal or directional inferences, we found support for the assumption. First, we found that knowledge about how science works was positively related to trust in science. Yet, the relationship was not very high ($r = 0.13$). This indicates that university-level education and (resulting) knowledge about how science works might have an impact on science-related beliefs, but it does not seem to be a very large impact. Thus, this effect has to be replicated by further research, and preferably the current directional interpretation should be validated by an experimental design.

The findings regarding the relationship of the number of methods courses taken, knowledge about how science works, and epistemic beliefs appear even more interesting. We found that more knowledge about how science works was related to less beliefs in personal justification, less belief in the simplicity of knowledge, and more belief in the uncertainty of knowledge. These results are in line with prior results suggesting that more disciplinary and/or content knowledge are related to more sophisticated beliefs (e.g., Rosman et al., 2017; Schoor et al., 2019), and they extend prior research to methodological knowledge. In addition, the number of methods courses taken was negatively related to beliefs in the simplicity of knowledge. All in all, these results suggest that university-level education and knowledge about how science works are related to more favorable epistemic beliefs.

Overall, we interpret these findings in the following way: People who know more about how science works may be more likely to appreciate the rigorous scientific approach and to trust in science, because they understand the advantages of this approach, as well as more aware of limitations and uncertainties of science and thus of knowledge generated by science. Nevertheless, the perception of the uncertainty of knowledge may also reduce (blind) trust in science and scientists because people with high uncertainty beliefs may consider qualifiers of this trust, which are not reflected in the trust scale items (e.g., we can trust scientists and their findings *only if* they are experts in the field and if the study was well-conducted).

## Limitations

Of course, the present study has several limitations. First, it was a cross-sectional study that does not allow causal inferences or inferences about the direction of influences. Second, the number of methods courses taken is only a coarse measure of university-level exposure to methodological instruction. While there are many explicit courses on scientific methods in some study programs (e.g., psychology), teacher education students learn about scientific methods rather within courses about specific topics (e.g., in a lecture about mental disorders of children and adolescents, scientific methods to research them may be shortly explained). Therefore, the number of methods courses taken is different across different study subjects. Because of this limitation, results on the knowledge measure should be preferred over the methods courses measure.

Third, the present study was based on self-report measures with regard to beliefs. These may be subject to various biases (e.g., social desirability, self deception; e.g., Bensch et al., 2017; Perugini & Banse, 2007). Implicit beliefs about science may overcome these biases (e.g., Gawronski & Bodenhausen, 2007; Schoor & Schütz, 2021). Also behavioral measures, such as selection of sources for getting information about socio-scientific issues (e.g., Salmerón et al., 2013) may be an interesting continuation of the present research. Moreover, the belief questionnaires referred to beliefs in science in general and not on specific topics. First, this may have been too abstract for participants such that they may have filled the abstract term with a more concrete domain or topic. Research on epistemic beliefs (e.g., Muis et al., 2016; Sandoval et al., 2016) and on trust in science (Hendriks et al., 2016) suggest that domain-specific beliefs differ from domain-general beliefs. Thus, we cannot rule out that our participants were thinking of different domains or topics when filling out the different belief questionnaires such that low correlations may be due to this way of measurement. Consequently, it may be interesting to replicate the present results on a topic level and with different topics. Also, a replication with specific (scenario) situations including concrete (fictitious) scientists, whose trustworthiness is judged, for example, with measures such as the METI (Hendriks et al., 2015), may be considered.

Last but not least, the sample consisted of students studying psychology, education, or teacher education. For other populations, the results, especially on the relationship between methods courses and knowledge, may be different.

## Conclusion

To our knowledge, the present study is the first that addresses the relationships of different beliefs about science to each other and to knowledge about how science works. The result most worth considering from our perspective is the close relationship of trust in science and justification by authority. It suggests that we revisit our notions of favorable epistemic beliefs, especially in the current context of post-truthism. In this context, we may also revisit the theoretical conceptualization of epistemic beliefs in order to connect them closer to the current issues with regard to post-truthism and science skepticism. For example, we may consider a dimension of justification by science.

In further steps, the possibilities to foster the perceived utility of science, trust in science, and favorable epistemic beliefs should be considered. The present study established a correlational relationship of knowledge about how science works with several of these measures. Future research may analyze whether methodological education has a causal effect. Thus, a better education regarding knowledge about how science works may counteract phenomena of post-truthism.

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**Data availability** The data of this study are made openly available in the Open Science Framework with the DOI https://doi.org/10.17605/OSF.IO/TSH2J

## Declarations

**Ethics approval and consent** Participation was voluntary and in accordance with APA principles regarding informed consent. The research project has been approved by the University of Bamberg's ethics committee.

**Conflicts of interest / Competing interest** The author has no conflicts of interest to declare that are relevant to the content of this article.



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*Current themes of research:*

Beliefs about science. Multiple document comprehension. Reading about science, data literacy.

*Most relevant publications:*

Schoor, C., Rouet, J.-F., & Britt, M. A. (2023). Effects of context and discrepancy when reading multiple documents. *Reading & Writing, 36*, 1111-1143. https://doi.org/10.1007/s11145-022-10321-2.

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