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Modern Technology in Geography Education—Attitudes of Pre-Service Teachers of Geography on Modern Technology

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Abstract: In this study, we focus on teachers' attitudes to compare and evaluate their ability and readiness to implement technology education in geography lessons. First, the lack of suitable measuring instruments for our intent was identified, and we thus attempted to develop the Modern Technology Attitude Index (MTAI) for remedy. An exploratory factor analysis helped to identify three distinguishable dimensions that depict areas of intimidation (INT), loss of control (LOC), and benefits and easement (BAE), with or through modern technology. The scales were then applied to German university students (n = 357). As a result, the pre-service geography teachers (n = 72) showed higher scores on the affinity scale than on the two aversion scales. Their subject-specific interest correlated negatively with *intimidation* and positively with the perceived *benefits and easements* of modern technology, while the perceived *loss of control* showed no significant correlation. This allows for the conclusion that the subject's technology-related interest has an influence on cognitive and behavioral attitudes, while this is not the case for affective ones. Further, there are indications that the much-discussed gender gap in technology topics might particularly be related to people's affective attitudes, while cognitive and behavioral dimensions seem not to be affected. Differing results in other studies on whether the gender gap still exists or not could be due to the fact that, in addition to growing social awareness and a generational change, the measuring tools used may have not yet been able to depict a sufficiently diverse range of attitudes.

Keywords: technology education; modern technologies; geography teacher education; attitude-study; factor analysis

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1. Introduction

Two phenomena in particular are increasingly affecting life on our planet and are followed by long-term consequences and effects on societies and the environment: Together with climate change, environmental degradation with the loss of biodiversity, and the resulting ecological and social crises [1–4], humanity is facing a constantly accelerating technological progress and the associated digital shift in society [5–7]. The latter might harbor social and ecological risks itself, but also brings great potential for solving some of the core problems of our time [8–11]. Moreover, this is a core concern of geography and geography education when it comes to the major challenges facing humanity in the context of global change.

In scientific practices, the value of modern technology (MT) for geographic research has long been recognized and by now is inevitable. Modern climate and ecological models depend on automatically measuring and communicating sensor networks and big data approaches with the use of artificial intelligence to gain a more comprehensive spatial understanding of the functions, interactions, and development of complex systems [12]. Geographical information systems (GIS) have mostly replaced the use of print media and maps in science and applied areas [13,14], even if they continue to be used in school education. Spatial analyzes have reached a new level through global positioning systems

(GPS) and remote sensing technologies, such as satellite-based or airborne surface scans at any scale [15].

MT, along with digitalization, has also conquered most people's professional and educational lives, most recently reinforced by the COVID-19 pandemic [16]. This also results in new professions with special demands on the skills and knowledge of current and future generations.

MT has also become an indispensable element of societies around the globe [17]. People live in Smart Homes equipped with the latest high-tech gadgets for more comfortable and efficient living, while digital entertainment, information, and communication are permanently available via global data networks [18,19]. Municipalities are developing fully networked cities based on the example of Industry 4.0 [20], where full automation with sensor networks and intelligent control algorithms has proven to be advantageous for many reasons [21]. This makes the entire supply system of a city, as well as its mobility structure, just as smart as the intelligent vehicles that move in it [22].

Most technology innovations can come with both risks or negative effects on the environment and society as well as the potential and the opportunities that arise with them. Currently, technology development and production are partially interlinked with the exploitation of natural resources and human labor and the use of immature disposal or recycling strategies [23,24]. Furthermore, the appearance of new technical aids has permanently changed the way how people cope and interact with their natural and social environments [25,26].

The fact that people are confronted with technology on a daily basis does not automatically mean that everyone has now become a sovereign and responsible user [7,11,27].

Nevertheless, the use of MT has the potential to cope with some of the current social and ecological challenges and offers many opportunities for the sustainable development of our future [10,28]. However, it would be wrong to just delegate the responsibility of solving today's environmental problems to technology without a literate society that has been educated and enabled to use it [7,29,30].

Thus, basic technological and digital competencies must take the place of a predominant digital and technological distance in the population [31,32]. To maintain or even facilitate a technologically literate ability to grasp, understand, and assess the potential of MT in social contexts, having an emancipated attitude for their sensible use is required [9,33,34].

Meanwhile, in schools, technology education (TE) is still mostly limited to specific educational formats or subjects. In the USA, the UK, and Australia, it is, for instance, the subject compound of science, technology, engineering, and math (STEM); in Malaysia, it is design and technology (DNT) and in German schools, there is math, informatics, natural sciences, and technology (MINT) [35–37]. Geography in Germany is not a traditional MINT or STEM subject, although there are overlaps. Examples include digital geomedia and contents such as GIS, aerial and satellite photographs, or climate data and climate change. These are topics and methods of geographic education (e.g., German educational framework) [38] that are directly connectable to STEM contexts. GIS, for example, is often required in geography curricula and frameworks in Germany, e.g., educational standards in geography for the intermediate school certification [38]. At the same time, there are various teaching materials for GIS in geography teaching [39,40], as well as GIS is discussed for higher education [41]. Furthermore, it is geography that, unlike other subjects, provides a framework from the outset to teach traditional science and MT in combined approaches [38,42]. Therefore, geography lessons bear a high potential to converge TE by not only keeping technology as an educational medium in the classroom but as an object of its content that needs to be critically examined [38,43].

It is a main focus of geography to recognize, understand, and evaluate the central economical, ecological, and societal challenges of mankind. Therefore, like no other subject, geography has the potential to capture and address the constantly evolving, technologically framed human-environment relationships in all their complexity.

Ultimately, however, the quality of a lesson is very much determined by the teacher [44]. Successful teaching for TE as an inclusive element of geography does not come from the mere existence of technologies in the classroom; the active involvement and support of teachers are crucial to foster students' competencies for the appropriate use of MT [35].

> *Teachers who are expected to educate their students, as highly qualified and ethically sensitive individuals in technology and environmental issues [that have emerged in recent years] should themselves be sensitive to these issues.*
>
> (Ceyhan and Sahin 2018, p. 2) [45]

Therefore, teachers need to be capable of assessing and exploiting the profound possibilities that technologies can provide for an educational process [43]. Personal values, convictions, and attitudes affect those capabilities and eventually the learning outcome of the students [44]. Therefore, to ensure that technology is treated as a high-quality educational subject in geography lessons, it is essential to take a close look at the teacher's dispositions.

In order to relate the role of geography teachers to the topic of societal technological literacy in geography for higher education and to assess and assure the quality of their practice, further research on teachers' attitudes towards technology is needed.

2. Theoretical Background

Kunter et al. (2011) describe the teacher as the central determinant of school success. In addition to motivational orientations [44] and professional knowledge [46], in the competency–theoretical approach of professionalism in the teaching profession, attitudes are particularly important dimensions of the professional competence of teachers [47].

In people's mindsets, attitudes work like filters for new experiences and determine people's behavior [48–50]. Teachers' attitudes, in particular, not only determine their own way of thinking and acting but even more influence the knowledge, attitudes, and behavior of their students [51]. Studies with science teachers indicate that their attitudes towards the natural sciences have an impact on the attitudes of the students [51]. Accordingly, teacher convictions are a central aspect of teacher professionalism [44]. Westerback assumed already in 1982 that there was a positive correlation between teachers' attitudes toward their subjects and their professional knowledge. In later studies, it was found that individuals who have a positive attitude towards a topic are more likely to seek additional information about it than those who assign a topic area only low relevance [52,53].

In general, attitudes are latent constructs that can be divided into cognitive, affective, and conative response behavioral dimensions [54]. A cognitive dimension of technological attitudes could, for instance, relate to the conscious exercise or loss of control on or with technology [55]. Other researchers describe perceived control as a separate, fourth dimension of attitude [56,57]. In our case, the presence or absence of control then contributes to the overall set of attitudes towards MT. It is similar to the contribution of affective elements; for example, for anxiety or trust that is evoked when the user is convinced of the technology's qualities or intimidated by its complexity [58,59]. Finally, behavioral components also come into play. This includes, among others, a perceived easement or difficulty evoked in or through the operation of MT [60]. Even if all three or four dimensions cover different psychometric areas, they do not necessarily have to be present as a unit, but can also shape the attitude as individual factors [54].

In the past, when it comes to examining technological attitudes in the educational context, the focus was much more on the learners than on the teachers. Researchers have identified students' attitudes towards technology as important factors influencing the success of learning about those topics and their behavior [43,61–65]. The most examined predictors for relations to technology in both groups are interest, age, gender, and the personal content focus [29,43,62,66–70].

Studies show a positive connection between teacher and student interest [70]. Reichhart (2017) [48] sees the teacher's interest also as a relevant factor influencing the teacher's attitudes. Interest in MT should therefore be considered in this context.

The age of the examined groups could also play an influential role depending on the target variable. For example, Kubiatko (2012) [71] found that older students have fewer positive attitudes towards geography than younger. In a meta-study from 2014, Potvin identified 24 international studies that reported a decline of either motivation, interest, or attitudes towards science and technology with age or school year. One year later, a study on French and Belgian students' attitudes towards technology came to the same conclusion [62]. Gómez-Trigueros et al. (2019) [29] found that future teachers show a lack of knowledge of certain technological concepts essential for their future teaching that differs with age.

Even if there are no known gender differences in attitudes towards geography [71], the gender gap in technological issues has been studied and discussed for years [65–67,72–74]. Despite all efforts at gender equality over the past decades, males, in general, seem to be more likely to perceive technology as something positive and even show higher levels of technological self-efficacy [66,69,75]. Studies with teachers only, however, show a more controversial situation. A recent study with 482 secondary teachers in India could not find any gender-specific differences in attitudes towards information technology [43]. The authors state that "rapid development and infiltration of technology in every aspect of the society to the point that technology has become an indispensable part of our daily lives, may have had an effect of equalizing difference between males and females." (Islahi 2019, p. 45) [43] Ceyhan and Sahin (2018) [45] came to a similar result for teachers' technological knowledge. Stöckert et al. (2020) [76], on the other hand, report findings of significant gender differences within pre-service teachers and other university students, when it comes to social aspects or interests related to technology.

The same group found that university students' social adjustment to technology differs significantly with their faculty affiliation. Ceyhan (2018) [45] also reports that teachers' ethical opinions about technology vary with their branches (e.g., science teacher or classroom teacher). This can be of interest since the natural science disciplines (e.g., math, informatics, physics, and biology) might be more closely related to technological topics than human and social subjects are (such as psychology, politics, or languages). Rosen and Weil (1995) [59] even report increased technophobia among secondary school teachers in the humanities subjects compared to others. Geography teachers are put in a position of exception since they have to combine perspectives from both areas and most of their disciplines, and therefore also should be open to technology-related issues.

A great variety of technical terms exists to describe a person's set of mind concerning certain topics [77–80]. In this study, we focus on attitudes, as for one, they are known to influence teachers' qualities (see above) [44,48,63], secondly, they can be expected to have a significant influence on students [48,51,81], and third, due to rather clear definitions, their measurability seems quite efficiently compared to other more abstract constructs, such as "orientations," "world view," or "beliefs" [77,80,82]. Therefore, the term attitudes seem suitable and tangible enough to conduct meaningful research.

According to Tücke (2003) [83], attitudes allow people to classify and evaluate their individual way of thinking, feelings, and experiences with regard to their environment. They are largely determined by the person's socio-cultural environment, knowledge, and beliefs [48]. Even the strength of an attitude can vary [54,84].

We assume that for the successful integration of TE in geography lessons, teachers' attitudes towards MT state an important factor [85]. In order to depict the respective characteristics and to describe differences and influencing parameters, it seems necessary to identify or develop appropriate instruments for the measurement of attitudes towards MT. Potentially suitable instruments were searched for, inspected, and assessed according to their actual suitability.

In summary, the following research gap can be derived: Despite the importance of MT for teaching geography, there is a lack of knowledge on teachers' attitudes toward MT for the subject.

This study aims to fill the gap and provide answers to the following questions:

(1) How can teachers' attitudes towards MT be measured and what attributes and qualities does the corresponding instrument have?
(2) What are the actual attitudes of pre-service geography teachers to MT?

3. Materials and Methods

To achieve the aim of the study, the following methodological steps were chosen. In a first step, existing measurement instruments and items were reviewed and evaluated for their suitability for use. In the second step, the suitable items were tested in mixed pretest procedures before they were used in the final step to measure the pre-service teachers' attitudes and compare them with peers of different ages, subjects, or types of graduation in a cross-sectional study.

3.1. Review of Measurement Instruments

When it comes to measuring teachers' attitudes towards MT, in particular, instruments are scarce. Some limit their research to certain technological areas or contexts such as information technologies [29,43] or social aspects of technology [66,76] or focus on the use of mobile devices [86] and computers only [74,87,88].

Tools to examine relations towards general technology used in educational settings mostly focus on the learners [62–65,68,89–92]. Two frequently used instruments here are the Pupil's Attitude Towards Technology (PATT) Scale [64,65,89,93], which was not developed for the target group of teachers and is therefore not very suitable, as well as the short Technology Questionnaire (sTQ, Marth 2019) [66], which, however, is less substantial as it depicts only two dimensions for this study. The few instruments used to examine teachers' relations towards technology, on the other hand, either focus on their sensitivity, intentions, interest, or thoughts [45,76,94–96], rather than the dimensions of their actual attitudes.

A compact scale that queries the most important dimensions of technology attitudes and can be used for adults, especially teachers in geography lessons, has yet to be developed. However, the valid Computer Attitude Scale (CAS) by Nickell and Pinto (1986) [74] fulfills the central requirements. Since its creation, the scale has proven itself in several international studies and different settings [97–99], and its alignment has already been successfully adapted once for the measurement of people's comfort with robots [100]. At the time of its development, computers could be seen as the central representative of MT and their increasing use in people's everyday life was aimed to be reflected from different perspectives in the items of the CAS. Even if later users of the scale report certain factors, e.g., "positive and negative attitudes toward computers" and "intimidation toward computers" supposedly being covered by the scale [99,101] the authors do not explicitly name any sub-dimensions. However, the creators discuss a substantial range of attitudinal reactions that should be reflected in their tool. They refer to positive aspects, such as the perceived ease of work and comfort, as well as critical points, such as anxiety and discomfort, that could be triggered by technology use. Finally, they developed a 20-item scale (eight positive and twelve negatives) that shows broad applicability and good internal consistency. Furthermore, none of the other instruments sighted (see above) seem to meet the requirements as well or be comparable in terms of their general validity with the CAS by Nickell and Pinto. Since they even suggested further validation and application of their scale in educational settings themselves, [74] it seems promising to pick up where they left off.

3.2. Survey

First of all, CAS by Nickell and Pinto was translated into the German language and the content of its items was adapted in line with the times and further purpose. A first version of the scale consisted, similar to the original instrument, of 20 Likert-scaled items, each with four possible answers: "fully agree," "tend to agree," "tend to disagree," and "strongly disagree". Before the actual investigation, the modified items were tested and optimized in two pre-testing phases in late 2020; first, with the help of cognitive techniques, e.g., think aloud, probing, and paraphrasing [102]. The sampling was composed of students from different age groups to citizens. The results showed high comprehensibility of the items in the cognitive procedures as well as a good fit to CAS by Nickell and Pinto. Subsequently, a descriptive statistical evaluation, including factor analysis, was conducted on the scale.

Finally, a total of 14 items within three subscales recording different dimensions of attitudes to MT were compiled. The factor analysis (see Results) confirmed the presence of three factors in the transformed scales. The newly created Modern Technology Attitude Index (MTAI) describes the affinities and aversions towards MT as:

- *Intimidation (INT),*
- *Loss of Control (LOC), and*
- *Benefits and Easement (BAE).*

After construction and pretesting of the MTAI, the complete measurement instrument included three parts:

1. The first part of the questionnaire consisted of questions aiming at the personal data of the students, such as age (AGE), gender (SEX), and specific data concerning their studies such as the count of semesters studied (SEM), the aimed type of graduation (TOG), and the field of science (FOS) they are studying.
2. In a second part, the respondents were asked to indicate their interest in the main topic of modern technology (MTI), each on a scale from 1–10. 1 equals "not interested" and 10 "strongly interested".
3. The third and final part aimed at the student's attitudes via MTAI.

3.3. Data Collection

The research presented in this article aimed to investigate and compare attitudes towards MT of German university students, with a focus on pre-service geography teachers. The methods are descriptive and based on quantitative data. $n = 357$ took part in an overall survey of all students at Philipps University, Germany. In a cleaned dataset, a total of 343 subjects could be analyzed by the use of their provided data. 209 female and 130 male (diverse genders (nd = 4) were also recorded, but could not be taken into account for the calculations due to matters of group size) participants were classified according to their field of science (FOS; as geography = GEO, natural sciences = NSC, or human and social sciences = HSSC) and differentiated according to the type of graduation (TOG; as TE = teacher, bachelor = BA, master = MA, or other, less common forms of study (such as "Magister" or "Staatsexamen," which can, for instance, be found in the disciplines of medicine and pharmacy in Germany) = Else). 139 studied geography (72 of them for teaching) and the other 197 (students with missing or no clear assignment (e.g., because of double enrolment), were recorded ($n = 7$) but excluded from this listing) other subjects in the humanities or natural science subjects (see Table 1).

The age of all participants ranged between 18 and 60 years (pre-service teacher geography, 19 to 32 years) and the semester between 1 and 13. For geography pre-service teachers, see Figure 1.

The data was collected in the winter of 2020/21. Therefore, an online survey was shared with the students via e-mail and, in the case of the institute for geography, also during lectures.

The questionnaire for an online survey was generated using SoSci Survey and was made available to users via www.soscisurvey.de (accessed on 12 May 2021). The free statistical software R and the additional program R-Studio, version R-4.0.2, were used for the cleansing of the data and the classic test theory, including factor analysis, for the development of the instrument [103]. Descriptive methods were conducted with the free statistical software JASP, version 0.14.1 [104]. The data presented in this study are openly available via the research data repository of Philipps University: https://data.uni-marburg.de/handle/dataumr/138 (accessed on 4 October 2021) [105].

Table 1. Frequencies of type of graduation (TOG).

FOS [1]	TOG	Frequency
Geography	Bachelor	61
	Else	0
	Master	6
	Teacher	72
	Total	139
HSSC [2]	Bachelor	27
	Else	18
	Master	15
	Teacher	28
	Total	88
NSC [3]	Bachelor	65
	Else	3
	Master	32
	Teacher	9
	Total	109

[1] field of science; [2] human and social sciences; [3] natural sciences; (cases with missing information or not clear assignment were excluded from this table).

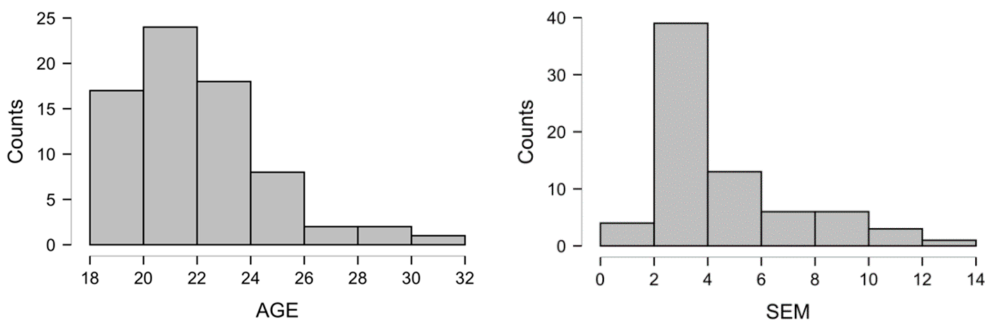

Figure 1. Age and semester of pre-service geography students.

3.4. Data Analysis

The MTAI was composed by using multivariate analysis techniques for item selection and identification of subdimensions through the examination of factor loadings, eigenvalues, and explanation of variance [106]. For further adjustments methods of classic test theory for assessment of difficulty, variance, and selectivity of the items and internal consistency by using Cronbach's Alpha were taken into account [107,108].

For the examination of underlying structures of the MTAI, an exploratory factor analysis (EFA) with oblimin rotation was chosen, for a sample of n = 343 [106,108].

EFA with oblique rotation was used because this makes it possible to undertake a data-driven exploration, considering the fact that latent variables might correlate and could contain some unexplained variance [63,106].

Additionally, the difficulty, selectivity, and variance of all items were examined and the results were used for a conclusive compilation of our instrument [107].

For the descriptive analyses in our study, the means of the final MTAI scales for each case were calculated as test values.

3.5. Scores

By convention, a level of statistical significance of alpha = 5% (=0.05) was determined for the analyzes. Each item was assigned a weightage ranging from 4 (strongly agree) to 1 (strongly disagree) for favorable items. The scales INT and LOC were defined to measure dimensions of disfavor, while BAE was measuring favor of MT. The attitude score of an individual was the mean of item scores on each scale.

To measure differences between several groups, separated field of science (FOS), or type of graduation (TOG) within the sample, the one-way ANOVA was used [109]. The fulfillment of the prerequisites, homogeneity of variance, and normally distributed residuals were confirmed with Levene's test and a quantile–quantile (QQ) plot [110–113]. A post-hoc test with Bonferroni p-value adjustment was used to identify any individual differences [111]. Since test mean values cannot be assumed to be distributed normally, correlations between AGE, SEM, and MTI were checked by the use of Spearman's Rank Correlation with the coefficient rho [110]. According to the above-named literature [29,62,69,71], AGE and SEM can be expected to correlate negatively with affinity and positively with aversion of MT, therefore a corresponding one-tailed correlation test was selected. For inspection of differences in gender, a Mann–Whitney U test was used since a deviation from normality had to be assumed [111].

4. Results

4.1. Quality of the Modern Technology Attitude Index (MTAI)

To answer the first research question—*How can teachers' attitudes towards MT be measured and what attributes and qualities does the corresponding instrument have?*—an adapted instrument should be developed. From the first 20-item-version of the MTAI, six items were removed due to reasons of low selectivity, too high or low difficulties, or lower and multiple factor loadings.

The factor analysis revealed a three-factor solution with clearly shaped dimensions which are also convincing in terms of content and fit into the psychometrical framework. The three dimensions are referred to below as the sub-scales *intimidation* (INT), *perceived loss of control* (LOC), and *perceived benefits and easement* (BAE) with or through MT.

The INT-factor, with an eigenvalue = 2.50, accounted for 17.8% of the covariance (see Table 2). Item loadings ranged from 0.70 to 0.91. The items defining this factor represent the affective dimension of intimidation through MT and contribute in a negative (aversion) direction to the MTAI. The second factor (LOC), with an eigenvalue = 2.07, accounted for 14.8% of the covariance. Item loadings ranged from 0.58 to 0.73. Those items depict the more cognitive dimension of control in relation to the use of MT, which also contributes negatively to the index. Items loading on the third and final factor (BAE) ought to represent the behavioral part of attitudes towards MT. They display the subject's affinity through perceived benefits and easement and therefore contribute positively to the MTAI. An eigenvalue of 1.87 and an explanation of 13.4% of the covariance, with factor loadings between 0.50 and 0.74, are achieved. The three factors together are able to explain 46% of the total variance in the sample.

Table 2. Factor loadings and variance of MTAI.

Abr.	Factor	Nr. of Items	Fact. Var. (%)
INT	Intimidation through MT	4	17.8
LOC	Perceived loss of control with MT	5	14.8
BAE	Perceived benefits and easement with MT	5	13.4
	Total Variance	14	46.0

The MTAI as a whole (Cronbach's α = 0.83) but also each of the three scales for itself show good internal consistencies (INT with four items, α = 0.87; LOC with five items, α = 0.79; BAE with five items, α = 0.72).

4.2. Geography Pre-Service Teacher's Attitudes on MT

To address the second research question—*What are the actual attitudes of pre-service Geography teachers to MT?*—the geography pre-service teachers are now considered.

Within the three dimensions of the MTAI, future geography teachers position themselves somewhat more positive in their attitude towards MT, as the average scores on the two aversion scales are lower (INT = 2.00; LOC = 2.69) than those on the affinity scale (BAE = 3.06).

The highest agreements are found in the BAE scale, with a maximum score on the items that state that *MT can eliminate a lot of tedious work for people* and *is responsible for many of the good things we enjoy* (BAE).

A minimum of agreement is particularly received by the statements that *MT is difficult to understand and frustrating to work with (INT)* and *soon our world will completely run by MT* (LOC).

Correlation testing with the pre-service geography teachers (n = 72) of content-related interest showed a moderate negative correlation between MTI and INT (ρ = −0.66), which is highly significant ($p = 9.28 \times 10^{-10}$). The correlations test between MTI and LOC showed no results with definite significance, while BAE shows a distinct positive correlation (ρ = 0.26, p = 0.03) with sufficient significance (see Figures 2 and 3).

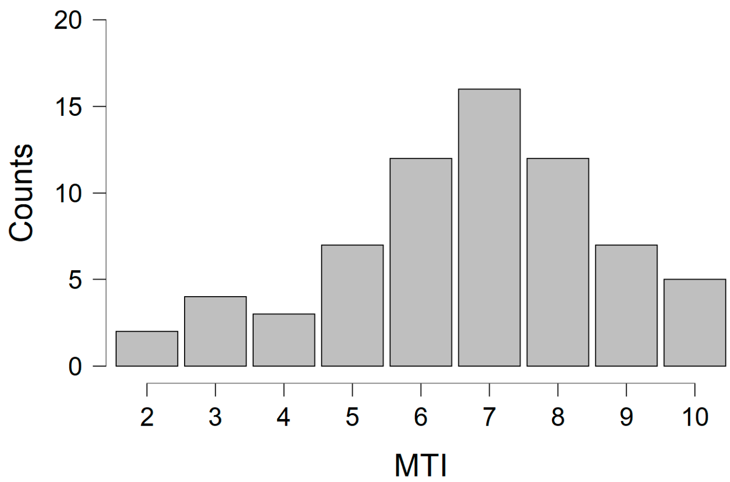

Figure 2. Distribution of geography pre-service teachers' interest in MT.

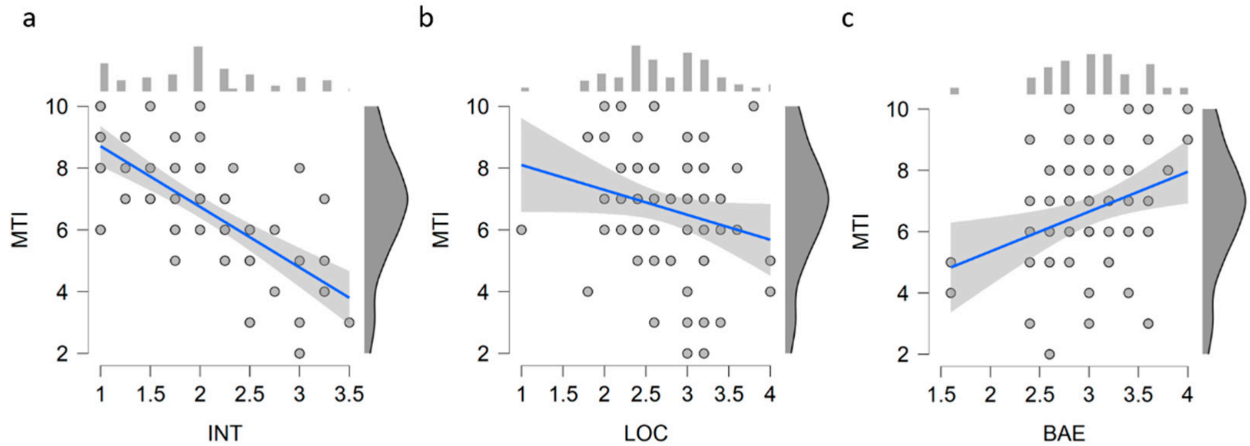

Figure 3. Correlations between (**a**) INT, (**b**) LOC (no significant correlation), and (**c**) BAE scores of geography pre-service teachers with their interest in MT.

Pre-service geography teachers do not show any significant correlations between either age (AGE) or semester (SEM) and any of the MTAI scales. The overall subject's AGE and SEM showed neither significant correlations with INT nor LOC. Only AGE correlates negatively with BAE (ρ = −0.23, p = 0.03), while SEM does not.

Differences in the gender of pre-service teachers of geography (n_m = 31 and n_f = 40) could be proven for the INT-scale (U-value = 800.00), which showed sufficient significance (p = 0.02) (Figure 4). This indicates that the psychological construct for affective aversions towards MT on cognitive levels measured by this scale might be pronounced stronger with females than males.

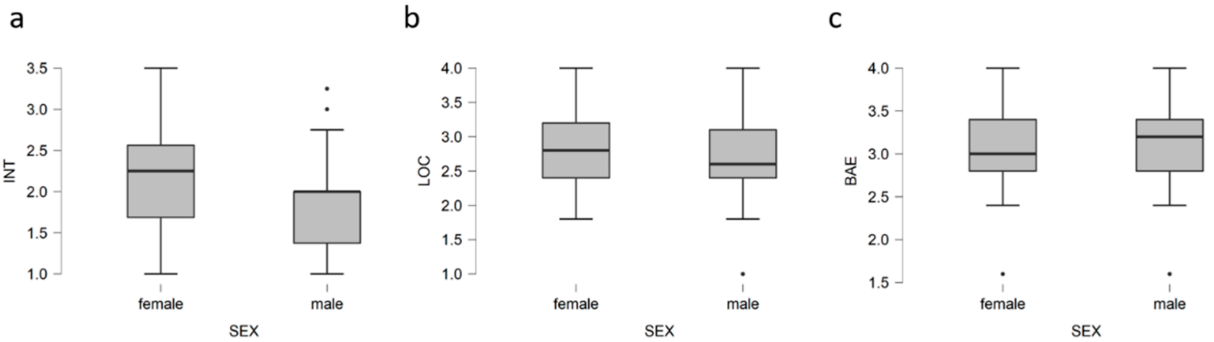

Figure 4. Gender distributions of geography pre-service teachers for their (**a**) INT, (**b**) LOC, and (**c**) BAE scores.

The same results for INT scores are achieved by overall gender (n_m = 130 and n_f = 209) (Diverse genders (n_d = 4) were also recorded, but could not be taken into account for the calculations due to matters of group size), with a U-Value of 16,704.0 and $p = 3.31 \times 10^{-4}$.

For LOC or BAE, no significant gender differences were found, neither for geography teachers nor in the overall cohort. Furthermore, the one-way ANOVA does not show any significant differences between the subject's field of science (FOS), in any of the three measured dimensions in the analysis of all students (n = 343). The same applies to the types of graduation. The comparison does not show any significant differences between the types of graduation (TOG) of the subjects in any measured dimensions of the MTAI.

5. Discussion

5.1. Discussion of Research Approach

This study aimed to answer the question—*How can teachers' attitudes towards MT be measured and what attributes and qualities does the corresponding instrument have?* Therefore, an instrument for quantitative measuring of attitudes towards MT was developed on the basis of existing items by Nickell and Pinto (1986) [74] and tested subsequently. The final instrument was used to measure the attitudes of pre-service geography teachers within three different sub-dimensions and to compare them with those of students from other subjects and forms of study. Even if no differences could be determined within any of these groups, some clear gender differences and influence of age and a connection between attitude and content-specific interest could be identified. The results will be discussed in the following light of the relevant literature.

5.2. Discussion of Sampling

The Philipps University of Marburg covers a wide range of different disciplines in the natural sciences, humanities, and social sciences so that a sufficiently wide sample could be assumed. Subjects for the study were recruited using a circular email that was sent to all students at the University of Marburg. In the geography department, there was additional verbal advertising for study participation in the lectures and courses.

Due to this type of recruitment, interested and motivated students mainly declared themselves willing to participate as test subjects. This fact could explain the low rates of participation, considering the total number of students in Marburg, and must be considered when interpreting the results.

The inequality of male and female test subjects is also an outcome of this advertising process and was not intended. When looking at our results, it should therefore be considered that the proportion of male and female participants does not represent the gender distribution of all students at the university or the department. Rather, the reason for this imbalance could be that there may be a greater willingness among women to participate in studies of this type [114].

Nonetheless, our sampling still meets the necessary empiric requirements and is sufficient to prove the suitability of our newly developed research instrument, on the one hand, and on the other, to gain valuable insights into the attitudes of pre-serve geography teachers towards MT.

5.3. Discussion of Instrument (MTAI)

The results show that the MTAI has several desirable properties. First of all, there is a clear separation of the underlying dimensions with relatively high and clearly differentiated factor loads on the items. The items correspond to the usual conventions in terms of selectivity, variance, and difficulty [108]. Compared with the original 20-item solution for computer attitudes, both the three sub-dimensions, despite their relatively small number of items, and the MTAI as an overall construct bare satisfactory internal consistency, as their Cronbach's alpha values show.

Since there is no other suitable reference tool for cognitive, emotional, behavioral, and/or control-related measurement in attitudes towards MT, our factors cannot be clearly assigned to these psychological dimensions either [54]. Still, a division into these areas is conceivable.

Yet, the alignment of the content-specific interest compared with our three scales helps to assign these to either the affinity or the aversion spectrum. The negative correlations of interest and *intimidation* and perceived *loss of control* due to MT indicate a measured aversion in these dimensions, as well as a positive correlation of the *benefits and easement* scale, which indicates a dimension of MT affinity. If one considers findings according to which interest is an implicit element of attitudes or at least strongly influences it, this is an important result [48,66]. That means that content-specific interests are predictors of content-specific attitudes for MT.

5.4. Discussion of Findings

Within the three dimensions of the MTAI, future geography teachers tend to position themselves more positively in their attitude towards MT, as the average scores on the two aversion scales are lower than those on the affinity scale. This can be interpreted as a positive result since it suggests a good precondition for the successful integration of TE in future geography lessons. Interestingly, neither the group of teachers from other fields of study (bachelor, master, else) nor the group of geography students from other subjects (natural sciences or humanities and social sciences) differ significantly in their scores. According to our findings, choice of the subject such as natural sciences, human and social sciences, or geography as some kind of cross-over does not show any influences on any level of the student's MT attitudes. In previous studies, differences in social or emotional attitudes towards technology were found, depending on the subject [45,76]. Additionally, for example, a higher technophobia was measured among teachers in human science subjects [59]. However, all those studies focused on in-service teachers only, who can be expected to most likely be at least a little older, more experienced, and maybe also already shaped by their subjects [45,59]. It is conceivable that young people, as in our case as a result of technologization, which is an integral part of most of their lives, are generally less biased and more open to MT than older generations, regardless of their professional interests. The same might apply to one's chosen type of graduation. Neither the attitudes of pre-service teachers, bachelors, masters, nor any other type of study differed significantly from the others. This, too, could be a sign that technology has arrived and is being accepted as an integral component at broad levels in younger society by now, and suggests a rather unconditionally positive attitude towards TE in this part of society.

It was not surprising that the two aversion scales showed negative and affinity scale-positive correlations with content-related interest. This supports the assumptions that we initially made based on existing theories of interest and motivational orientations by Reichhart (2017) [48] and Kunter et al. (2006) [47]. Thus, subjects who indicated a strong interest in MT also had higher scores on the affinity scale and lower scores on the aversion scales.

The pre-service geography teachers' age or semester did not show significant results in terms of correlation with their MT attitudes, which could be explained due to the rather small sample size. In the overall cohort, at least age correlates negatively with perceived *benefits and easement* with MT. This also fits into the above explained thesis that younger people bring an inherent openness to MT. Even if the values here are not very strong either, they get along with the results of previous studies in which a decrease in positive attitudes with increasing age was reported [69,71]. A correlation with the factors INT and LOC, however, cannot be found within any of our subject groups. If there was actually no relation here, it could be concluded that the expressions of the affective and cognitive attitude dimensions to MT might be independent of age groups. Since all three dimensions cover different psychometric areas, they can also influence attitudes as individual factors and correlate (or not) individually with other parameters [54]. This is also evident in the results on gender differences.

We found that female pre-service geography teachers as well as the other female students differ from the male, particularly in the affective dimension. They show significantly higher perceived intimidation than the males. Furthermore, no differences in gender can be identified in the other two dimensions (LOC, BAE). In many other studies, different aspects and psychometric areas of attitudes towards technology were examined, and here too the results with regard to the gender differences were ambivalent [43,66,72,76]. In the long series of studies on this subject, this now is the first that suggests that the differences between male and female attitudes may only be reflected on certain levels of attitude and not in an overall view. In the case of MT, it is the emotional or affective dimension that differs, while cognitive and behavioral levels do not differ. In addition to the selected aspect of the technology, the ambivalence of previous studies could then also be explained by the choice of insufficiently differentiating measuring instruments.

In order to close the gender gap, concepts should be created in teacher training that focuses on the affective, i.e., the emotional, dimensions of technology attitudes. If fears and concerns can be dealt with rationally during the studies, those affected may be positively influenced and can later pass this attitude on to their students. One approach to creating appropriate measures might be to make use of the influence of the content-related interest on attitudes.

We suggest further use and trials of the instrument. It seems likely that the MTAI can also be applied beyond the group of student teachers without ruling out any further adjustments or improvements. It would also be quite interesting to use the instrument together with similar or different attitude measurement tools to learn more about the dimensions of attitudes towards MT.

We see that our findings are not only relevant for the development and design of training for future geography teachers but also consideration from the perspective of sustainability education. Technology itself and its effects have become an integral part of our lives. It is expedient here to consciously recognize TE as a component of all areas of modern life and especially to incorporate it into school subjects, just as it happens with education for sustainable development [9,115,116]. After all, TE and ESD have a lot in common from which innovative teaching-learning concepts can be derived [35,117]. Hardly any subject is better suited to accomplish this task than geography.

5.5. Limitations of the Study

Limitations of our study that could not be avoided but should be considered are briefly summarized below.

With the choice of a bipolar four-point Likert scale, a compromise was deliberately made for this study. Whether a Likert scale should contain an even or an odd number of options or an "undecided" option is a matter of controversy [108,118]. We made our decision with the aim of maximum clarity and simplicity.

Some restrictions certainly result from the sample, which was made up exclusively of students from the University of Marburg. A larger, national, or even international sample could, for organizational reasons, not be implemented. If it was, it could have produced more meaningful or detailed results under certain circumstances. In particular, a larger group of pre-service geography teachers might have enabled the identification of possible correlations between age and attitude, as it was also found in the overall sample.

Low participation rates, even within the limited range of suitable subjects, might be due to the voluntary and mostly impersonal recruitment process, which unintentionally extracted the rather motivated and interested individuals. Just as unwanted was the imbalance between male and female test subjects in our sample, which unfortunately does not represent the population and is probably, at least in part, also due to the recruiting process [114].

Another caveat concerns the verification of our instrument. This comes with the lack of suitable comparison scales, which would have allowed better adjustments of our instrument, and maybe even help identify more dimensions of MT attitudes [54].

6. Conclusions

MT is playing an increasingly important role in our society. Responsible use of it based on a literate mindset should be the goal of TE, which, like ESD, should be an integral part of all levels of education. The subject of geography can be given particular importance due to its interdisciplinary positioning and strong application focus. That is why it is particularly the geography teachers of the future from whom we must expect an open and responsible attitude towards the role of MT in our society, in addition to the competencies to convey it along with the respective skills. With the MTAI, we created and successfully tested a practical instrument to depict teachers' attitudes towards MT within three different psychometric dimensions. With subscales for each of the dimensions, it covers a cognitive, an affective, and a behavioral range of attitudes related to MT. Next, we suggest that our instrument should be tested further in other settings and with different subject groups. We found out that the general attitudes of pre-service geography teachers towards MT are rather positive ones, and that they could partially be described by the participants' content-specific interests. A gender gap does not seem to be a fundamental phenomenon when it comes to overall MT attitudes, but it could be mainly due to the affective side of attitudes. Based on our results, better teacher training concepts can be developed in which the influence of the content-specific interest is used and the gender gap in MT attitudes can be counteracted on an affective level. In further research, the MTAI could also help evaluate the quality of new teacher training and further education programs or compare attitudes towards MT to other success factors of innovative educational concepts.

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