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Fostering students' willingness to act pro-environmentally through an identity-oriented socio-scientific exhibition on the energy transition

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Successfully communicating the importance of a global energy transition toward carbon-free energy sources and increasing participation in it depends on society as a whole, including the socio-cultural identities and personal values of all involved. Since a person's willingness to engage in the energy transition is strongly influenced by their social environmental identity, we argue that interventions offering students opportunities to develop this part of themselves should foster their overall willingness to do so. We argue that modern museum exhibitions on socio-scientific issues addressing visitors as individual, social or political actors, represent particularly suitable sites for such an approach. We investigated the extent to which students' overall willingness to act pro-environmentally changed after visiting a socio-scientific exhibition on the energy transition and the extent to which students' subsequent overall willingness to act was influenced by their prior conceptual knowledge about energy and topic-related interest. Data for the study was collected in a pre-post design, with students (N=185) visiting the exhibition for 90min in between. We found that students' overall willingness to act changed significantly from prior to after their exhibition visit, and we found that students' prior energy knowledge but not their interest impacted their willingness to act after the visit to the exhibition. Based on these findings, we discuss that providing a broad range of opportunities for identity work to students outside of the school context fosters their willingness to act on a global scale – and that modern socio-scientific museum exhibitions are thus a useful way to complement formal education.

KEYWORDS

energy transition, energy literacy, pro-environmental behavior, social environmental identity, socio-scientific issues, museum, exhibitions

1. Introduction

To meet climate change and increasing resource scarcity, two of the greatest challenges of the 21st century, a global energy transition is urgently needed (United Nations, 2021; World Economic Forum, 2021). The aim of this energy transition is to shift away from fossil fuels toward low-carbon energy sources and a sustainable energy system. But the necessary

technological and systematic changes will only come to fruition when they are supported by a wide range of stakeholders in all sectors and at all levels of society (Miller et al., 2013; Steg et al., 2016). Considering that these stakeholders are not only representatives from industry and science, politics and interest groups but people with personal values and attitudes toward the issue, it becomes clear that a global energy transition ultimately depends on every person's able- and willingness to engage with the energy transition and to act in a way that is promoting its goals (Sanz-Hernández, 2020).

Helping students to become energy-literate citizens, who are able to make informed energy-related decisions and ultimately act in an energy-conscious way (e.g., U.S. Department of Energy, 2017; Lowan-Trudeau and Fowler, 2021) and will represent the future stakeholders in all areas of society is therefore of great importance. However, although the goal of science and environmental education is to prepare students to address "wicked problems" (Rittel and Webber, 1973) such as the energy transition, research shows that this objective is oftentimes missed (Bywater, 2014). This is equally true for energy literacy considerations and interventions, where it also appears to be as yet unclear how the behavioral domain of this multidimensional concept can actually be encouraged (Białynicki-Birula et al., 2022). This difficulty in influencing desired behavior, which we can observe in research in general, is surely highly attributable to the inherently complex nature of human behavior, and the multitude of personal and situational factors by which it is influenced. Yet, in part, this could also be due to the often-prevalent tendency in research on environmental and energy-related behaviors, to design linear interventions aiming at specific behaviors through knowledge increase or attitude change (e.g., Stets and Biga, 2003; McGuire, 2015).

Therefore, in this article, we want to find out more about how to communicate the importance of the energy transition to young people and increase their participation in it. We explain why we believe that a more integrated approach that addresses adolescents as individuals and provides opportunities for them to work on their social environmental identity has the potential to holistically support their tendency to engage in pro-environmental behaviors and why modern socio-scientific exhibitions constitute a particularly promising context to investigate such an effort. We then use a repurposed instrument to examine the extent to which visiting such a socio-scientific exhibition on energy transition, which incorporates opportunities for identity work into its design, influences students' overall willingness to act in an environmentally friendly manner. As we are moving with this study at the interface between formal and informal education, we also investigate how far the impact of that visit is influenced by students' prior interest in the energy transition and school knowledge about energy. By supplying findings at the formal-informal education interface, we hope to bring these worlds closer together to make use of their respective inherent strengths.

1.1. Energy literacy

For the energy transition to succeed, we urgently need an energy literate society (McCaffrey et al., 2012). Helping students to become productive citizens in national energy policy debate and actions (Liu and Park, 2014, p. 182) is therefore paramount and reflected in the emphasis many educational standards put on the importance of energy and energy literacy (e.g., Kultusministerkonferenz, 2005; NGSS Lead States, 2013). Although there are various descriptions of the energy literacy construct (e.g., U.S. Department of Energy, 2017; Lowan-Trudeau and Fowler, 2021), it is normally assumed to span along three domains: The cognitive domain including content knowledge and cognitive skills, the affective domain containing attitudes and values and the behavioral domain including predispositions to behave and actual behavior (DeWaters et al., 2013, p. 57), see Figure 1. Ultimately, an energy literate person is expected to act in an energy-conscious way, which makes sense considering that only behavior might have an actual impact on climate change or resource scarcity. Yet it remains unclear how to foster that kind of behavior. While it is often assumed that energy-related knowledge forms the cognitive basis of energy literacy, that affective elements such as attitudes build upon it, and both positively influence the behavioral domain of the energy competent person, to date, research has not been able to empirically support this assumption (Białynicki-Birula et al., 2022). However, the fact that this assumption does not work seems to be due less to characteristics of energy literacy studies than to the general problem of the non-functioning deficit model (e.g., Baram-Tsabari and Lewenstein, 2016; Gomes da Costa, 2019) and the so-called "attitude-behavior gap" (LaPiere, 1934) that echoes through the whole field of environmental education (Chawla and Cushing, 2007; Bywater, 2014; Allen and Crowley, 2017).

1.2. Problems with fostering pro-environmental behavior

A recurring problem with promoting behaviors that could accelerate the energy transition is that most studies that seek to promote such behaviors are often limited to only one energy sector (Rau et al., 2022) or exclusively focus on the realm of individual energy use, particularly in the home (e.g., Abrahamse and Steg, 2013; Coskun et al., 2015). That is unfortunate, considering that promoting pro-environmental behavior only in the private sphere or one individually considered sector is simply not enough to "stop global warming" (McGuire, 2015, p. 696), bears the risk of teaching students an overly "simplistic and individual approach to

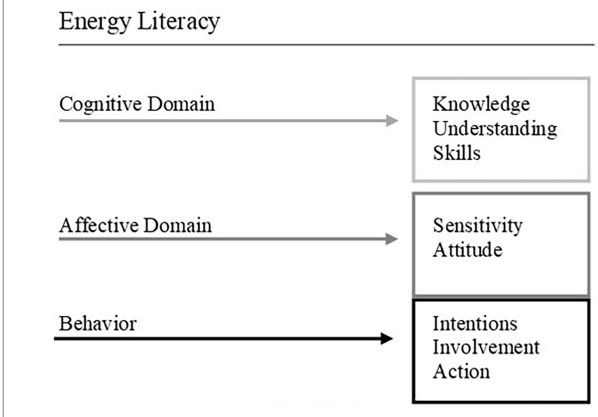

FIGURE 1
Energy literacy (simplified after DeWaters et al. (2007)).

environmental problems and their causes" (Jensen and Schnack, 1997, p. 172) and ignores that "large institutions such as government and industry are major contributors to waste, pollution, and the consumption of nonrenewable resources, as well as structural barriers to greener lifestyles" (Chawla and Cushing, 2007, p. 438). In reality, a wide range of measures is necessary for the success of the energy transition (Steg et al., 2021, p. 3), including direct, indirect, individual, and collective behaviors in consumption, housing, mobility, food, energy production, and transport, and most importantly, the participation in the energy policy discourse (Brosch et al., 2016a,b, p. 2).

Knowing about all these intertwined issues seems to be an important first step toward pro-environmental behavior, but research shows, that only increasing students' factual knowledge does not suffice (Sutton and Robinson, 2020, p. 3; Allen and Crowley, 2017, p. 300). Providing knowledge about the consequences of, i.e., climate change and dwindling resources, and how they are caused by human beings, however, may raise awareness and appeal to students' sense of responsibility which can predict pro-environmental behavior (Kollmuss and Agyeman, 2002, p. 243). However, this is only true, as Jensen and Schnack noted in their essential work on action competence, as long as students are not overwhelmed by how "bad things actually are" (Jensen and Schnack, 1997, pp. 171–172), feel helpless or "like their individual actions might have no significant impact" (Kollmuss and Agyeman, 2002, p. 255). Rather, students need to be empowered to "feel that they can take action, and that their actions will make a difference" (Braus, 2013, p. 29). Why interventions that included so-called "action knowledge" (van de Wetering et al., 2022, p. 9) on how to engage in pro-environmental behavior or opportunities to directly engage in such behavior (Chawla and Cushing, 2007, p. 441, Chen and Liu, 2020, p. 10) showed indeed some success. Still, for people to actually show pro-environmental behavior, they must not only feel that they can perform a particular action, but the effect of this action must also align with their personal values and attitudes.

The assumption that attitudes are predictive of behavior has led to many studies, but, although there seems to be a "modest relationship" (Stets and Biga, 2003, p. 398) between environmental attitudes and behavior, attitudes generally only noticeable predict behavior under certain conditions (McGuire, 2015, p. 699) and only with (very) small impacts (Kollmuss and Agyeman, 2002, p. 252). Environmental values on the other hand "are seen as more central to the self and transcend objects and situations" (Stets and Biga, 2003, p. 400) and guide persons in their behavior (e.g., Bolderdijk et al., 2013). For example, values that reflect concern for nature and the environment are most likely to predict consistent sustainable energy behavior and support for sustainable energy policies (Steg, 2016). Unfortunately, from an educational perspective, values are mostly shaped by a person's closest social group and personal cultural context (e.g., Boer and Boehnke, 2016) and are difficult to reach through educational interventions.

All in all, knowledge alone does not seem to be sufficient, attitudes appear not to be reliable enough, and values seem too difficult to influence in order to promote environmentally friendly behavior in its entirety. Therefore, it seems that fostering a more holistic tendency to behave pro-environmentally does also require a more holistic approach which we try to provide by introducing identity work in the exhibition context.

1.3. The social environmental identity lens

People's perceptions on what measures should be taken in order to accelerate the energy transition or their willingness to do so does not only reflect their knowledge, attitudes, and beliefs but also depends on factors such as the group they belong to (Bolderdijk et al., 2013) their needs and everyday challenges (Steg, 2022). Thus, the willingness to act pro-environmentally depends on the whole person in the reality of his or her life and therefore requires an integrated approach of encouragement. Looking at the challenge of promoting pro-environmental behavior through the lens of identity may reveal a perspective for such an approach. For although it has long been known that the self and one's identity guide behavior (Burke and Reitzes, 1981) and that the effects are robust even when controlling for attitudes and situational characteristics (McGuire, 2015, p. 703), this perspective has surprisingly rarely been incorporated into the design of educational interventions.

An individual's identity is to the many roles and relationships a person might hold. All of them make for a person's self-concept, but not every aspect is as important as the other nor are they all expressed at any given time. Stapleton describes this nicely when she writes: "Environmental identity could be envisioned as a section within an individual's identity binder. The section could be thick and/or toward the front of the binder, it could be an appendix, or it could be missing altogether" (Stapleton, 2015, p. 101). Therefore, the extent to which environmental identity influences a person's behavior depends, on the one hand, on how large its share of the person's overall identity is or how "strong" it is (Clayton, 2003). On the other hand, environmental identity can also be made "salient" by being activated situationally in someone's mind (Rahmani et al., 2022, p. 2) and thus be brought to the foreground of someone's "identity binder." There is evidence that identity salience might even be a bigger predictor for behavior than identity strength (Rahmani et al., 2022) and that it can be encouraged through socio-cultural interaction (for an outline, see Verhoeven et al., 2019, pp. 52–53).

Fittingly, Kempton and Holland (2003) propose a "social environmental identity" which is used by people to define their position in relation to others in terms of their environmental views and lifestyles and describe its development in three stages: salience, or becoming aware of environmental problems; identification with and seeing oneself as an actor in the environmental context; and becoming more knowledgeable about how to engage in environmental practice (Kempton and Holland, 2003 as cited in Stapleton, 2015, p. 96). Stapleton additionally depicts social environmental identity as malleable over time, tightly connected to practice, continually informed by and recreated through social interactions, simultaneously existing on multiple levels, and as largely impactable by education and schooling (Stapleton, 2015, p. 97). All these aspects show why social environmental identity is highly valuable for environmental education and at the same time point out the need for multileveled interventions that provide the opportunity for students to engage in such an identity development. This kind of engagement can be described as "identity work" (Calabrese Barton et al., 2013) that includes both social and cognitive learning as well as participation in a learning community (Gonsalves et al., 2021, p. 5) or "identity exploration" in which "the action of gathering information, questioning, experimentation, and critical reflection on one's identifications, beliefs, qualities, and roles" (Marcia, 1966 as cited by

Kaplan and Flum, 2010, p. 56) leads to individual changes in identity through the engagement in a sociocultural situated environment. Therefore, repeated opportunities for identity work in learning environments that provide students with chances for "participation and action in environmental activities as well as recognition as an environmental actor have the potential to further environmental identity development" (Stapleton, 2015, p. 107) might lead to increased pro-environmental behavior.

1.4. The role of museums in fostering pro-environmental behavior

Particularly suitable sites to provide sociocultural situated environments for students to engage with might be museum exhibitions. Not only are museum exhibitions already known to play a key role in supporting the overall science literacy of society (Falk and Dierking, 2010) and to promote knowledge, interest, motivation, and attitudes (Falk and Dierking, 2010; Schwan et al., 2014; Phelan et al., 2017; Lewalter et al., 2021), due to their free-choice-learning they also offer "powerful opportunities for doing identity work" (Rounds, 2006, p. 133) in a way that might complement formal education in its efforts to help students become active energy literate citizens.

Naturally, schools are indisputably important sites for the identity formation of students. Through school knowledge, norms, and perception students might develop a science identity (Vincent-Ruz and Schunn, 2018) or find themselves to identify as a physics person (Hazari et al., 2022). But as these subject identities rely on self-perceptions that tend to be integrated into a student identity, the person "one is in school" (Verhoeven et al., 2019, p. 40), interventions outside of school might provide novel entry points for identity work that are neither school nor learning related.

In addition, museums recognize a growing responsibility to work toward a sustainable global society (McGhie, 2018, 2020; Sutton, 2020; Sutton and Robinson, 2020) and are increasingly focused on addressing complex issues like, i.e., climate change and energy (Pedretti and Navas Iannini, 2020). The resulting "critical" or "agential" exhibitions, examine complex issues critically from different angles and often encourage active engagement and dialog within the exhibition and/or between visitors (Pedretti and Navas Iannini, 2020, p. 61). Critical exhibitions mainly focus on dialog, decision-making, and understanding of socio-scientific issues. Agential exhibitions challenge visitors more clearly to act on a personal, family, or societal level and provide excellent opportunities for students to take part in environmental activities and be recognized as environmental and political actors. Since both exhibition types overlap and complement each other, we would like to summarize them in the following under the term "modern SSI-exhibitions." In this dialogical communication and the choice of the offered possibilities of action within modern SSI-exhibition, may lie the key to social environmental identity work as:

> "It is the mediating function between what's inside and what's outside, between the agent who chooses to act and the structures that provide the opportunities for acting, alternatives among which actions may be chosen, and the consequences of acting. Agency and structure are like the two blades of a pair of scissors that need to work together to do their job. An agent confronts a world—sometimes by visiting a museum—and out of the interaction constructs an image of what kind of person she wants to be, and how she should live her life." (Rounds, 2006, p. 137)

We believe that a modern SSI-exhibition on the energy transition can help to construct such an image and hypothesize that it can influence the pro-environmental behavior of students through the mechanisms of identity work. Since it is important to promote a wide range of behaviors to accelerate the energy transition, and since we regard identity work as holistic enough to promote a general tendency, we would like to examine the influence of such an exhibition on students' overall willingness to act pro-environmentally. However, for such an influence to occur, there must be a primary motivation on the part of students visiting the exhibition to initiate this type of identity work, or any type of free-choice learning at all, as it is highly dependent on visitors' personal characteristics (Falk and Storksdieck, 2005; Falk et al., 2011), such as interest or knowledge. Interest is known to influence attention, concentration, and joy when engaging with a topic and personal interest seems to increase learning through, i.e., higher engagement (for an overview see Renninger and Hidi, 2016). Higher interest in the topic of energy transition should therefore lead to higher engagement with the exhibition and probably higher engagement with identity work. Hence, we consider students' interest in the topic of the energy transition to be an important motivational variable for students' engagement with the exhibition. Prior knowledge, on the other hand, facilitates further knowledge acquisition and evaluation and categorization of new information (e.g., National Academies of Sciences, Engineering, and Medicine, 2018). In formal education, conceptual energy knowledge (CEK) is widely perceived and taught as a prerequisite for energy literacy (Chen et al., 2014; Nordine, 2016; U.S. Department of Energy, 2017). Although we have seen before that content knowledge alone seldomly leads to behavior change and CEK alone probably does not lead to desired behavior, CEK might be very useful in the sense that it helps students to evaluate information about the influence energy-related behavior might have on climate change and resource scarceness. Based on these assumptions we also hypothesize that the higher the level of students' prior interest in the energy transition and conceptual energy knowledge, the more effective will be the mechanism of identity work.

1.5. Research questions and hypotheses

We, therefore, pose the following research questions and hypotheses:

RQ1: How does students' overall willingness to act change during a visit to a modern SSI exhibition on the energy transition including opportunities for identity work?

> H1: The exhibition visit will have a positive impact on students' overall willingness to act pro-environmentally.

RQ2: In how far is students' overall willingness to act after their visit to a modern SSI exhibition on the energy transition including opportunities for identity work influenced by their prior interest and conceptual energy knowledge?

H2.1: The higher students' prior interest in the energy transition the higher will be their overall willingness to act after their exhibition visit.

H2.2: The higher students' prior conceptual energy knowledge the higher will be their overall willingness to act after their exhibition visit.

2. Method

2.1. The *energie.wenden* exhibition

The special exhibition *energie.wenden*, that students visited in this study was shown at the Deutsches Museum in Munich from February 2017 to November 2018.[1,2] The exhibition was created in collaboration of an interdisciplinary curatorial team with energy transition experts from science, industry, and politics and focused strongly on the socio-scientific aspects of a global energy transition. It especially emphasized the public's ability to creatively shape the process of the energy transition addressing particularly youth and young adults (Newinger et al., 2017; Kellberg and Newinger, 2018). The first author of this article was significantly involved in the conceptual development and realization of this exhibition. This study, however, was part of an independent third-party-funded research group. None of the co-authors had any connection with the exhibition.

The far-reaching areas of the energy transition were presented in "thematic rooms," where various technologies were put in their socio-scientific context and considered with regard to their significance for the energy transition. Wherever possible, links between the areas were highlighted, cruxes of technologies and measures were discussed and best practice examples were examined from different perspectives. This implemented knowledge about the consequences of the use of certain technologies, motivating examples for action as well as the promotion of a systemic consideration of energy production, transport, and usage. Special care was taken to emphasize both the individual and collective effectiveness of peoples' actions, as well as the limiting or facilitating influence of systemic regulations, and to reveal how such regulations could be changed (for more information see Newinger et al., 2017; Kellberg and Newinger, 2018). This exhibition area could be used separately by visitors but was also intended as knowledge repositories for the interactive element at the heart of the exhibition.

Upon entering the exhibition, visitors were invited to take on the role of a politician and, with the help of information from the thematic rooms and in an exchange with various stakeholders of the energy transition as well with potential voters, decide on energy policy measures to drive the energy transition forward. The stakeholders, visitors encountered in the exhibition, were impersonated by actors on life-sized screens, which were activated by motion sensors. That way, visitors were personally addressed by the actors when they walked by them. The stakeholders then shared their opinions and demands regarding major focal points of the energy transition, trying to convince visitors in their role as politicians to act in their favor. The visitors were then able to decide how they wanted to react to these demands at the according decision station. They activated these stations with a paper card they received upon entering the exhibition. First, a question about the major focal points of the energy transition the respective stakeholder had just talked about, appeared on a screen. Then, three possible answers about the implementation of various technical or political energy measures emerged. By selecting a measure, various characters representing different groups of voters popped up, vividly expressing their positive or negative reactions to the respective measure. The visitors' decision process thus included a variety of perspectives incorporated by various energy transition-oriented identities. Visitors could, however, interrupt their decision process at any time and visit the spatially and thematically adjacent thematic room for research. In the end, however, they ultimately had to decide on one measure per decision station. Visitors did so by selecting the desired answer and then pressing a lever that punched a physical irretrievable hole in their paper card. Gradually, these holes formed patterns, which finally were analyzed at an assessment station at the end of the exhibition visit. The result was then printed on the card, and at the end, visitors had all their choices and the resulting personal energy transition profile – their "energy transition persona" – in their hands and could compare them with each other and with their own (previous) ideas about themselves as an "energy transition person" (for insight in energy transition-profiles, see Kellberg and Newinger, 2018).

Inviting visitors to take on the overviewing role of a politician not only facilitated the display of the systemic reach of the energy transition but also provided visitors with a shift in perspective and responsibility that gave especially young visitors the possibility to explore future possible selves within that role play (e.g., Ibarra and Petriglieri, 2010; Chen and Martin, 2015). While the exhibition as a whole made connections to the personal lives of young visitors in particular, the game outstandingly allowed to recognize visitors as persons and active actors in the energy transition. The game also highlighted visitors' relevance for the success of the energy transition and showed how influential they can be in its process. The variety of identities represented in the exhibition additionally served as potential role models with which visitors could identify or from which they could distance themselves. They prepared the basis for an identity work to which each visitor could find his or her individual access (Avraamidou, 2020, p. 324) and position themselves in this highly versatile community committed to the energy transition (Jans et al., 2018). Therefore, we think that this exhibition should have the potential to foster students' "environmental identity development" (Stapleton, 2015, p. 107) and adherently their overall willingness to act pro-environmentally.

2.2. Study design

This study was reviewed by the Bavarian Ministry of State for Education and Culture, Science and Art and approved subject to compliance with the Ministry's requirements before it was conducted. In this pre-post study, students were given a pen and paper test 1 week prior and 1 week after their visit to *energie.wenden*. Students came to the exhibition in their classes or as part of their

1 www.deutsches-museum.de/museumsinsel/ausstellung/sonderausstellungen

2 https://space4.de/projekt/energie-wenden/

physics course and were given a brief introduction about the exhibition content and design just before they started their 90-min visit. Due to ethical considerations, it was decided not to experimentally divide students into groups that could or could not participate in the exhibition's role-playing game. Because due to the time constraints of the visit, this would have meant depriving some of the students of the experience of this central element of the exhibition. Therefore, all students were explicitly told that they could use the exhibition at their own discretion and could decide for themselves whether or not to participate in the exhibition's role-play. Teachers were invited to visit the exhibition as their students did. Data collection took place from September 2017 to November 2017. Testing took place at school during physics classes and was consented to by a legal guardian of the students. All tests were conducted, explained, and supervised by the first author.

2.3. Sample

Ten classes from five secondary schools, from eighth (students' age on average 13–14 years) to tenth grade (students' age on average 15–16 years), participated in this study, $N = 222$. For the current analyses, only students who visited the exhibition with data from pre- and post-test were included. The final data set consisted of 185 students (166 students from 8th grade Gymnasium, the high achieving secondary school track and 19 from 10th grade Realschule, the medium achieving secondary school track; Age 12–17, M (SD) = 13.58, (1,058), 42.2% female, 57.3% male, 0.5% gender neutral).

2.4. Willingness to act

For students' willingness to act, we chose to assess a wide variety of behavioral intentions that are relevant to the acceleration of the energy transition. For this, we drew on a pre-existing instrument: Boyes and colleagues developed a widely used instrument, asking about students' willingness to act in several areas of the energy transition, thereby also taking political, situational, financial, or personal factors into account (Boyes et al., 2009). We chose 16 of their items representing actions "that could, to different extents, contribute to the reduction of global warming" (Boyes et al., 2009, p. 664). These items were translated from English into German and in a first pilot study we tested students' understanding of the items, making minimal changes to item wordings afterwards. In a second pilot study, we confirmed that all items mapped onto one common scale in an internally consistent way (Cronbach's alpha = 0.914). All items were measured on a five-point Likert scale ranging from "not at all" to "very much." Item wordings for the final scale can be found in the Supplementary material S1. For the current study, we were interested in willingness to act as an overall behavioral tendency. Therefore, we averaged across all items and used this overall score for all further analyses. Internal consistency of the scale was high (Cronbach's alpha = 0.87 for prior and = 0.89 for after students' visit to the exhibition).

2.5. Interest in the energy transition

Students' interest in the energy transition was measured with four items based on Krapp (2002). Students were asked how much they agreed with statements such as "For me, dealing with the topic of the energy transition is personally significant" or "Engaging with the issue of the energy transition is personally meaningful to me." All items were measured on a five-point Likert scale ranging from "not at all" to "very much." The internal consistency of the scale was high (Cronbach's alpha = 0.84).

2.6. Conceptual energy knowledge

To gain insight into students' conceptual energy knowledge (Chen et al., 2014; Nordine, 2016; U.S. Department of Energy, 2017), we included a single-choice test in the pretest. The test is based on the Energy Concept Assessment (ECA) (Neumann et al., 2013, p. 168) and includes four key ideas about energy (energy forms and sources, energy transfer and conversion, energy degradation, and energy conservation; e.g., Duit and Neumann, 2014). From ECA we selected 24 items based on their closest content relationship to the energy transition, their balanced representation of the four key ideas, and their level of difficulty for each of the key ideas. Each item featured one question and four possible answers for students to choose from, with only one answer correct. The test was coded 0 for incorrect and 1 for correct answers. For the overall assessment of students' conceptual energy knowledge, we calculated the percentage of correctly solved tasks for each student and used this value for all further analyses. Students who did not complete at least 50% of the conceptual knowledge test were excluded from further analyses that included conceptual energy knowledge, leaving 169 students to be included ($N = 169$).

3. Results

3.1. Descriptives

Table 1 includes the descriptive statistics of students' overall willingness to act before and after their visit to the exhibition as well as

TABLE 1 Descriptive statistics and correlations for study variables.

Variables	*n*	Min	Max	*M*	*SD*	*Mdn*	Correlations			
							1	2	3	4
1. Interest in the energy transition	185	1.00	5.00	3.34	0.803	3.25		0.16*	0.37**	0.33**
2. Conceptual energy knowledge	169	0.00	0.96	0.48	0.194	0.48			0.18*	0.26**
3. Overall willingness to act (T1)	184	1.31	5.00	3.31	0.687	3.38				0.82**
4. Overall willingness to act (T2)	184	1.38	4.88	3.37	0.727	3.41				

*$p < 0.05$; **$p < 0.01$.

their prior interest and conceptual energy knowledge. Students' conceptual energy knowledge varied between a score of zero (all items solved incorrectly) and 0.96 (almost all items solved correctly); students' interest in the energy transition and overall willingness to act at both time points varied considerably. Students' overall willingness to act after the exhibition visit ($M = 3.37$) was descriptively larger than before the visit ($M = 3.31$). All correlations between study variables were significant and positive, albeit varying in size. Except for the expected large correlation between students' overall willingness to act at T1 and T2, there are moderate correlations between the overall willingness to act variables and interest and conceptual energy knowledge, but only a weak correlation between interest and knowledge.

3.2. RQ 1: How does students' overall willingness to act change during a visit to a modern SSI exhibition on the energy transition including opportunities for identity work?

Because students' overall willingness to act (T1, T2) was not normally distributed and since the *t*-test is highly sensitive toward a violation of the assumption of normal distribution, we chose a Wilcoxon signed-rank test to test whether students' overall willingness to act changed before to after the exhibition visit. The test is used to determine whether the central tendencies of two dependent samples are different using rank orders of the two time points and comparing them. The differences between the ranks of the two time points in this study are given positive and negative signs. If the distribution is similar or equal, the negative ranks and positive ranks should be approximately equal. If positive ranks should significantly eclipse negative ranks, then the study hypothesis can be accepted. Table 2 shows the results of the Wilcoxon signed-rank test for the within-person comparison of overall willingness to act at the two different time points (Wilcoxon signed-rank tests for each item of the scale of willingness to act can be seen in the Supplementary material S2). Thereby, students' overall willingness to act changed significantly from T1 to T2 and was significantly higher after their exhibition visit (Mdn = 3.40) compared to before (Mdn = 3.38, $z = -2.418$, $p = 0.016$, $r = 0.18$). Specifically, the test revealed that although 68 students were less willing to act (negative ranks), 103 stated that they were overall more willing to act pro-environmentally (positive ranks) and only 13 students showed no change (ties) after their exhibition visit. Thus, and in line with our hypothesis, students seem to have increased their overall willingness to act pro-environmentally in the exhibition, albeit with a small effect size ($r = 0.18$).

3.3. RQ 2: In how far is students' overall willingness to act after their visit to a modern SSI exhibition on the energy transition including opportunities for identity work influenced by their prior interest and conceptual energy knowledge?

To answer our second research question, we conducted multiple linear regressions for students' overall willingness to act after their exhibition visit (T2), with students' prior (T1) overall willingness to act as the control variable and students' interest in the energy transition and conceptual energy knowledge as independent variables. We first included only our control variable in the linear regression calculation, then analyzed our two independent variables, and finally included all variables in the calculation. The results are presented in Table 3. As can be seen and as expected, students' overall willingness to act prior to their exhibition visit (T1) had a strong effect ($\beta = 0.78$) on and explained about 61% of the variance in their overall willingness to act after the visit. Above and beyond prior overall willingness to act, only students' conceptual energy knowledge still contributed significantly to overall willingness to act at T2 ($\beta = 0.13$, $p < 0.01$) and explained an additional 1% of variance after controlling for prior overall willingness to act (T1). The positive effect of interest in the energy transition on overall willingness to act T2 ($\beta = 0.25$, $p < 0.01$) vanished when controlling for overall willingness to act T1 ($\beta = 0.02$, $p = 0.76$). The results therefore only partially confirm our hypothesis that both students' interest in the energy transition and conceptual energy knowledge would influence their overall willingness to act after the exhibition visit.

4. Discussion

4.1. Principal findings

The current study found that students' overall willingness to act pro-environmentally significantly increased after their visit to *energie. wenden* exhibition, albeit with a small effect. These findings are consistent with our theoretical assumptions about how such a modern SSI-exhibition on the energy transition potentially might foster students' overall willingness to act. Throughout the exhibition, students were provided with knowledge in use on an individual, collective and political dimension in a systematic and sociocultural context (Newinger et al., 2017; Kellberg and Newinger, 2018). Further, the exhibition allowed students to assume the role of a competent and relevant actor in the energy transition, thereby

TABLE 2 Results of Wilcoxon signed-rank test for changes in student's overall willingness to act prior (T1) and after (T2) their exhibition-visit.

	n	Negative ranks			Positive ranks			Ties	Z	*p*	*r*	*Mdn* T1	*Mdn* T2
		n	Mean rank	Sum of ranks	*n*	Mean rank	Sum of ranks						
Overall willingess to act (T2–T1)	184	68	85.10	5786.50	103	86.60	8919.50	13	−2.418[b]	0.016	0.18	3.38	3.40

$Z =$ [b] Based on negative ranks. $r =$ Effect. $r < 0.3 =$ small effect, $r > 0.30 - < 0.5 =$ moderate effect and $r > = 0.5 =$ large effect.

TABLE 3 Results of multiple linear regressions testing the influence of students' prior overall willingness to act (T1), interest in the energy transition and, conceptual energy knowledge on student's overall willingness to act (T2) after their exhibition-visit.

	Overall willingness to act (T2)													
		ß	CI 95%		SE	p		ß	CI 95%		SE	p		
			Lower	Upper					Lower	Upper				
(Intercept)			0.30	0.95	0.16	**			1.73	2.68	0.27	**		
Overall willingness to act (T1)		0.78	0.73	0.92	0.05	**		–	–	–	–	–		
Interest in the energy transition		–						0.25	0.09	0.35	0.07	**		
Conceptual energy knowledge		–	–	–	–	–		0.23	0.31	1.41	0.28	**		
Explained variance, R^2	0.61						0.12						0.62	

*$p<0.05$; **$p<0.01$.

providing students with the opportunity to shape and practice their social environmental identity (e.g., Calabrese Barton et al., 2013; Stapleton, 2015; Verhoeven et al., 2019; Gonsalves et al., 2021). They did so by engaging with different personalities and perspectives on how to positively contribute to the energy transition as part of the exhibition. Of particular importance is the fact that the students in the exhibition were not told how to act and were not judged on their "right" or "wrong" actions, but that showing them different perspectives and possibilities for action and providing them with insights into what energy-transition-person they are, led them to change their willingness to act – an approach that is difficult to implement in a curricular setting in such a short time. A closer look at the details further supports our assumption that this increase does actually reflect a change in students' overall behavioral tendency and not merely some changes in a few concrete behavioral intentions (see Supplementary material S2): Wilcoxon signed-rank tests for all items of student's willingness to act show only three significant changes (including one with a negative effect) with respect to individual behaviors but several more items with more positive than negative ranks, indicating that this overall tendency really cannot be attributed to individual items, but only emerges in its entirety. This indicates that this novel behavioral tendency measurement is headed in a promising direction when it comes to studying the impact of socio-scientific learning environments. We interpret the increase in students' overall behavioral tendency as an indication that the identity work favored by the elements of the exhibition described above has indeed taken place.

It is important, however, to note that despite the overall positive result, 37% of the students were *less* willing to act pro-environmentally after their visit to the exhibition than before. There could be several reasons for this, which could either be found in the design of the exhibition, in the personal prerequisites of the students or could have been due to a combination of both. In light of the literature reviewed earlier in this article, we believe it is quite possible that the complexity of the exhibition may have resulted in some students being overwhelmed. As this can, as already described years ago by Jensen and Schnack (1997), lead to paralyzing and preventing action rather than encouraging it, it might be possible that the exhibition visit dimmed some students' initial assessments of their willingness to act. It may also be that students, during their exhibition visit, have gained a more realistic picture of the effort or cost behind each action and re-assessed their personal capability to do so, and adjusted their willingness to act accordingly (Steg et al., 2014). And indeed, the challenge of presenting complex issues in an understandable and motivating way that does justice to their complexity *without* denying the effort required to address them is well-known in the communication of SSI issues, particularly in the context of climate change (Moser, 2010; Howarth et al., 2020). Therefore, while we believe that the approach explored here is promising, we also believe that further research is needed to shed light on interindividual differences in how people perceive and use information (Longnecker, 2016) and their response to exhibitions on complex SSI topics. This knowledge will help future efforts to communicate such complex SSI topics, particularly in museums, in a way that broad audiences are able to make use of it (Lackner et al., 2019). Further results of this study indicate that student's overall willingness to act pro-environmentally after their exhibition visit is dependent on their prior conceptual energy knowledge but not on

students' interest in the topic of the energy transition, when controlled for student's overall willingness to act pro-environmentally prior to their exhibition visit. This does not align with previous research findings that typically identify interest in a topic as a good predictor of engagement for the learning topic and learning (Renninger et al., 1992; Rotgans and Schmidt, 2017; Carman et al., 2021). However, it seems possible that in our data the lack of effect for interest might be due to interest being moderately correlated to prior overall willingness to act (T1) which was included as a covariate when investigating the effect of interest and knowledge on overall willingness to act after the exhibition (T2). Interestingly, students' conceptual energy knowledge positively influenced their overall willingness to act pro-environmentally after the exhibition visit, even when controlling for prior willingness to act. This confirms our expectations and is in line with findings stressing the importance of prior knowledge (e.g., National Academies of Sciences, Engineering, and Medicine, 2018) and the prominent role that conceptual energy knowledge should play in energy literacy (Chen et al., 2014; Nordine, 2016; U.S. Department of Energy, 2017). Prior research shows that learning experiences in exhibitions are generally perceived as more meaningful when the fit between the exhibition and visitors' personal characteristics is high (Bamberger and Tal, 2008, p. 4). Thus, we assume that students with higher conceptual energy knowledge were better able to make use of the exhibition, resulting in an overall change in their willingness to act. This finding ties in well with the assumption that CEK might be generally useful for interpreting the complex systemic and cross-disciplinary information students were provided with during their exhibition visit (Chen et al., 2014). From an identity perspective, it could be that students who acquired more conceptual energy knowledge in school were more likely to have seen themselves as an "energy person" from the start (Brickhouse et al., 2000; Hazari et al., 2022). In both cases, students would have felt more competent during their exhibition visit in dealing with energy transition-related information and in their role as actors in the energy transition. Overall the study findings indicate that conceptual knowledge as acquired in school (Chen et al., 2014; Duit and Neumann, 2014; Nordine, 2016; U.S. Department of Energy, 2017) is beneficial and important for making use of free-choice learning activities in socio-scientific contexts for instance in museum exhibitions.

Even though the effects of the change in student's overall willingness to act (T2 – T1) and the influence students' conceptual energy knowledge had on student's overall willingness to act after their visit to the exhibition were small, they are significant for the field for two reasons. First, the indication that the perception of different personal perspectives, as well as addressing the visitor as a complex person, provided sufficiently broad gateways to connect with and develop students' ecological social identity, can provide practical guidance for further exhibition development. For the result shows that it can be beneficial for museums that want to motivate people to act to address "identity" in their exhibitions and to create explicit connecting points for its further development. Second, the albeit small influence of conceptual energy knowledge on students' overall willingness to act after their exhibition visit still shows, that successful exhibition design does well to take school knowledge into consideration and thus potentially further supports the synergistic use of formal and informal learning venues.

4.2. Limitations and implications for future research

This study has several limitations that we would like to address with recommendations for future research. The first limitation is that we did not experimentally vary different elements of the exhibition. As a result, we can only theoretically argue but not provide empirical evidence of which specific design elements of the exhibition contributed to the observed change in students' overall willingness to act. Future studies might include this experimental variation in order to provide evidence and guide museum practitioners in designing exhibitions. Second, we assume identity work as the mechanism explaining the observed change of willingness to act prior to after the exhibition. However, we did not check this assumption by including corresponding covariates (e.g., self-efficacy or information derived from interviews). Future studies should remedy that and shed further light on how identity work unfolds when students engage with different elements of an exhibition in an out-of-school free-choice learning environment. In addition, we also had a considerable number of students in this study whose overall willingness to act pro-environmentally decreased after their exhibition visit. Unfortunately, the design of this study keeps the exploration of the reasons for this in the realm of speculation within this article. We, therefore, would like to recommend for future studies to include variables that measure more personal characteristics of visitors as well as instruments that allow to measure visitors' level of engagement, stimulation, or possible overstimulation during their exhibition visit and gathering more detailed information about what exactly they did in the exhibition. This could for (1) allow for exploring interindividual differences in how people react to and make use of an exhibition (for instance *via* cluster analysis), and (2) eventually tie those differences to concrete elements of the exhibition. Finally, although intentions to act are still the strongest predictors of behavior we have (Hines et al., 1987), and some of the necessary behaviors to accelerate the energy transition are nearly impossible to observe, future studies could still enhance their measurement of pro-environmental behavior by, i.e., including a follow up that extends "beyond the site itself" (Ballantyne and Packer, 2009, p. 5) allowing to investigate in how far these might actually transfer to students' "real life."

4.3. Conclusion

In this study, we set out to find out more about how to communicate the importance of the energy transition to adolescents and foster their participation in it. For this, we investigated how a modern museum exhibition that provides students with opportunities for environmental identity work has an impact on students' overall willingness to act pro-environmentally. We found that students' overall willingness to act was higher after their visit to the exhibition compared to before. This change in overall behavioral tendency could not be traced to changes in specific behavioral indicators, but rather emerged on an aggregated level. In other words, the individual pieces of behavioral intentions add up to more on an overall level of students' behavioral intentions than just their sum. This ties in nicely with the holistic approach of the exhibition which provided students with a broad range of opportunities for identity work, resulting in the

observed change of overall behavioral tendency. Since we as a society rely on fostering the development of complex multifaceted competencies like energy literacy in students for them to be able to confront wicked problems and socio-scientific issues such as the energy transition, we have to design our learning environments to foster those competencies not only in a linear and granular but further in a comprehensive and holistic way.

Data availability statement

The raw data supporting the conclusions of this article will be made available by corresponding author, without undue reservation.

Ethics statement

This study was reviewed and approved by the Bavarian Ministry of State for Education and Culture, Science and Art subject to compliance with the Ministry's requirements before it was conducted. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

SK was the principal investigator and author, responsible for conducting the empirical study, coding of data, and writing the first draft of the manuscript. DL and JN participated strongly in the conception and design of the study as well as the conception of the manuscript and the data analyses. MK significantly contributed to the process of data analysis and interpretation of results as well as the writing process of this manuscript. DL, JN, and MK participated equally in the manuscript revision and approved the manuscript to be considered for publication. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2023.1081633/full#supplementary-material

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