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Promoting Pre-service Physics Teachers' Science Media Literacy

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Abstract
The *Science Media Literacy (SML)* framework aims to prepare students for the rapidly changing mediascape, where the task of gatekeeping is increasingly transferred to consumers. In this explorative study we reconstructed pre-service physics teachers' ideas of the communication of science in society and the strategies they apply when examining a scientific claim made in social media. Furthermore, we investigated to what extent *SML* could be promoted during an intervention. Results indicate that initially held ideas had been challenged and their strategies for dealing with a scientific claim in public were shifting from epistemic to sociological.

Keywords
Nature of Science, Science Media Literacy, Media Literacy, Science Communication

Theoretical Background and State of Research

Citizens need "the ability to engage with science-related issues and with the ideas of science" (OECD, 2015), which is the essence of *Scientific Literacy*. In addition to scientific content and methodological knowledge, adequate ideas about *Nature of Science (NOS)* are of utmost importance for reaching this goal (Holbrook & Rannikmae, 2007; Albe, 2008; Abd-El-Khalik, 2003). Therefore, *NOS* has been integrated into numerous curricula e.g., the *Next Generation Science Standards* (2013), where several aspects of *NOS*, such as the tentativeness of scientific knowledge, are listed. The German *Bildungsstandards* (Kultusminister Konferenz, 2020) do not include *NOS* explicitly but nevertheless give implications for learning about *NOS* e.g., when asking students to understand how science affects our environment materially, intellectually and culturally.

In everyday life students encounter science in a mediated way and hopefully based upon reliable and relevant expertise. The latter is often not the case (e. g., *false expert problem* addressed by Oreskes & Conway, 2010; Allchin, 2021), since over the past two decades the mediascape has rapidly changed towards an increasing number of online sources exhibiting systematic differences compared to the role of traditional (print) media as gatekeepers (Kozyreva et al., 2020). This development has a compelling impact on science communication and the resulting challenges must be taken into ac-

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count in science education. When striving for successful social participation, it therefore has to be considered how scientific knowledge is publicly communicated, mediated and transformed through the new media environment (Höttecke, 2020). The *Science Media Literacy (SML)* framework (Höttecke & Allchin, 2020) takes all of this into account by aiming to reconceptualize *NOS* within a science-in-society framework. In doing so, conventional *NOS* concepts are being complemented by new concepts (e.g., Allchin, 2011) that take account of social-communicative practices and mechanisms of control and critique within the scientific community (e.g., peer review). Covering a set of competencies that include reflecting one's own role when consuming (social) media and knowledge about the changing role of the media, *SML* enables students to take a bird's eye view of science and its communication in society.

Challenges of the rapid change in the media arise in particular against the background of social media becoming an increasingly popular source of scientific information, which especially applies to adolescents (Höttecke, 2020). Due to psychological effects (e. g., *confirmation bias*, Geschke et al., 2019) as well as a lack of control mechanisms, social media contribute to a growing number of non-scientific claims regarding socio-scientific issues, such as climate change or vaccination. The process of gatekeeping, which in traditional (print) media mitigates the epistemic dependence of laypersons on expert knowledge (Hardwig, 1985), is absent in social media. Gatekeeping instead is rather transferred to the individual consumer. Hence, *science media-literate* students should be able to make reasoned decisions about whether any claim publicly made can be considered as scientific and trustworthy. In addition to epistemic strategies, sociological criteria deriving from new *NOS* concepts (Allchin, 2011) represent a promising but so far neglected approach in this context (Zemplén, 2007).

An implementation of didactic concepts in secondary school education requires an implementation of these concepts in teacher training. Since students' naïve ideas about the *NOS* could be traced back to inadequate ideas on the part of teachers (Chen et al., 2015), implementation in teacher training is an important task. Firstly, in the case of *SML*, teachers need to understand how science is communicated in society including the particular roles scientists, the media and the public play. They should be aware of the respective actors' underlying logic and interests as well as the transformations of scientific knowledge. Secondly, to teach strategies to school students, teachers themselves need to have a wide variety of fruitful strategies at their disposal which they can apply to make reasoned decisions about the credibility of claims. These include epistemic strategies concerned with the plausibility of knowledge claims and sociological strategies, which involve making a judgement of trustworthiness based on sociological criteria (Bromme & Kienhues, 2014; Zemplén, 2007). Sociological strategies are particularly important if one's own scientific expertise is not sufficient to make a plausibility judgment. Reflecting on one's own epistemic dependence therefore plays a pivotal role in selecting and applying a variety of coping strategies.

Previous research has shown that pre-service physics teachers hold numerous inadequate ideas of the conventional *NOS*, which concern, for example, the existence of a single scientific method and the tentative nature of scientific knowledge (e.g., Lederman, 1992; Irez, 2006; Höttecke & Rieß, 2007). Studies on ideas about the transformation of knowledge in the course of science communication as well as on strategies for the verification of knowledge claims represent a hitherto unexplored field. Our investigation aims to provide a starting point for future research in this field.

Research Questions and Study Design

This study aims at answering two explorative research questions both concerned with SML:

(RQ1) Which **ideas about the path of scientific knowledge**, starting from research to the public, can be identified among pre-service physics teachers (a) and how do they change due to an intervention? (b)

(RQ2) Which **strategies do pre-service physics teachers apply** to verify scientific claims (a) and how do they change due to an intervention? (b)

To answer these research questions, we developed an instrument to explore the *SML* of pre-service physics teachers. To answer (RQ1), an open-ended activity was developed: participants were asked to express their own under-

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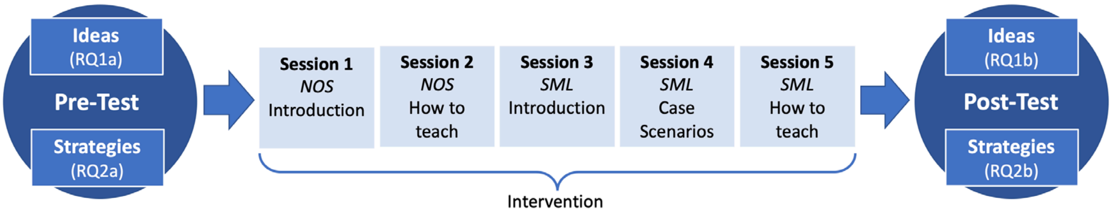

Figure 1: Study design. Pre- and post-test, each consisting of an activity concerned with ideas about the "path of scientific knowledge" as well as an activity which asked participants to apply strategies. The intervention is given by five seminar sessions dealing with NOS and SML.

standings by making a drawing of the "path of scientific knowledge" from scientific research to the public. Both a starting and an end point of such a path were given and located on the left and right margins of an otherwise blank sheet of paper. The space in between had to be filled by the participants. The "path" serves as a metaphor for initiating and structuring ideas (Henke & Höttecke, 2013). A drawing sample from the post-test data can be found in the appendix.

Based on an additional activity in which a scientific assertion had to be examined, we explored strategies participants in our study had applied to answer (RQ2). Participants were examining a diagram and a quote from a lecture about the Coronavirus and its impacts. The lecture was given by a scientist addressing lay people in a non-scientific setting. She presented data in a diagram to purposefully downplay the threat of COVID-19. Participants in our study were then asked to imagine themselves in a role of giving advice to a friend how to deal with this presentation. The activity was designed as being encouraging on the one hand, but not too directive on the other.

Our exploratory survey instrument was administered to a convenience sample of N = 15 pre-service physics teachers, who were all enrolled in a physics teacher preparation course (20 participants, 4th - 6th semester of Bachelor-program) at our faculty and voluntarily participated in our study. Our instrument was set up in a pre-post design, in which the intervention of five seminar sessions 90 min each was conducted between pre- and posttest (fig. 1). During the intervention, pre-service teachers were listening to lectures as well as doing various activities related to *SML* (e. g., Höttecke, 2021; Allchin, 2020). They were also engaged in open-ended discussions about *NOS* and *SML* and were analyzing case scenarios. Data comparison led to insights about pre-service physics teachers' ideas and strategies concerned with *SML* (RQ1a, RQ2a) as well as how they had changed (RQ1b, RQ2b). Data were collected June – July 2021. 11 pre-service teachers each participated in the pre- and post-test. Data were analyzed using a structuring qualitative content analysis (Mayring, 2015). Thereby, a theory- and data-driven coding scheme suitable to answer our research questions was developed.

Results

Regarding (RQ1a), out 8 of 11 participants mentioned science and the media as decisive stakeholders along a chain of information transfer from science to the public. However, communicative processes among scientists or media stakeholders and interest-driven actions (e. g. media striving for attention, scientists striving for credibility) were only mentioned incidentally by 2 participants. Accordingly, analysis of pre-test data led to the result that participants understand the "path of scientific knowledge" from science to the public primarily as a mere transmission of knowledge. The basic role of the media was acknowledged but appeared to be generally biased.

In the process of science communication, a rather passive role was assigned to the public. For example, 2 participants noted that opposing opinions among the public were merely a result of how media coverage was framed. This contrasts with a more adequate view according to which citizens actively choose their news sources and thereby shape information flow in society. Indeed, the sociological dimension of science communication between laypersons is highly influenced by the use of social media. Despite this, social media were mentioned by

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only one participant in the pre-test dataset. At the same time, 5 participants recognized an epistemic dependence of the public from scientific expertise in the pre-test.

Regarding science, both adequate as well as inadequate ideas were found. 4 participants showed adequate ideas regarding the tentative character of scientific knowledge in the pre-test. Nevertheless, very little attention was paid to interpersonal exchange and communication between scientists. This indicates inadequate ideas of participants concerning the high significance of team work and trust within the scientific community.

Post-test data indicated that initially held ideas had been challenged (RQ1b). This concerns social aspects of *SML*: the (international) exchange and communication between scientists was emphasized by 6 participants as a significant part of scientific knowledge acquisition versus only one participant in the pre-test. Scientists were addressed as persons by 7 participants versus 4 participants in the pretest, when the more abstract notion of "science" was predominant. Furthermore, 6 out of 7 pre-service teachers who participated in both pre- and post-test identified a more active role of the public instead of thinking about the public as a passive receiver of science. More precisely, the public was assigned the task of making decisions about which sources and which spokespersons in science to trust. Other ideas, however, were found to persist. These included the lack of consideration of social media as a significant source of information for the public. Post data also indicated that participants did not consider the scientific community's social control mechanisms (e. g., peer-review) to be an essential part of scientific research.

With regard to (RQ2a), we found participants in the pre-test primarily used epistemic strategies concerned with the scientific content at stake. Doing so, 6 pre-service teachers mainly focused on questioning and interpretating the diagram presented in the activity whereas 4 participants applied their scientific content knowledge about coronavirus. Strategies using sociological criteria hardly played any role in the pre-test. The trustworthiness of the scientist was addressed to some extent by 2 participants. However, it became apparent that this was done without application of certain criteria or justifications.

Post-test data indicated that the participants in our study used significantly more versatile strategies to examine scientific claims (RQ2b). In addition to epistemic strategies, 8 out of 11 participants also applied sociological strategies. These included checking the professional background of a person making a (non-)scientific claim. Some of the participants made rather specific suggestions: For example, 3 participants considered checking whether the scientist is indeed an expert in the scientific field (virology in our case) and emphasized the necessity of exploring the socio-academic network of the scientists under scrutiny (who she is collaborating with). Another sociological strategy is to relate the scientific claim made by the scientist to a scientific consensus in a wider community of scientists. 2 participants thereby clearly realized that the claim made by the scientist contradicted a widely held scientific consensus regarding the threat of the coronavirus. Furthermore, in the post-test 4 participants started reflecting their own epistemic dependence for example by explicitly designating themselves as laypersons concerning the given subject matter.

Discussion

SML as part of science education seeks to promote successful social participation by enabling citizens to make well-founded and reasoned judgments about scientific claims. The prerequisite for this is a perspective on scientific knowledge as being critically developed within social communities of expertise. Our exploratory intervention study was conducted with a sample of 15 pre-service physics teachers, all of whom were enrolled in a physics teacher preparation course. Our results indicate that *SML* was enhanced in the course of an intervention. Significant learning gains were evident with respect to the strategies used to verify scientific claims (RQ2). Participants extended their initially held epistemic strategies with sociological strategies. Thus, learning about the use of sociological strategies is an appropriate means to promote *SML*. Moreover, our data indicate that some inadequate ideas about the "path of scientific knowledge" could be challenged by the intervention (RQ1). Accordingly, the intervention provided adequate learning opportunities regarding *SML* with special focus on science as a social system of expertise and the active role of the public in science communication. On

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the downside, psychological effects of social media and sociological control mechanisms within the scientific community were hardly addressed by participants. This could be an indication that these topics should have been addressed more intensively without presuming any prior knowledge. Another learning objective which was not fully achieved is profound knowledge about the specific interests and approaches of the individual stakeholders within science communication. For this purpose, it is necessary to develop and test further suitable learning opportunities. A promising approach can be role play arrangements as indicated by recent research (e. g., Roozenbeek & v.d. Linden, 2019).

The empirical study presented here is subject to limitations. The sample size is rather limited but nevertheless allowed an initial exploration of how *SML* might be fostered in teacher education. There was only a period of three weeks between pre- and post-test, which increases the chance of learning gains due to the test instead of the intervention. Moreover, the stability of learning gains was not checked by a follow-up test. In addition, participants' ideas had to be derived from their drawings and written comments in a highly inferential manner and without the chance of any communicative validation. However, the metaphor-based drawing activity turned out to be a fruitful stimulus for generating ideas. In future research, the drawing activity should be followed by a focus interview based on the drawing. This would allow further, deeper, and more refined insights into participants' ideas about the "path of scientific knowledge" from science to the public.

Overall, our results indicate that pre-service physics teachers' *SML* could be promoted as a result of a short-term intervention. A remarkable shift from only epistemic strategies to additionally applied sociological strategies was observed. Moreover, our results provide guidance for the development of further learning opportunities on the concept of *SML*, which are supposed to be based on students' ideas as well as prior knowledge. Future research should take a closer look at how teaching and learning about *SML* as part of science education can enable students to successfully apply a variety of strategies to verify (non-)scientific claims.

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Appendix

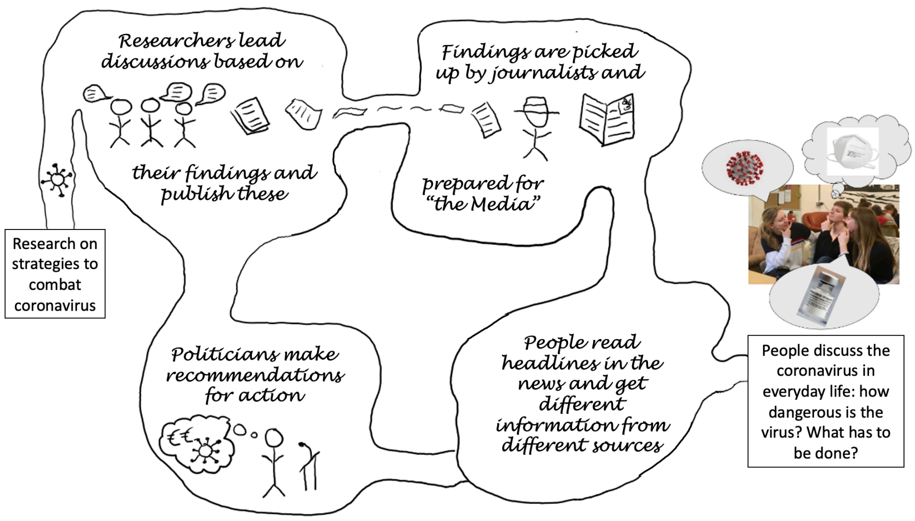

Figure 2: Drawing sample of the "path of knowledge" from the post-test data. The square boxes and the contents inside of these as well as the colored image with speech bubbles were given. Anything else was drawn by the participant. To preserve anonymity the drawing was traced and the handwritten was retyped. Additionally, the instrument and the data were translated from German to English.

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