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Physics Teachers' Acceptance of Multimedia Applications—Adaptation of the Technology Acceptance Model to Investigate the Influence of TPACK on Physics Teachers' Acceptance Behavior of Multimedia Applications

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Although multimedia applications can undeniably have a positive impact on the learning success of students, they are not used by all physics teachers. The study presented in this paper examines the influence of technological knowledge of physics teachers on their acceptance behavior by adding TPACK of a physics teacher, as an additional variable to an adapted technology acceptance model (TAM). In addition, the TAM has been adapted to study the acceptance of multimedia applications of physics teachers in physics education. For this purpose, both, the design features were adapted and items were reworded to adjust them to the usage of multimedia applications in school and teaching context. While the first part of the study evaluates the changes of the TAM, the second part of the study deals with the extension of the TAM by the factor TPACK. TPACK acts as a superordinate moderator variable, which has a highly significant influence on the adapted TAM's design features "perceived ease of use," "perceived usefulness for pupils" and the "personal job relevance assessment." Interestingly, the results of the study show that TPACK has no significant influence on the "perceived personal usefulness" of multimedia applications in physics teaching. Nevertheless, the prediction of the acceptance behavior of multimedia applications in physics teaching can be improved by extending the adapted TAM2/UTAUT model by TPACK.

Keywords: TPACK, technology-acceptance-model (TAM), multimedia applications, physics teaching, teacher education

INTRODUCTION

Hattie (2008) discovered in his meta-study that teachers' professional knowledge in designing appropriate lessons have a major impact on their students' performance. The current conceptualizations of teachers' professional knowledge are based on Shulman's taxonomy from 1987. Shulman distinguished mainly between the content knowledge and the pedagogical knowledge and worked out the pedagogical content knowledge as "the special amalgam of content and pedagogy" (Shulman, 1987, p. 8).

Since then, many conditions have changed. Today we live in the information age, where smartphones and other devices provide access to information anytime, anywhere. In recent years, a wide variety of information technologies has found its way into everyday life of students and teachers. To face this rapid social progress, schools have to adapt. This development can also be determined by the change in the classroom itself (Behrens and Rathgeb, 2017). Teaching is evolving from a teacher-centered lesson to a more student-centered lesson (Lee et al., 2009), which mostly requires a significantly higher level of technology use. While teachers worked almost exclusively with chalkboard, books and overhead projectors a few years ago, today they have to be able to confidently deal with tablets, smartphones, document cameras and projectors. Additionally there are innumerable software products for desktop computers and handhelds. Especially in physics, teachers need electronic measuring systems, simulations and animations to perform experiments and explain connections. For some years, smartphones and tablets, which require even more skills from a teacher, have been added as further innovative experimenting devices (Kuhn and Vogt, 2013; Vogt and Kuhn, 2013; González and González, 2016; Crompton et al., 2017; Strzys et al., 2017; Thees et al., 2017; Bano et al., 2018). All these technologies require additional skills for purposeful application in the classroom, which in turn requires knowledge of the technologies to be used.

Technological, Pedagogical and Content Knowledge (TPACK)

Koehler et al. (2014) discuss that topic by further developing the PCK theory into TPACK framework (also: Mishra and Koehler, 2006) in order to articulate and improve teachers' use of technology for teaching and learning. Since introducing the framework, researchers, and teacher educators have adopted TPACK as a tool for understanding and advancing preservice and in-service teachers' abilities to integrate technology into their instruction (Graham et al., 2009b; Baran et al., 2011; Mouza et al., 2014; Crompton et al., 2017; Claro et al., 2018).

TPACK consists of 7 different knowledge areas:

The pedagogical knowledge (PK) and the content knowledge (CK) as well as the pedagogical content knowledge (PCK) are already known from Shulman (1986). Adding the technology knowledge (TK) results in new intersections, the technology-specific content knowledge (TCK), the technological-pedagogical knowledge (TPK) and the technological pedagogical and content knowledge (TPACK). The technology knowledge (TK) in the context of integrating technologies in school includes digital technologies such as desktop PCs, laptops, tablet PCs, the Internet, and software applications. The TK also includes knowledge that enables the user to change the purpose of an existing technology to fit into a learning environment enhanced by this technology (Mishra and Koehler, 2006; Koehler and Mishra, 2009; Koehler et al., 2014). The technology-specific content knowledge (TCK) refers to knowledge about how technology can be used and what it offers to deliver new content. For example, digital animations allow students to get an idea of what is going on inside a dipole and what meaning electrons have for it (Mishra and Koehler, 2006; Koehler and Mishra, 2009; Koehler et al., 2014). The technological pedagogical knowledge (TPK) refers to the needs and constraints of technology as the enabler of different teaching methods (Mishra and Koehler, 2006; Koehler and Mishra, 2009; Koehler et al., 2014). Finally, the technological pedagogical and content knowledge (TPACK) refers to the knowledge and understanding of the interaction between CK, PK and TK when using technology in the teaching-learning process. It provides an understanding of the complexity of relationships between students, teachers, content, methods, and technologies (Mishra and Koehler, 2006; Koehler and Mishra, 2009; Koehler et al., 2014).

Although or perhaps because of the fact that there are also critical voices about TPACK (Graham, 2011), TPACK framework has evolved. Work on TPACK framework initially focused on developing a basic definition (Mishra and Koehler, 2006), explaining and interpreting the construct, and discussing the properties of TPACK and its use in different content areas. Meanwhile, TPACK has reached a second generation, focusing on using the construct in research and development projects (Thompson, 2013; Bibi and Khan, 2015; Kiray, 2016; Claro et al., 2018). In this sense, TPACK is used in this study as a tool for describing attitudes and skills of teachers. Furthermore, because of the enormous bandwidth of new technologies, this study only deals with the field of multimedia applications in physics teaching at schoolüü, manage and cross-link multimedia content, like simulations and animations of physical content, movies of physical experiments, merge content of different webpages and simple methods to check the learning success. Examples of such applications include Learning Management System (LMS) such as Moodle, Schoology, Canvas LMS or the LMS PUMA@LMU developed at the LMU Munich.

Technology Acceptance Model (TAM, TAM2/UTAUT)

One goal of modern education must be to prepare students for life in a digital world. Of course, this requires a suitable use of digital media in the classroom. The use of digital media, though, depends especially on how much teacher accept it. One way to examine the teachers' acceptance of multimedia applications is the Davis Technology Acceptance Model (TAM) (Davis, 1986, 1989; Davis et al., 1989) and its extension to the TAM2/UTAUT model (see **Figure 1**) (Venkatesh and Davis, 2000; Venkatesh et al., 2003). The TAM is an adaptation of the Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1975, 1977), which in turn is a theory developed in the field of social psychology that explains a person's behavior through their intentions. Therein, the intention is determined by two constructs: first, the individual attitudes toward the behavior and second the social norms describing the belief that specific individuals or a specific group would approve or disapprove of the behavior.

While TRA was theorized to explain general human behavior, TAM specifically explains the determinants of computer acceptance that are general and capable of explaining user behavior across a broad range of end-user computing technologies and the user population (Davis et al., 1989). The

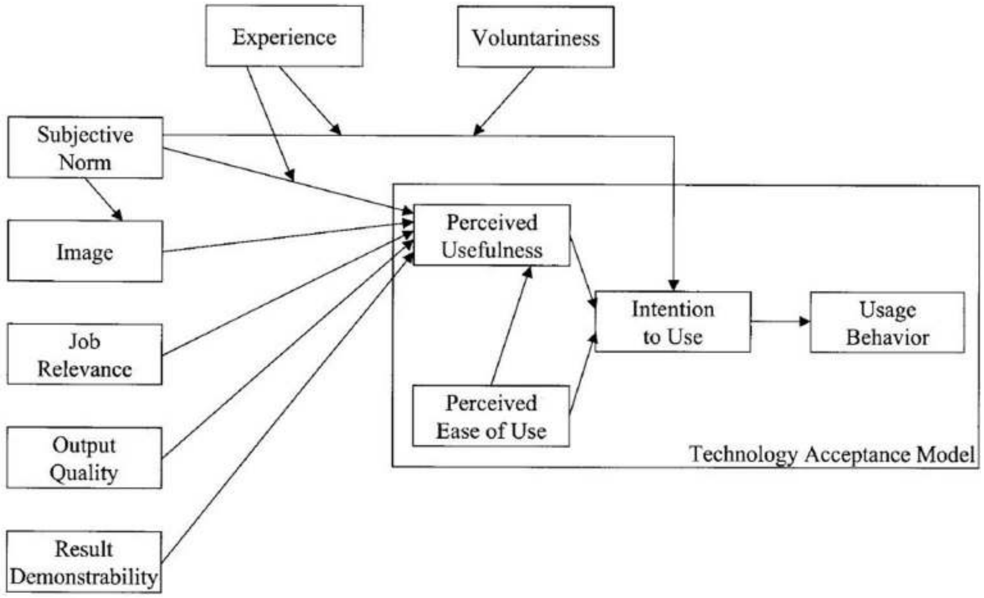

FIGURE 1 | Original technology acceptance model (TAM2/UTAUT) (Venkatesh and Davis, 2000).

TAM originally came from the business world and was intended to be used, among other things, for researching buying behavior online as well as offline (Lin and Wang, 2005; Kulviwat et al., 2007; Thong et al., 2011) and optimizing marketing strategies as well as analyse the acceptance of systems among employees in companies until the 1990s. Meanwhile, the TAM is also used in the analysis of the acceptance of cryptocurrencies (Kumpajaya and Dhewanto, 2015), mobile or virtual payment systems (Schierz, 2008), personal computers or tablets (Venkatesh and Brown, 2001; El-Gayar et al., 2011), or the acceptance of Online Games (Hsu and Lu, 2004) and e-Learning in companies (Olbrecht, 2010; Wu et al., 2012).

In acceptance research, TAM is considered to be the best empirically evaluated and operationalized predictive model for explaining the acceptance of technical systems when describing relationships between attitudes and behavior (Legris et al., 2003; King and He, 2006; Schepers and Wetzels, 2007; Venkatesh and Bala, 2008). Davis (1989, p. 320) uses the behavioral intention as an immediate predictor of behavior. He describes that the behavioral intention (see TRA: Attitude Toward Using, ATU) expresses the intention of a person to use a relevant and possible technical system in the future. Furthermore, he assumes that the intention is influenced by two subjectively perceived and considered system dependent components, the "perceived usefulness" (PU; Davis:U) and the "perceived ease of use" (PEOU; Davis: E). These components are influenced by other variables, which Davis first calls "Design Features" (Davis, 1986, p. 24) and in his further elaborations describes them as "External Variables" (Davis, 1989; Davis et al., 1989, p. 985). External variables are interpreted differently from study to study. For example, according to Venkatesh and Davis (2000), the "perceived job relevance," the "subjective norm," the "output quality" or even the "result demonstrability" have to be mentioned. While the output quality describes the quality of the results of using technologies, the result demonstrability describes how tangible the results of using technologies are. The Subjective norm indicates "the person's perception that most people who are important to him think he should or should not perform the behavior in question" (Fishbein and Ajzen, 1975, p. 302). Later several different, business specific factors were added to the external variable by Venkatesh and Bala (2008).

However, according to Davis (1989), Davis et al. (1989) and Olbrecht (2010), in certain cases no influence of the subjective norm can be demonstrated. Davis explains this because the subjective norm has to be considered as a factor only if the use of technology goes along with social interactions, such as in social networks or collaborative applications. The same applies to the factor image, because "individuals often respond to social normative influences to establish or maintain a favorable *image* within a reference group" (Venkatesh and Davis, 2000). However, if there is no reference group, as the teacher mostly teaches alone, then this factor can be neglected, too.

The TAM and its extensions have so far not been used, in essence, to investigate the acceptance of the use of technologies in school education. The aim of this study is to investigate the acceptance behavior of teachers toward multimedia applications in physics teaching and to identify school-specific influencing factors on the acceptance behavior. So far, the TAM and its extensions examined the acceptance behavior of a specific actual user. In physics lessons, the actual user of a multimedia application is not necessarily the teacher, but it can also be the student. In the context of school, it has to be clarified whether the TAM can also be used if the actual user is often a third person and the teacher makes an assessment for the actual user.

METHODS AND MATERIALS

The Participants

Idcgatekiva and Lindner (2015) showed that teachers do not fully exploit the opportunities that multimedia offers in the classroom. Instead, teachers continue to use traditional presentation methods. Among other things, Idcgatekiva and Lindner (2015) attribute this to a lack of knowledge about the possibilities of using multimedia applications in the classroom and their pedagogical impact on an individual student. In addition, the acceptance of new technologies on the part of in service teachers is also an essential prerequisite for actually using technologies in the classroom. In the different subject areas, there are often very different scenarios of how multimedia content can be used purposefully. A study designed to cover this broad spectrum naturally becomes extremely complex. To avoid this, this study was restricted to physics teachers. On the one hand, this teacher group has the advantage that there is a large number of sources of multimedia teaching materials for physics teaching worldwide, that physics teacher can use (e.g., research institutes, chairs, commercial offers, teacher content) and, secondly, there are numerous empirically examined application scenarios for a targeted use of multimedia applications (e.g., Garofalakis et al., 2013; Opfermann et al., 2017).

The adapted instrument developed for this study was applied to a total of 174 active physics teachers at high schools in the area of Munich in Germany as part of a teacher training. The resulting sample consists of 58% (101) male and 39% (68) female teachers. 5 teachers gave no indication of gender. The difference between male and female teachers roughly corresponds to the sex composition of physics teachers working in Bavaria (Germany). The teachers were aged between 24 and 65 years and had an average age of 42.4 years (SD: 11,4a). About 35% were younger than 35 years, about 48% were between 36 and 55 years old and about 17% were older than 55 years old. The average age also corresponds to the average age of the physics teachers in Bavaria (Germany). Each of the participants has completed at least nine semesters of physics studies and thus have a correspondingly good physical-technical background. The working experience of the participants is 12,9 years (SD: 10,4a).

Adaption of the TAM/UTAUT Model

The context of school therefore requires some changes to the TAM/UTAUT model. For this, the "External Variables" are adapted to the needs of the context of school and teaching. First of all, in this study the factor "subjective norm" is dispensed with, as no social interactions, such as data exchange or cooperation between the users, are intended. Other influencing factors, such as "personal job relevance assessment", "output quality" or "result demonstrability", on the other hand, will be used in this study. However, with regard to the context of school, the factors "output quality" and "result demonstrability" are summarized and interpreted as a new factor. This is necessary because it is extremely difficult to measure the "output quality" of students. Since it is not clear what is actually the output of a school (learning success, good grades, personal development, preparation for working life) this factor cannot be measured directly. The same applies to the verifiability of the results. Therefore, for this specific context, we bring these two factors together into a new factor, which we call "perceived usefulness for students." This factor should be subjectively assessed by the teacher, because only the teacher is able to evaluate the success of different objectives of the lesson.

As another external factor, we propose the previously described TPACK, because in the increasingly digitized world the technology knowledge of a teacher has an increasing importance and therefore should not be neglected in the assessment of the acceptance. We assume that TPACK has a direct influence on the perceived personal usefulness. Although the TAM actually prohibits a direct effect of an external variable on another external variable, we still assume that TPACK of a teacher has a direct influence on the PEOU, the "perceived job relevance assessment," and the "perceived usefulness to students." This assumption is supported by the fact that TPACK, which includes technology knowledge (TK), should have a positive influence on the "perceived ease of use." In this case, a teacher with a high TK should rate an application as easier to use than a person with a lower TK. A teacher who has a high TPACK also has a comprehensive knowledge about how to use an application specifically in the classroom. Thus a direct influence on the perceived job relevance assessment is to be expected. The same applies to the perceived usefulness to students.

The Instrument

The items for TPACK scale were adapted from different surveys of Archambault and Crippen (2009), Graham et al. (2009a) and An and Reigeluth (2014). The items for the TAM scales were adapted from a version of Venkatesh and Davis (2000) questionnaire, which were partly translated into German by Olbrecht (2010). All items have been adapted to the context of multimedia applications usage in physics teaching in schools. The survey consists of 74 items. In addition, there were 10 sociodemographic items. Each item of the survey had the following response categories: (1) *I Totally agree about*, (2) *I agree about*, (3) *neither nor*, (4) *I do not agree* (5) *I do not agree at all*. To test the reliability of the scales, the internal reliability coefficient Cronbach's alpha was calculated by using SPSS 25.0 software. The scale characteristics can be seen in **Table 1**.

STUDY—PART 1

Research Question and Hypotheses

It has already been shown that the TAM can be successfully applied to the usage of different technologies (e.g., Olbrecht, 2010; Evans et al., 2014; Fathema et al., 2015; Kim and Woo, 2016). In the majority of the studies using the TAM, the theoretical assumptions could be sufficiently confirmed. Nevertheless, there are no empirical findings in the literature concerning the applicability of TAM using multimedia applications in physics education or the associated effects.

To adapt the TAM to multimedia applications, all items were reworded in such a way that they are as close as possible to

TABLE 1 | Instrument—overview with example items.

	Cronbach's α	r
Personal Job Relevance (PJR) ***(8 items)***	0.85	0.817–0.850
Multimedia applications are capable of illustrating complex new content.		
Perceived Usefulness for Pupils (PUfP) ***(7 items)***	0.84	0.740–0.830
I expect that students who have been taught with the support of multimedia applications have gained more expertise.		
Perceived Ease of Use (PEOU) ***(4 items)***	0.75	0.618–0.747
Handling multimedia applications is self-explanatory for me.		
Perceived Personal Usefulness (PPU) ***(6 items)***	0.84	0.797–0.845
The use of multimedia applications improves my teaching performance.		
Behavioral Intention (BI) ***(2 items)***	0.90	
When I get access to multimedia applications, I predict that I will use them.		
Acceptance Behavior (AB) ***(2 items)***	0.91	
I often use multimedia applications in the classroom.		
Content Knowledge (CK) ***(4 items)***	0.86	0.786–0.873
I have sufficient expertise in teaching my field of expertise.		
Pedagogical Content Knowledge (PCK) ***(7 items)***	0.86	0.831–0.869
I manage, without the use of modern technologies, to stimulate my students to solve everyday problems in my area of expertise.		
Pedagogical Knowledge (PK) ***(5 items)***	0.88	0.821–0.900
I am able to guide my students to internalize adequate learning strategies.		
Technological Pedagogical and Content Knowledge (TPACK) ***(5 items)***	0.90	0.865–0.903
With the help of multimedia applications, I can design activities for student-centered research on subject-specific teaching subjects.		
Technological Content Knowledge (TCK) ***(4 items)***	0.88	0.824–0.869
I can use appropriate multimedia applications to illustrate my lesson.		
Technological Pedagogical Knowledge (TPK) ***(4 items)***	0.90	0.849–0.885
I am able to help my students plan and monitor their own learning process by providing appropriate technologies.		
Technological Knowledge (TK) ***(4 items)***	0.93	0.900–0.923
I have the necessary technical skills to use computers effectively.		

The example items are translations from the German survey instrument.

the original item, but the relation to multimedia applications is clearly recognizable. Because of the extensive modifications of the items and the scales, an initial test of the questionnaire is essential. This results in research question 1:

> *Are the model parameters as well as the model fit parameters of the modified TAM2/UTAUT model comparable to the corresponding parameters of the original TAM2/UTAUT model?*

The question can only be answered, if the following hypotheses can be verified.

Hypothesis 1 The perceived ease of use of multimedia applications influences the behavioral intention (BI) of using them in the classroom. The easier and more intuitive the operation of an application is perceived by a physics teacher, the greater the intention is to use the application in the future.

Hypothesis 2 The perceived personal usefulness of multimedia applications is influenced by the perceived ease of use of the application. The simpler and more intuitive the operation of the application is perceived by the physics teacher, the more positively the utility provided by the teacher's application is assessed.

Hypothesis 3 The perceived personal usefulness of multimedia applications is influenced by the perceived usefulness of multimedia applications for students. The higher the score on the scale of the perceived usefulness of multimedia applications for students is, the better a teacher perceives the personal usefulness of multimedia applications.

Hypothesis 4 The personal job relevance assessment (PJRA) of a multimedia application influences the perceived personal usefulness of the multimedia application. The higher the PJRA of the multimedia application is, the higher is the perceived personal usefulness of the multimedia application.

Hypothesis 5 The perceived personal usefulness of the multimedia application influences the behavioral intention. The higher the personal usefulness of the multimedia application is perceived by a teacher, the more pronounced the intention is to use a multimedia application in the future.

Hypothesis 6 The behavioral intention has a direct influence on the acceptance behavior toward multimedia applications. High values on the scale of intention are a prerequisite for the actual behavior.

The perceived usefulness of multimedia applications for students have a direct impact on the perceived personal usefulness that a teacher sees in a multimedia application. High scores on the scale of the teacher's expected utility of a multimedia application result in a teacher rating the personal value of a multimedia application higher.

Results

The path model was tested using AMOS 25 with the Maximum Likelihood (ML) method. The condition for the ML method, the multivariate normal distribution, was tested and given. There was also no correlation with the age of participants or their gender.

While **Figure 2** shows the adapted technology acceptance model used, as a conceptual model with the help of which the hypotheses belonging to research question 1 will be statistically tested, **Figure 3** shows the result of the statistical model calculation. The appropriate fit parameters, show that the model has a good fit ($CMIN/DF = 2.106$; $RMSEA = 0.08$; $CFI = 0.80$) (Bentler, 1990; Browne and Cudeck, 1993; Hu and Bentler, 1999).

It could be shown that the "perceived personal usefulness" is a strong predictor of the behavioral intention (H5, $\beta = 0.781$, $C.R. = 7.901$, $p < 0.001$). The "expected personal usefulness," is strongly influenced by the "personal job relevance assessment" (H4, $\beta = 0.659$, $C.R. = 7.036$, $p < 0.001$) and the "expected usefulness for students" (H3, $\beta = 0.380$, $C.R. = 5.010$, $p < 0.001$). It is also possible to confirm the influence of the "perceived personal usefulness" by the "perceived ease of use" (H2, $\beta = 0.328$, $C.R. = 3.648$, $p < 0.001$). The predictive effect of the behavioral intention on the acceptance behavior predicted in the UTAUT model can also be confirmed as expected (H6, $\beta = 0.410$, $C.R. = 4.620$, $p < 0.001$). Overall, the explained amount of variance in the "acceptance behavior" (AB) is $R^2 = 0.168$ ($C.R. = 5.038$ $p < 0.001$) and in the "behavioral intention" is $R^2 = 0.559$ ($C.R. = 4.837$ $p < 0.001$). For the "perceived personal usefulness" the explained amount of variance is $R^2 = 0.686$ ($C.R. = 3.823$, $p < 0.001$).

However, the study showed a very interesting result in terms of the mediator property of the variable "behavioral intention." According to Urban and Mayerl (2018) a mediator test was carried out. Similar to other studies, no mediator effect of the variable "behavior intention" can be found (see also Olbrecht, 2010; Wu and Zhang, 2014). This suggests that the variable "perceived personal usefulness" is by far the most important factor for predicting the acceptance behavior.

STUDY—PART 2

Framework

The modified technology acceptance model is extended by additional factors which are to be considered in school context. Politicians for example in Germany (KMK, 2016), the UK (e.g., The Scottish Government, 2016) or the US (South and Stevens, 2017) have therefore paved the way for schools by providing guidelines for education in a digital world that teachers will need to take even more into account in the future. But this also increases the demands on a teacher, especially in the technical field. At the same time, numerous studies show reasons why modern information technologies are not or only rarely used in teaching: These studies include, for example, institutional frameworks (curriculum) (Mumtaz, 2006; Keengwe et al., 2008), technical frameworks (equipment) (Mumtaz, 2006; Panda and Mishra, 2007; Keengwe et al., 2008), perceived lack of success through the use of technologies (Haßler et al., 2016), or insufficient dissemination and continuing education of teachers (Koc and Bakir, 2010), which may adversely affect the acceptance of such technologies on the part of teachers. The mentioned factors at the beginning can only be influenced marginally from a pedagogical point of view and from the teachers perspective.

However, a teacher also needs a broad understanding of technologies and how these technologies can be used in teaching (Mishra and Koehler, 2006; Koehler and Mishra, 2009; Koehler et al., 2014). Thus, a teacher's TPACK plays a key role in the integration of new technologies, and multimedia applications in particular. However, this aspect is not taken into account in the current research on the technology acceptance model, which is why the modified technology acceptance model (basic model) has been expanded by the factor TPACK within this study.

Research Question and Hypotheses

With the accompanying changes to the basic model, another research question can now be deduced:

> *Can the model parameters of the Technology Acceptance Model (TAM2/UTAUT) be improved in its predictive power for the usage of multimedia applications in physics teaching by adding TPACK and adapting it to the school context?*

This question can only be answered with yes if the following hypotheses can be verified (see **Figure 4**).

Hypothesis 7 TPACK affects the personal usefulness of a multimedia application perceived by a teacher. If a teacher has a high value on TPACK scale, this teacher perceives the use of multimedia applications as profitable for himself.

Hypothesis 8 TPACK affects the teacher's perceived usefulness of a multimedia applications for students. If a teacher has a high value on TPACK scale, this teacher perceives the use of multimedia applications as profitable for his students.

Hypothesis 9 TPACK affects a teacher's personal job relevance assessment in using multimedia applications for his students. If a teacher has a high value on TPACK scale, that teacher considers multimedia applications to be relevant to his teaching.

Hypothesis 10 TPACK has a direct impact on the teacher's perceived ease of use of a multimedia application. If a teacher has a high value on TPACK scale, he perceives a multimedia application as easy to use.

Hypothesis 11 Behavioral intention occurs as a mediator variable between the perceived personal

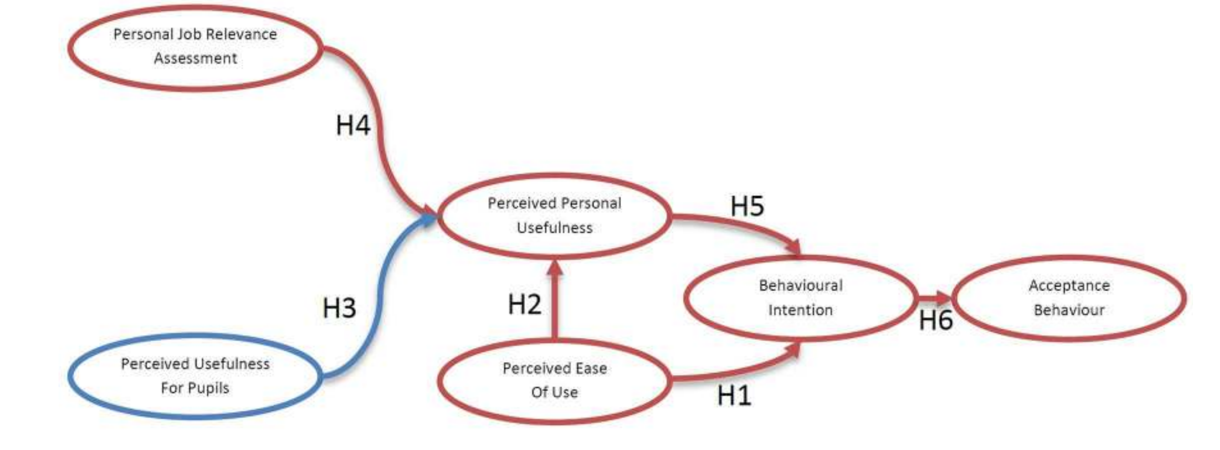

FIGURE 2 | Conceptual model of the adapted UTAUT model.

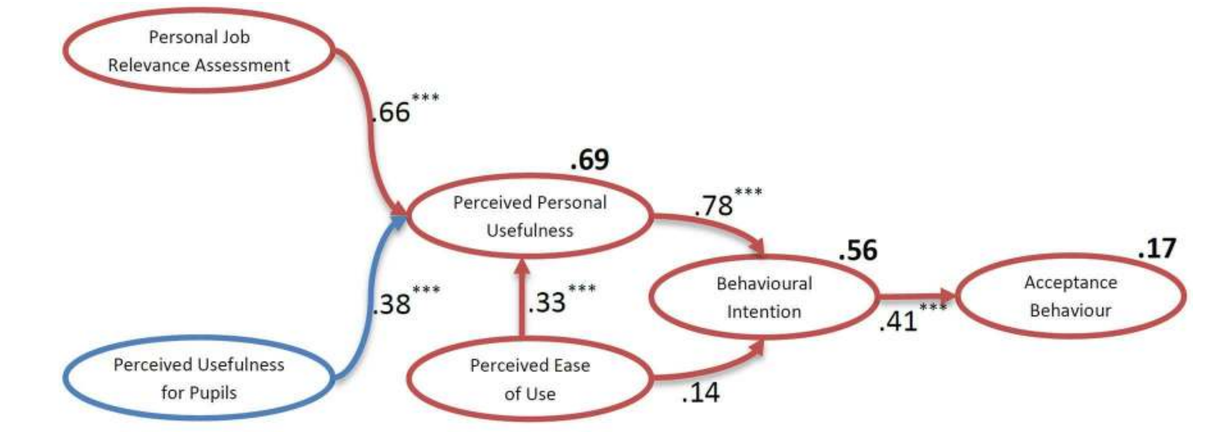

FIGURE 3 | Results of the statistical model calculation.

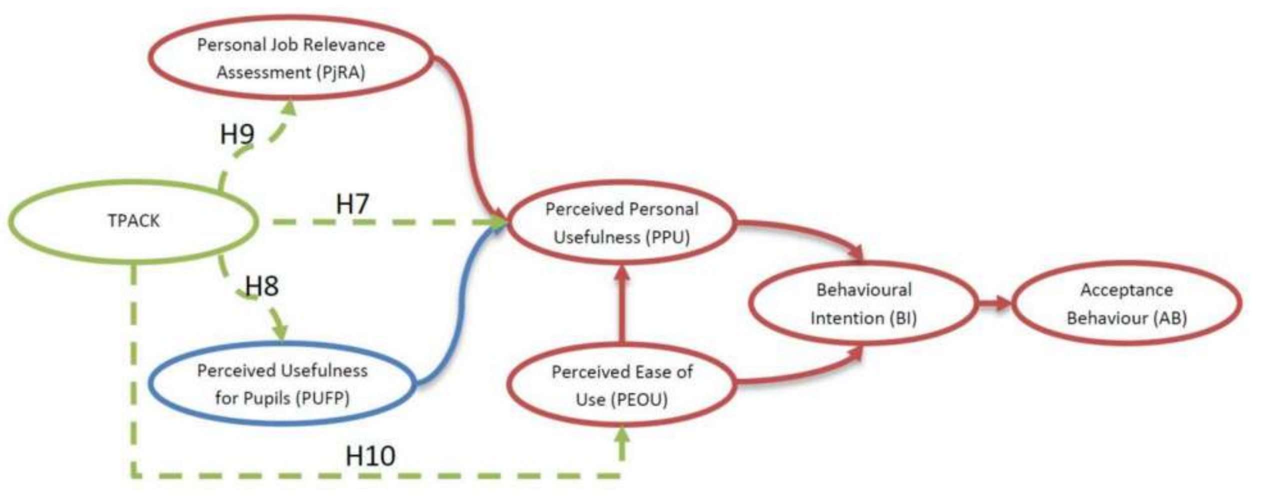

FIGURE 4 | Conceptual model of the adapted UTAUT model with TPACK extension.

usefulness of multimedia applications expected by the teacher and the acceptance behavior.

Hypothesis 12 Due to the extension of the adapted UTAUT model by the influencing factor TPACK, there are no significant changes in the functional relationships compared to the basic model without the influencing factor TPACK.

Results

The extended TAM2/UTAUT model continues to take into account the prevailing conditions according to which the factors "perceived ease of use" and "perceived personal usefulness" have no direct influence on the acceptance behavior, so that according to Davis (1989) the "acceptance behavior" is directly predicted (mediated) by the "behavioral intention."

Figure 5 shows the result of the statistical model calculation and the appropriate fit parameters show that the model has a good fit ($CMIN/DF = 1.92$; $RMSEA = 0.073$; $CFI = 0.79$) (Bentler, 1990; Browne and Cudeck, 1993; Hu and Bentler, 1999).

Overall, it can be shown that TPACK has a very strong influence on the "perceived ease of use" of multimedia applications (H10, $\beta = 0.761$, $C.R. = 3.962$, $p < 0.001$). This means that if TPACK increases by one standard deviation, the "perceived personal usefulness" increases by 76% of the standard deviation. Likewise, TPACK has a strong impact on the teacher's "perceived usefulness of multimedia applications for students" (H8, $\beta = 0.471$, $C.R. = 3.780$, $p < 0.001$). The influence of TPACK on "personal job relevance assessment" is also highly significant (H9, $\beta = 0.612$, $C.R. = 4,263$, $p < 0.001$). Only the influence of TPACK on the "perceived personal usefulness" (H7, $\beta = 0.142$, $C.R. = 1.019$) is not significant and has a low charge as well.

It can also be stated that the "perceived personal usefulness" is a very strong predictor of the behavioral intention ($\beta = 0.845$, $C.R. = 7.923$, $p < 0.001$). The "perceived personal usefulness" is strongly influenced ($\beta = 0.552$, $C.R. = 5.839$, $p < 0.001$) by the "personal job relevance assessment" and the "perceived usefulness to students" ($\beta = 0.306$, $C.R. = 4.214$, $p < 0.001$). Finally the "behavioral intention" strongly influences the "Acceptance Behavior" ($\beta = 0.443$, $C.R. = 5.118$, $p < 0.001$).

The variance explanation of the acceptance behavior lies at $R^2 = 0.20$ ($p < 0.001$) and for the "perceived personal usefulness" at $R^2 = 0.78$ ($p < 0.001$). While the variance analysis of the "acceptance behavior" is about the value of the adapted TAM2/UTAUT model ($R^2 = 0.17$), it increases in "perceived personal usefulness" by 9 to 78%. Since there are no essential changes compared to study 1, this means that hypothesis 12 can also be accepted.

However, a mediator test showed that the factor "behavioral intention" cannot be considered as a mediator in the sense of Davis (1989) as required in hypothesis 11. Because the path BI → AB decreases to a not significant β value while the additional path PPU→ AB have a significant regression weight ($\beta = 0.864$, $C.R. = 5.018$, $p < 0.001$). However, the second additional path $PEOU \rightarrow AB$ is not significant.

DISCUSSION

In this study, the hypotheses of the research questions on the modified UTAUT model and its extension by the influence factor TPACK were investigated.

Study 1 was dedicated to test the adaption of the UTAUT model to multimedia applications. The hypotheses describe the individual interactions in order to adapt the technology acceptance model to multimedia applications in schools and to conceptualize them as a structural model. The assumptions were verified by a set of structural equation models computed using IBM AMOS 25 with the Maximum Likelihood (ML) method.

With this adapted technology acceptance model, the theoretically expected causal relationships can be shown. The correlations of the TAM2/UTAUT model ($PPU \rightarrow BI{:}\,\beta = 0.78$ $cf.\,\beta = 0.55$; $PEOU \rightarrow BI{:}\ \beta = 0.14$ $cf.\ \beta = 0.17$ $BI \rightarrow AB{:}\,\beta = 0.41$ $cf.\ \beta = 0.52$) are similar to Venkatesh and Davis (2000, pp. 196–197). Also the R^2 coincides well with this previous studies ($PPU{:}\,R^2 = 69\%$ $cf.\,R^2 = 60\%$; $BI{:}\ R^2 = 56\%$ cf $37\% < R^2 < 52\%$). Only the R^2 of the Acceptance Behavior (AB) is outside the range ($R^2 = 17\%$ cf $44\% < R^2 < 57\%$) of Venkatesh and Davis (2000, pp. 196–197). All in all the measurements indicate that the adapted model fits well with the survey instrument and can be used for further investigation. Also, the question of the applicability of the TAM can be answered positively if a third person (teacher) has made an assessment for the direct user (student). However, it should be noted that the "acceptance behavior" must have other influencing factors that have not been taken into account in study 1. These aspects have to be considered in future studies. The results also matches with numerous previous studies (e.g., Davis, 1989; Venkatesh and Davis, 2000; Venkatesh et al., 2007; Wu and Zhang, 2014). Furthermore these results are consistent with the results of the study by Joo et al. (2018). Thus among preservice teachers, TPACK has an impact on the "perceived usefulness" of multimedia applications.

The one exception is the influence of the "perceived ease of use" of a multimedia application on the "behavioral intention," as intended by hypothesis 1. As in other studies, no significant correlation could be found (see also Davis et al., 1992; Horton et al., 2001; Olbrecht, 2010). This initially appears as a strange result. But when looking at the participants, some reasons can be mentioned. The participants of the study are only physics teachers, and it should be noted that physics teachers are a special group of teachers. Because of their physical-technical studies, physics teachers have a deeper understanding of modern technologies and are able to understand the different possibilities modern technologies can provide them with. Furthermore, physics teachers often have to work with less intuitive but partly excellent software packages for school purposes, such as "Cassy Lab" by Leybold Didactic in Europe or by Klinger Educational Products in the US. It seems that the considered population of teachers do not attribute too much importance to the usability of an application. Instead, physics teachers also take advantage of applications that seem

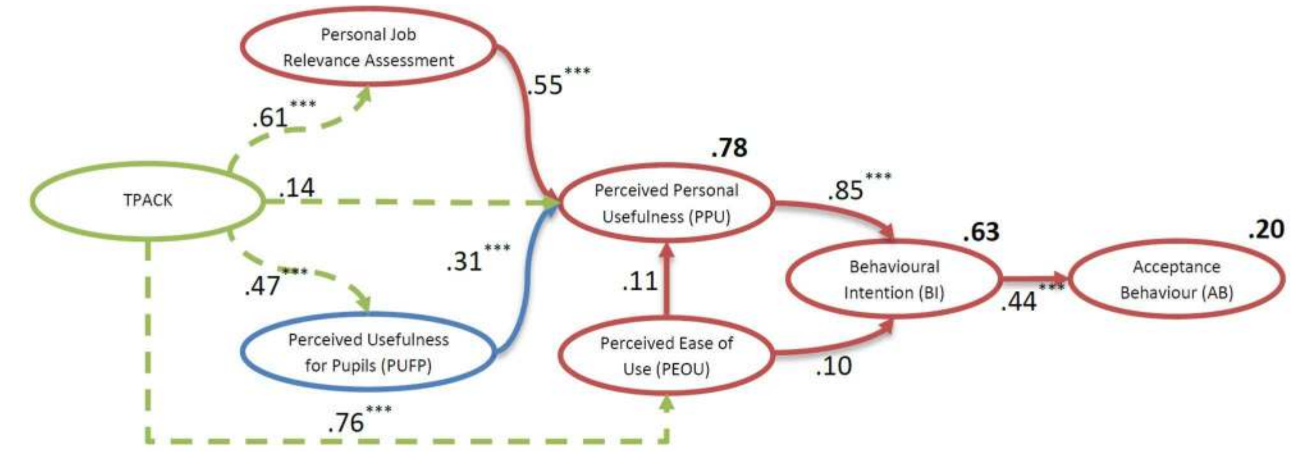

FIGURE 5 | Results of the statistical model calculation of the extended UTAUT model.

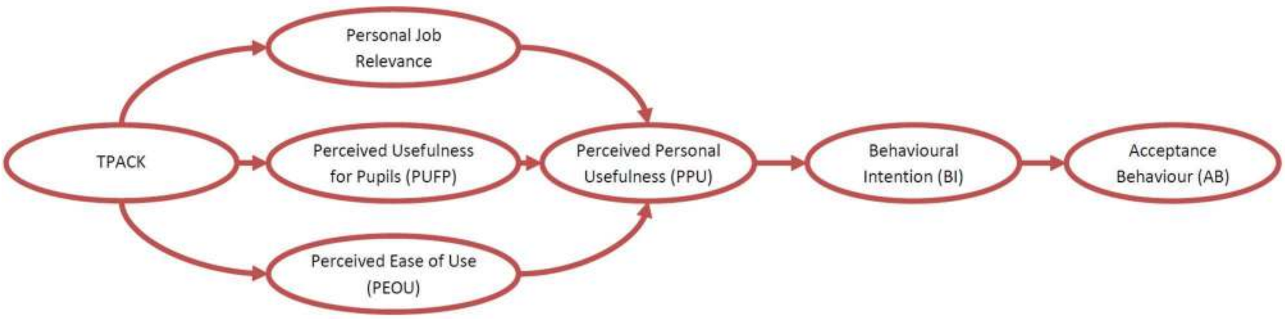

FIGURE 6 | Conceptual model of the adapted and extended UTAUT Model.

to be less easy to use. This can explain the insignificant relationship between the "perceived ease of use" and the "behavioral intention."

Study 2 shows that the adaptation and extension of the UTAUT model by the factor TPACK is suitable for investigating the "acceptance behavior" of multimedia applications.

Unlike the suggestion of Davis et al. (1992), the results show that the variable TPACK as an external variable has no direct influence on the "perceived usefulness." Instead, the results show, that TPACK stands outside Davis's suggested core frame as a superordinate moderator variable of the external variables "perceived ease of use," "personal job relevance assessment" and "perceived usefulness for students." Teachers with a strong TPACK have pronounced knowledge of technology and a strong pedagogical knowledge concerning the use of technology, they also have an in-depth knowledge of how to use multimedia applications in the classroom. In addition, they know which possibilities multimedia applications offer and which misconceptions can be counteracted by targeted use. Therefore, they see the benefits that students can gain from using multimedia applications in the classroom. As mentioned earlier, this study has shown that teachers who have a high TPACK rate multimedia applications as more relevant to their teaching. One possible reason for this is a better understanding of the possibilities that multimedia applications offer for targeted and, in part, student-centered instruction. So, if a teacher sees more opportunities to use a multimedia application in the classroom, this teacher will of course assess a multimedia application as more relevant to his teaching. This is further reinforced by the knowledge of how multimedia applications and the associated teaching methods can specifically counteract physic specific beliefs. The role of TPACK as a superordinate moderator variable, on the other hand, is likely to be applicable to other groups of teachers.

This model can therefore be used to investigate the effectiveness of teacher training events with regard to increasing the acceptance of multimedia applications.

However, since no mediator effect of the "behavior intention" could be shown in either of the two studies, the question arises, which meaning the "behavior intention" actually has for the acceptance of multimedia applications in the context of school. Although this result is consistent with other studies (Horton et al., 2001; Olbrecht, 2010), it is in contrast to Davis et al. (1992), who have been able to demonstrate a mediator effect.

Furthermore, an interesting finding is, that when removing the BI from the model (see **Figure 6**), the models fit-parameters become better and about 39% of the variance of the AB can be explained. One reason for that finding could be that the items that are supposed to measure this construct were not precise enough. Another possibility would be that in the sample examined, the BI actually has by far a smaller influence on the "acceptance behavior" than expected. The second possibility should also be considered in the context of the result of the mediator test, which could serve as an indication of this possibility. Because the failed mediator test indicates, that the BI can be neglected in the context considered. However, this finding is unsatisfactory and requires further investigation of the relationship.

This study limited itself to providing evidence that the TAM could be adapted to the context of physics education in schools, to reduce the complexity of the study and to reduce the size of the survey instrument, since both would have meant that the sample of teachers would have been much smaller. Of course, this means that some influential factors, like constitutional conditions of the individual school, curricula, technical conditions of the individual schools and the available lesson time, could not be investigated. However, as these influencing factors were frequently mentioned in the commentary section, a strong influence on the "perceived personal usefulness" and the "acceptance behavior" can be expected by these factors. Therefore, in further studies, the model should be extended by these factors, although this will significantly increase the complexity of the model and the whole study.

DATA AVAILABILITY

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

An approval by an ethics committee was not required for this study as per applicable institutional and national guidelines and regulations and the informed consent of the participants was implied through survey completion. At this point we will refer to the submission of the Ethics Committee of the German Psychological Society. It describes general information for participants that was fully followed during the preparation and execution of this study. All the participants were informed about the following regulations in detail. The participation in the study is voluntary. Participants may terminate participation in this study at any time without giving cause or the danger of suffering from any consequences. Even if the participants cancel the study prematurely, they can participate in the lecture and the practical part. The data and personal information collected in this study will be kept confidential. The staff who have personal data through direct contact with the participants are subject to confidentiality. Furthermore, the results of the study will be published anonymously without revealing the personal data of participants. The collection of the personal data of the participants is completely anonymised, i. e., at no point a name is requested. The answers and results are stored under an anonymous token, so that personal data cannot be associated with any specific participant. The anonymous data will be stored for at least 10 years. However, subscribers can request the deletion of the data, whenever they want to. For this, the participants do not have to tell their name, but only give their token. In accordance with current practice, participants were explicitly advised that they automatically agree to these terms and conditions when participating in the study.

AUTHOR CONTRIBUTIONS

PM carried out the study and its evaluation and wrote the essay. RG was involved in the development, execution, and evaluation of the study.

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