frontiers | Frontiers in Education

TYPE Original Research
PUBLISHED 13 June 2023
DOI 10.3389/feduc.2023.1197938

OPEN ACCESS

EDITED BY
Stefinee Pinnegar,
Brigham Young University, United States

REVIEWED BY
Roberto Sanchez-Cabrero,
Autonomous University of Madrid, Spain
José Cravino,
University of Trás-os-Montes and Alto Douro, Portugal

*CORRESPONDENCE
Jörg Großschedl
✉ j.grossschedl@uni-koeln.de

RECEIVED 31 March 2023
ACCEPTED 17 May 2023
PUBLISHED 13 June 2023

CITATION
Gussen L, Schumacher F, Großmann N, Ferreira González L, Schlüter K and Großschedl J (2023) Supporting pre-service teachers in developing research competence.
Front. Educ. 8:1197938.
doi: 10.3389/feduc.2023.1197938

Supporting pre-service teachers in developing research competence

Lea Gussen[1], Fabian Schumacher[2], Nadine Großmann[1], Laura Ferreira González[3], Kirsten Schlüter[1] and Jörg Großschedl[1]*

[1]Faculty of Mathematics and Natural Sciences, Institute for Biology Education, University of Cologne, Cologne, Germany, [2]Center for Teaching and Learning, Bielefeld University, Bielefeld, Germany, [3]Department Special Education and Rehabilitation, Faculty of Human Sciences, University of Cologne, Cologne, Germany

Introduction: Teachers need research competence to reflect on their teaching and to interpret and implement research-based recommendations. However, many pre-service teachers have critical attitudes toward research, little motivation to engage in research, and comparatively low knowledge of research methods and thereby consequently indicating a low research competence. Flexible online modules in university teaching could be a promising approach to address these issues. Online modules can potentially promote self-determined motivation, but should be sufficiently structured to support learners' need for competence.

Methods: We designed two learning environments with different types of structure: a non-restrictive structured environment and a restrictive structured environment. A total of N = 108 pre-service biology teachers were randomly assigned to the two learning environments.

Results and discussion: Contrary to our assumption, the restrictive type of structure of the learning environment did not lead to a higher perception of competence. This might be a consequence of external pressure, for example, the examination at the end of the course. Regarding pre-service teachers' research competence, we found a decrease in the affective-motivational domain and an increase in the cognitive domain in both learning environments. These results suggest that fostering pre-service teachers' research competence should focus on the affective-motivational domain. In order to positively affect this domain, care must be taken to ensure that structuring elements are not experienced as control and that given choices are meaningful to students.

KEYWORDS

structured learning environment, perceived competence, research competence, pre-service teacher education, basic psychological needs

1. Introduction

Schools and universities are responsible for preparing learners for working with data. Learners should be able to evaluate empirical results and analyze, present, and interpret data. The respective competence profile provides a basis for evidence-based decisions (Humpert et al., 2006) and is known as research competence (Wessels et al., 2018). Research competence is not a clearly defined term. It is usually interpreted in subject-specific terms (Thiel and Böttcher, 2014; Gess et al., 2017) and is a relatively new goal of teacher education (OECD, 2005). In German teacher education, research competence is considered an objective of higher education (The German Science and Humanities Council, 2006) and an integral part of teachers' professional competence (MSW NRW, 2010). It ensures that (pre-service) teachers can interpret

scientific sources and studies (e.g., PISA, TIMSS, Hattie study; Fichten and Meyer, 2014), act competently in the classroom, make objective, reliable, and valid assessments of students' performance (Humpert et al., 2006; Mandinach and Gummer, 2016; KMK, 2019b), and continuously develop teaching quality (e.g., see Johnson et al., 2014).

Research shows that students as well as pre-service teachers find university courses on research methodology, which is needed to be competent in research, uninteresting, irrelevant, challenging, and have a poor attitude toward research (Vittengl et al., 2004; Spronken-Smith, 2005; Ball and Pelco, 2006; Braguglia and Jackson, 2012; Earley, 2014). Previous findings show that students lack motivation and mathematical skills and display a critical attitude toward doing research (Stark and Mandl, 2000). If research competence is a goal of teacher education, learning opportunities must be integrated into teacher education programs (Hochschulrektorenkonferenz (HRK), Kultusministerkonferenz (KMK), Bundesministerium für Bildung und Forschung (BMBF), 2017) to help overcome these problems. Fostering self-determined learning processes could be a beneficial approach as it increases motivation, engagement, and learning performance (see Ryan and Deci, 2017). This could be done for example by using online modules that allow flexible learning.

Online modules allow pre-service teachers to access content individually, regardless of time, and as often as needed (Naidu, 2017) and promote the experience of meaningful choice in engaging with content. This form of autonomous learning, however, can lead to distractions, disorientation, and can be overwhelming to learners (van Loon et al., 2012). Structuring the learning environment can help to avoid such feelings and is crucial in promoting learners' perceptions of competence (Jang et al., 2010). However, structuring the learning environment can be perceived as controlling and can negatively affect the satisfaction of the two basic needs for competence and autonomy and, in turn, learning (Eckes et al., 2018). To investigate our assumptions, we designed two learning environments dealing with research methodologies that differ in their degree of structure: a non-restrictive structured environment and a restrictive structured environment.

2. Theoretical framework

2.1. Research competence

In the 1990s, the instruction paradigm for higher education shifted from teaching to learning (Barr and Tagg, 1995), meaning that students are expected to construct their knowledge rather than receive content. In 1999, this shift was documented by the Bologna Declaration for the European Universities (Bologna Process Committee, 1999) and is expressed in the concept of competence. Klieme and Leutner (2006) describe competence as a behavioral disposition (cognitive domain) that can be trained in the sense of skills (see also Koeppen et al., 2008). Weinert (2001) expands this definition and includes abilities in the affective-motivational domain. This holistic concept of competence refers to the ability and willingness to meet the challenges of a situation. In the context of teachers' professional research, Baumert and Kunter (2013) build on Weinert's (2001) model. Here, teachers' professional competence is defined as a profession-related "amalgam" of abilities in the affective-motivational and cognitive domains. The abilities in the *affective-motivational domain* describe the motivational orientations and self-regulatory abilities of (pre-service) teachers. These abilities are related to classroom actions and the management of one's own resources (Baumert and Kunter, 2013). A teacher's motivation and passion for her profession and subject can impact learners and their performance (Kunter et al., 2020). Responsible management of one's resources is important for teachers because it can affect the quality of the profession, the quality of teaching, and the length of time in the profession (Baumert and Kunter, 2013). The abilities of the affective-motivational domain of research competence have only been investigated in a few studies in previous research (Deicke et al., 2014; Schumacher, 2020; Wessels et al., 2020). The *cognitive domain* describes the professional knowledge of (pre-service) teachers. A teacher's professional and competent action is shown in an appropriate assessment and analysis of situations as well as subsequent reflection (Kunter, 2011) and is taught in the framework of teacher training (MSW NRW, 2010; KMK, 2019a).

Research competence refers to this concept that encompasses a range of knowledge, attitudes, and behaviors that are essential for successful research (Wessels et al., 2018). Research competence includes skills such as critical thinking, ethical reasoning, and the ability to effectively communicate research findings (see Böttcher and Thiel, 2018; Mkrttchian and Belyanina, 2018). Related to research competence is research engagement, which Borg (2010) defines as a link between "engagement in research," which means, for example, doing research, and "engagement with research," which means, for example, reading and using research.

Studies on research competence primarily focused on cognitive learnable abilities (according to Klieme and Leutner, 2006; Böttcher and Thiel, 2017; Gess et al., 2019), and the results demonstrated an increase in the cognitive domain after participating in a research course (Böttcher and Thiel, 2017). The interaction of abilities in the affective-motivational and cognitive domains is relevant for the formation of (research) competence (Blömeke et al., 2015; Zlatkin-Troitschanskaia et al., 2015), influences performance and coping with professional demands (Kunter et al., 2013) and, thus, supports action in practice (Baumert and Kunter, 2013). Previous studies find an increase in student knowledge and a decrease in students' attitudes toward research after a research methods course (Sizemore and Lewandowski, 2009; Wessels et al., 2020). To optimally support the cognitive learning process and counteract a decrease in motivational variables, measures can be implemented to foster motivation in dealing with research content. Such measures can be derived from self-determination theory (Ryan and Deci, 2017), which will be discussed in the following section.

2.2. Basic psychological needs

Self-determination theory (SDT; Ryan and Deci, 2017) distinguishes extrinsic and intrinsic motivation. Extrinsically motivated behavior is performed with instrumental purpose and is characterized by pursuing goals independent of the action. Intrinsically motivated behavior reflects actions with the sole purpose of performing the action (Ryan and Deci, 2017, 2020). In these actions, individuals perceive an internal locus of causality (Ryan and Deci, 2017, 2020). The experience of pleasure and interest

sustains intrinsic motivation (Ryan and Deci, 2002). Regarding SDT (Ryan and Deci, 2017), long-lasting and sustainable learning is based on self-determined motivation. Self-determined motivational qualities (such as intrinsic motivation) lead to higher engagement and better learning performance (Reeve and Jang, 2006; Ryan and Deci, 2017). SDT (Ryan and Deci, 2017) assumes that satisfying basic psychological needs is a precondition for self-determined motivation, for example, while learning. Two of these basic psychological needs are relevant to our study: the need for competence and autonomy (Ryan and Deci, 2017, 2020). The need for competence describes the individual's desire to experience and improve one's abilities through interaction with the environment (Ryan and Deci, 2017, 2020). The need for autonomy describes the desire to perform actions voluntarily, to be the origin of one's actions, and to feel that one has a choice (Reeve et al., 2003; Ryan and Deci, 2017). Although, for a long time, only the satisfaction of these needs was considered, recent findings suggest that it is also important to consider the frustration of these needs (Heissel et al., 2018). This perspective arises from the fact that satisfaction and frustration are not a one-dimensional construct and do not act contrarily to each other (Heissel et al., 2018).

SDT suggests designing measures according to the abovementioned needs to support motivational variables in the learning process, such as acquiring research competence. To support the need for competence, the learning environment must provide sufficient structure (Jang et al., 2010; Ryan and Deci, 2017). Structure is of special importance for learning environments that address complex content. If such learning environments provide too little structure, they can evoke disorientation, create distractions, and overwhelm learners (van Loon et al., 2012). However, if the structure is perceived as control, it can negatively impact perceptions of autonomy and self-determined motivation (Jang et al., 2010; Eckes et al., 2018). Based on these assumptions, we investigated the following research question:

Do differently structured learning environments impact the development of research competence in pre-service biology teachers?

Based on the theoretical background, the following hypotheses can be derived:

> H_1: Pre-service teachers who receive restrictive structure express a higher self-assessed affective-motivational domain of research competence than students who receive non-restrictive structure.
>
> H_2: Pre-service teachers who receive restrictive structure express a higher self-assessed cognitive domain of research competence than students who receive non-restrictive structure.
>
> H_3: Pre-service teachers who receive restrictive structure perceive a higher satisfaction of their needs for autonomy and competence than students who receive non-restrictive structure.
>
> H_4: Pre-service teachers who receive restrictive structure perceive a lower frustration of their needs for autonomy and competence than students who receive non-restrictive structure.

3. Materials and methods

3.1. Sample

The study was conducted as part of a biology education postgraduate module in the master's program at a German university. Data were collected from the summer semester of 2020 to the summer semester of 2021. Participants gave their consent to use their anonymous data for scientific purposes. Longitudinal data from $N = 108$ pre-service biology teachers ($M_{age} = 25.33$ years, $SD_{age} = 3.89$ years; $M_{semester} = 2.81$, $SD_{semester} = 1.01$; 82.4% female, 0.9% diverse, 1.9% gender not specified) were analyzed. The non-restrictive structured group consisted of 56 pre-service teachers ($M_{age} = 25.30$ years, $SD_{age} = 3.31$ years; $M_{semester} = 2.88$, $SD_{semester} = 0.94$; 82.1% female, 1.8% diverse, 3.6% gender not specified) whereas 52 pre-service teachers were part of the restrictive structured group ($M_{age} = 25.37$ years, $SD_{age} = 4.46$ years; $M_{semester} = 2.73$, $SD_{semester} = 1.09$; 82.7% female).

3.2. Study design and procedure

The developed research course was first examined in the current study. All investigated pre-service teachers took part in this course. In the research course, the pre-service teachers learned about the theoretical background of empirical research. Moreover, the course contained research methods and insights into subject-specific research. Thus, the pre-service teachers had the chance to learn about research methods and to develop research competence. The content was taught digitally with the help of online modules (asynchronous). Before the start of the course, the pre-service biology teachers were randomly assigned to two learning environments (treatments): non-restrictive structured or restrictive structured. Both groups worked with online modules, providing learning opportunities on biology education research methodology. Each module consisted of multiple sequences. Between each sequence, content-based questions were positioned. In the restrictive structured treatment, the pre-service teachers could not proceed to the following sequence until answering the questions correctly (in the sense of mastery-learning; Bloom, 1978). The tasks were repeated as often as necessary until they were solved correctly. The non-restrictive structured group worked with the same modules, but the questions did not have to be answered (correctly) to proceed to the following sequence. The pre-service teachers in this group were also able to answer the content questions as many times as they wanted.

This quasi-experimental intervention study includes three measurement time points. Pre-service teachers' self-assessed abilities in affective-motivational and cognitive domains were assessed in a pre-posttest design. Basic needs were assessed in the middle of the course (mid-term) and at the end (posttest). A research course lasted one semester (about 14 weeks). There were approximately eleven weeks between the pretest and the posttest. At the pretest and posttest, research competence was assessed using self-assessments and demographic data (pretest only). A mid-term survey for basic need satisfaction and frustration was administered approximately six weeks after the pretest.

3.3. Measurements

The research competence was assessed by using two scales, each scale for one domain of research competence. For the **affective-motivational domain** three subscales were used (see Table 1). The subscale *finding joy in conducting research* of the affective-motivational domain was assessed with a 5-point rating scale (1 = "I do not enjoy this at all," 5 = "I enjoy this very much"; Wessels et al., 2018). The other subscales (*value-related interest in research*, *perceived benefits of research for practice*) deployed a 5-point rating scale as well but with different wording (1 = "strongly disagree," 5 = "strongly agree"; Wessels et al., 2018). These subscales were evaluated by Wessels et al. (2018) and were also used by Schumacher (2020) to evaluate pre-service biology teachers research competence after a long-term internship.

For the **cognitive domain**, we used the evaluated subscales (see Table 2) by Böttcher and Thiel (2018). The subscales deployed a 5-point rating scale ranging from 1 = "strongly disagree" to 5 = "strongly agree" (Böttcher and Thiel, 2018).

The items of both domains the affective-motivational and the cognitive one were adapted to biology education (see Tables 1, 2; Böttcher and Thiel, 2018; Wessels et al., 2018).

To evaluate how the different learning environments (non-restrictive structured and restrictive structured) affect the basic psychological needs, we assessed **basic need satisfaction and frustration** (mid-term survey and posttest) with four subscales (BPNSFS; Heissel et al., 2018). Theses scales are part of a validated German measurement instrument by Heissel et al. (2018). The items were rated on a 5-point rating scale (1 = "strongly disagree," 5 = "strongly agree"; Heissel et al., 2018) and adapted to the online modules (see Table 3).

All scales' reliabilities were estimated using Cronbach's alpha, which was found to be disputable to excellent (DeVellis and Thorpe, 2022) and adequate for our analyses (Lienert and Raatz, 1998).

3.4. Data analyses

To investigate differences between the two treatments and different points in time (pretest and posttest), we ran repeated measures multivariate analyses of variance (MANOVA) for each domain of research competence (affective-motivational and cognitive, respectively; H_1 and H_2). We also applied a MANOVA to investigate differences between the treatments regarding basic psychological need satisfaction and frustration (scale: BPNSFS) taking into account two time points of measurement (mid-term and posttest; H_3 and H_4). In a final step, we used oneway *t*-tests to check whether the values in research competence differed significantly from the scale mean. That is, we checked whether the values were significantly above or below the scale average. Because of using multiple testing, we corrected the significance level according to Bonferroni-Holm for each domain of research competence separately.

4. Results

We investigated whether differently structured learning environments affect the development of research competence in pre-service biology teachers (H_1 and H_2). Repeated measures MANOVA showed no significant time x treatment effect in the affective-motivational domain, $F(3, 103) = 1.16$, $p = 0.329$, $\eta_p^2 = 0.033$, indicating that the treatment did not affect the affective-motivational domain of research competence over the time. However, repeated measures MANOVA showed a large significant main effect (Cohen, 1988) of time on the affective-motivational domain of research competence, $F(3, 103) = 5.93$, $p < 0.001$, $\eta_p^2 = 0.147$. All affective-motivational domain subscales decreased over time (see Table 4).

Repeated measures MANOVA showed no significant time x treatment effect in the cognitive domain as well, $F(5, 102) = 0.58$, $p = 0.713$, $\eta_p^2 = 0.028$, indicating that the treatment did not affect the cognitive domain of research competence over time. However, repeated measures MANOVA showed a large significant main effect (Cohen, 1988) of time on the cognitive domain of research competence, $F(5, 102) = 19.57$, $p < 0.001$, $\eta_p^2 = 0.490$. While the affective-motivational domain's abilities decreased, the cognitive domain's abilities increased (see Table 5).

Moreover, we examined the effects of differently structured learning environments on pre-service biology teachers' basic psychological need satisfaction and frustration (scale: BPNSFS; H_3 and H_4). In the mid-term survey, the MANOVA showed no statistically significant differences between the treatments in any of the four subscales, $F(4, 103) = 1.28$, $p = 0.282$, $\eta_p^2 = 0.047$ (see Table 6). This also applies to the posttest, $F(4, 103) = 1.04$, $p = 0.389$, $\eta_p^2 = 0.039$ (see Table 6).

Regarding the oneway *t*-tests for the affective-motivational domain of research competence, results show no significant differences from the scale average for finding joy in conducting research in the pre- and posttest. We further found that the subscales value-related interest in research (pretest Cohen's $d = 0.62$; posttest Cohen's $d = 0.75$) and perceived benefits of research for practice (pretest Cohen's $d = 0.53$; posttest Cohen's $d = 0.58$) were significantly higher than the scale average in the pre- and posttest with a medium effect (see Table 7).

Regarding the oneway *t*-tests for the cognitive domain of research competence we found that the subscales skills in reflecting on research finding (pretest Cohen's $d = 0.68$; posttest Cohen's $d = 0.65$) and communication skills (pretest Cohen's $d = 0.77$; posttest Cohen's $d = 0.76$) were significantly higher than the scale average in the pre- and posttest with a medium effect. For the subscale content knowledge, we found significantly lower values than the scale average in the pretest with a medium effect (Cohen's $d = 0.64$), but no difference from the scale average in the posttest. Regarding the subscales skills in reviewing the state of research and methodological skills, no significant differences from the scale average were found in the pretest, whereas significant differences occurred in the posttest. In the posttest, the values were significantly higher than the scale average with a medium effect (skills in reviewing the state of research: Cohen's $d = 0.79$; methodological skills: Cohen's $d = 0.68$; see Table 8).

5. Discussion

In our study, we aimed to investigate whether differently structured learning environments affect the development of research competence in pre-service biology teachers (H_1 and H_2). Regarding the preconditions for developing research competence, we found that the degree of structure did not impact the pre-service teachers'

TABLE 1 List of scales used with sample item and Cronbach's alpha (α) of pretest and posttest regarding affective-motivational domain of research competence.

Subscale (number of items)	Time	Example	α
Finding joy in conducting research (11)	Pretest Posttest	I enjoy developing an own research question.	0.88 0.91
Value-related interest in research (6)	Pretest Posttest	Research in biology education contributes to solving current problems relevant to schools.	0.77 0.86
Perceived benefits of research for practice (6)	Pretest Posttest	Extensive scientific knowledge is important for coping with everyday school life.	0.66 0.77

TABLE 2 List of scales used with sample item and Cronbach's alpha (α) of pretest and posttest regarding cognitive domain of research competence.

Subscale (number of items)	Time	Example	α
Skills in reviewing the state of research (4)	Pretest Posttest	I know how and where to target a search of the state of research regarding biology education.	0.85 0.88
Methodological skills (7)	Pretest Posttest	I am able to plan a research process.	0.86 0.89
Skills in reflecting on research findings (5)	Pretest Posttest	I am able to adequately interpret my own research findings by relating them to key theories in biology education.	0.87 0.88
Communication skills (4)	Pretest Posttest	I can write up research findings in accordance with the current conventions in biology education.	0.77 0.81
Content knowledge (8)	Pretest Posttest	I have a good overview of the main (current) research findings in biology education.	0.87 0.89

TABLE 3 List of scales used with sample item and Cronbach's alpha (α) of mid-term survey and posttest regarding BPNSFS.

Subscale (number of items)	Time	Example	α
Autonomy satisfaction (4)	Mid-term Posttest	I feel a sense of choice and freedom in studying the online modules.	0.73 0.74
Autonomy frustration (4)	Mid-term Posttest	Most of the things in studying the online modules feel like "I have to."	0.84 0.86
Competence satisfaction (4)	Mid-term Posttest	I feel confident that I can do things regarding the online modules well.	0.84 0.89
Competence frustration (4)	Mid-term Posttest	I have serious doubts about whether I can do things regarding the online modules well.	0.84 0.82

TABLE 4 Means, standard deviations, and the results of the univariate analyses of variance (F- and p-values) concerning the subscales of the affective-motivational domain of research competence (main effect of time).

Subscales	Univariate			Pretest		Posttest	
	F^a	p	η_p^2	M	SD	M	SD
Finding joy in conducting research	8.64	0.004	0.076	3.14	0.75	2.99	0.81
Value-related interest in research	7.49	0.007	0.067	3.52	0.62	3.37	0.75
Perceived benefits of research for practice	8.58	0.004	0.076	3.63	0.53	3.48	0.58

[a]Univariate $df = 1, 105$. $N = 107$.

perceived competence or autonomy in both the satisfaction and frustration scales (H_3 and H_4). We assumed that the content-based questions between the sequences of the online modules could provide additional guidance but might also be perceived as control, thereby affecting the experience of competence positively and that one of autonomy negatively (see Jang et al., 2010; Eckes et al., 2018). Such effects cannot be found in our data. Perceiving competence is the result of expressing and expanding one's competencies in interacting with the environment (see Ryan and Deci, 2017). It might be that the online modules did not, or only to a small degree, allow such interaction. Furthermore, it could be that the pre-service teachers in the restrictive structured group experienced the structure as a kind of control and not as guidance in their learning process. However, this effect is rather unlikely, considering that the values for competence

TABLE 5 Means, standard deviations, and the results of the univariate analyses of variance (*F*- and *p*-values) concerning the subscales of the cognitive domain of research competence (main effect of time).

Subscales	Univariate			Pretest		Posttest	
	F^a	*p*	η_p^2	*M*	*SD*	*M*	*SD*
Skills in reviewing the state of research	51.82	< 0.001	0.328	2.98	0.84	3.53	0.79
Methodological skills	17.65	< 0.001	0.143	3.13	0.65	3.41	0.68
Skills in reflecting on research findings	7.99	0.006	0.070	3.32	0.68	3.52	0.65
Communication skills	7.73	0.006	0.068	3.42	0.77	3.63	0.76
Content knowledge	91.12	< 0.001	0.462	2.20	0.64	2.96	0.73

[a]Univariate $df = 1, 106$. $N = 108$.

TABLE 6 Means and standard deviations of the subscales of the BPNSFS in the middle (mid-term survey) and at the end of the course (posttest) for each treatment.

Subscales	Mid-term				Posttest			
	Non-restrictive structured		Restrictive structured		Non-restrictive structured		Restrictive structured	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Autonomy satisfaction	2.25	0.74	2.21	0.71	2.31	0.73	2.19	0.74
Autonomy frustration	3.78	0.69	3.73	0.83	3.68	0.90	3.66	1.01
Competence satisfaction	3.05	0.83	3.27	0.72	3.16	0.85	3.30	0.79
Competence frustration	2.72	0.85	2.37	0.81	2.52	0.90	2.23	0.75

Non-restrictive structured: $n = 56$; Restrictive structured: $n = 52$.

TABLE 7 Results of tests for significant deviation of the mean values from the scale average (M=3) of the subscales of the affective-motivational domain of research competence.

Subscales	Pretest				Posttest			
	M	*SD*	*t*(107)	*p*	*M*	*SD*	*t*(107)	*p*
Finding joy in conducting research	3.14	0.75	1.98	0.100	2.99	0.81	−0.16	0.872
Value-related interest in research	3.52	0.62	8.83	0.006	3.37	0.75	5.16	0.006
Perceived benefits of research for practice	3.63	0.53	12.55	0.006	3.48	0.58	8.69	0.006

TABLE 8 Results of tests for significant deviation of the mean values from the scale average (M=3) of the subscales of the cognitive domain of research competence.

Subscales	Pretest				Posttest			
	M	*SD*	*t*(107)	*p*	*M*	*SD*	*t*(107)	*p*
Skills in reviewing the state of research	2.98	0.84	−0.29	>0.999	3.53	0.79	6.93	0.010
Methodological skills	3.13	0.65	2.02	0.138	3.41	0.68	6.25	0.010
Skills in reflecting on research findings	3.32	0.68	4.96	0.010	3.52	0.65	8.26	0.010
Communication skills	3.42	0.77	5.68	0.010	3.63	0.76	8.73	0.010
Content knowledge	2.20	0.64	−13.14	0.010	2.96	0.73	−0.52	>0.999

satisfaction in both groups studied were moderate (see Table 6). These values indicate that the pre-service teachers in both groups perceived themselves as moderately competent in dealing with the content what should be highlighted positively.

A possible reason why no effects were detected on autonomy satisfaction and frustration is that the needs for competence and autonomy are mutually dependent (Krapp, 2005; Ryan and Deci, 2017). If no effects are found on one scale, no effects can be expected on the other scale. This can be explained as follows: To express and expand their competencies, individuals need autonomy (Krapp, 2005; Ryan and Deci, 2017). At the same time, autonomy is only needed if the individual possesses corresponding competencies (Krapp, 2005; Ryan and Deci, 2017). In our study, one might have expected that the pre-service teachers in the non-restrictive structured environment express a higher perception of autonomy since they had choices about their learning process. Apparently, the provided choice was not

perceived as meaningful (see Katz and Assor, 2007). This might stem from the fact that the choice was merely whether and when the pre-service teachers wanted to learn the content and whether they wanted to test themselves between the sequences of the online modules. Thus, the pre-service teachers were not allowed to choose what they wanted to learn; in addition, they had to learn the content anyway for the examination at the end of the semester, which took place shortly after our last survey. At this point, the pre-service teachers may experience themselves just as competent as the pre-service teachers in the restrictive structured group since they no longer had a choice to postpone learning the content. The decreasing abilities in the affective-motivational and the increasing ones in the cognitive domain lend credence to this assumption. To design meaningful choices, the pre-service teachers should have been given freedom of choice regarding the task content or difficulty.

Regarding the development of research competence (H_1 and H_2), our study shows that the pre-service teachers' self-assessed abilities in the affective-motivational domain decrease over time and increase in the cognitive domain (regardless of the treatment). Nevertheless, participants in our study rate their abilities in the affective-motivational domain as moderate in the pre- and posttest. This result is consistent with Schumacher (2020) findings on the affective-motivational domain in another sample of pre-service teachers. It should be emphasized that the pre-service biology teachers rated themselves significantly higher in the two subscales of the affective-motivational domain (value-related interest in research and perceived benefits of research for practice) before and after the intervention compared to the scale average. The decline of self-assessed abilities in the affective-motivational domain may be due to the perception that research is difficult to plan, complex, and open-ended. Pre-service teachers learn that the validity of results can be low and that results are (sometimes) only preliminary (Wessels et al., 2020). Moreover, the scientific work and statistical requirements present potential hurdles for pre-service teachers. Overcoming these hurdles could be complicated when having a lack of research methodological competence (Braguglia and Jackson, 2012; Riewerts et al., 2018), low research-related motivation (Fichten, 2010b), and a low interest in research (Vittengl et al., 2004; Braguglia and Jackson, 2012). Low motivation in dealing with research-related topics and low interest in these topics might stem from students perceiving the content of having little relevance to their future professional path (see Ryan and Deci, 2017). The increase in self-assessed abilities in the cognitive domain (regardless of treatment) indicates that the pre-service teachers learned about research. This can be underscored by the oneway *t*-test that we calculated for the content knowledge subscale. In the pretest the pre-service teachers rated themselves significantly lower compared to the scale average, but this was not significant in the posttest. This is also confirmed by the results of the oneway *t*-test for the subscales skills in reviewing the state of research and methodological skills. In both subscales, the pre-service teachers rated themselves significantly higher in the posttest compared to the scale average.

6. Limitations and implications

Although our findings provide important starting points for further research and teaching, we must address our study's limitations. A first limitation of this study is that the test instrument assessing research competence was based on the pre-service teachers' self-assessment, so bias may have occurred in their perceptions of their abilities. In future studies, a more objective measure, such as a knowledge performance test (pre- and posttest), should be implemented to check the adequacy of the pre-service teachers' self-perception. Moreover, it should be taken into account that the posttest does not take place immediately before an exam in order to avoid that the exam preparation affects the findings.

Second, this study did not assess whether the pre-service biology teachers perceived the given freedom of choice as such, that is, whether the choice was meaningful for the pre-service biology teachers. Therefore, measures to assess the perceived meaningfulness of choices might be integrated in future research (Meyer-Ahrens and Wilde, 2013). Moreover, freedom of choice could be operationalized differently in future studies. Freedom of choice can be given by choosing the context in which the content is taught, for example (practical vs. theoretical or the field of research) or by choosing the difficulty level of the tasks to assess one's knowledge. With a special focus on structuring the learning environment and, consequently, the perception of competence, integrating other learning aids, such as prompts, could also be considered.

Last, recording the use of the online modules, for example, the time the pre-service teachers spent dealing with them, would have helped interpret our results more precisely. In the non-restrictive structured group, it might be that the online modules were only clicked through, and the interim questions were not used for learning/self-monitoring.

7. Conclusion and contribution to the teaching and learning

In both treatments, the affective-motivational domain of research competence was rated lower and the cognitive domain higher in the posttest. This could speak for the fact, that the online modules have affected the cognitive domain positively. However, no differences between the treatments were found. Differences could not be found for the pre-service teachers' need satisfaction and frustration either. However, the moderate values that we found for the pre-service teachers' competence satisfaction indicate that the pre-service teachers in both groups (regardless of restriction) perceived themselves to be moderately competent in dealing with the content.

For teacher training, it can be summarized that (pre-service) biology teachers should be sensitized to the relevance of statistical knowledge and research competence, as these can be useful for their (later) professional practice (see Braguglia and Jackson, 2012). Research competence can, for example, offer innovative perspectives for the further development of the educational system or enrich personal development (Albert, 2016) and contributes to the acquisition or sustainability of professionalism (see Fichten, 2010a; Altrichter and Soukup-Altrichter, 2014; Albert, 2016). One way to gain this competence might be for pre-service teachers conduct own research or carry out relevant elements of a research process. In this way, they might experience the relevance and usefulness for their later professional practice. In this way, perceived competence may be fostered. Moreover, practical and specific content (relevant to schools) can lead to increased enjoyment of research (see Wessels et al., 2020). Teacher education might therefore emphasize the

practical value of research competence, as this can also increase skills in the affective-motivational domain (see Wessels et al., 2020).

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by Ethics committee of Bielefeld University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

JG and KS supervised the project. FS, JG, KS, and LFG developed the conception and design of the study. JG, LFG, and LG collected the data. LG wrote the manuscript and made the statistical analyses with the support of FS, JG, and NG. FS, JG, KS, LFG, and NG have proofread the manuscript. All authors contributed to the article and approved the submitted version.

Funding

The authors acknowledge support for the Article Processing Charge from the DFG (German Research Foundation, 491454339).

Conflict of interest

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

Publisher's note

References

Albert, S. (2016). Die Bedeutung der reflexiven Selbstforschung für die Professionalisierung von Lehrpersonen [The importance of reflexive self-exploration for teacher professionalization]. *HiBiFo* 5, 35–46. doi: 10.25656/01:20338

Altrichter, H., and Soukup-Altrichter, K. (2014). "Lernen in der Lehrer_innenbildung durch Forschung [Learning in teacher education through research]" in *Last oder Lust? Forschung und Lehrer_innenbildung*. eds. E. Feyerer, K. Hirschenhauser and K. Soukup-Altrichter, (Göttingen: Waxmann), 55–76.

Ball, C., and Pelco, L. (2006). Teaching research methods to undergraduate psychology students using an active cooperative learning approach. *Int. J. Teach. Learn. High. Educ.* 17, 147–154.

Barr, R. B., and Tagg, J. (1995). From teaching to learning—a new paradigm for undergraduate education. *Change* 27, 12–26. doi: 10.1080/00091383.1995.10544672

Baumert, J., and Kunter, M. (2013). "The COACTIV model of teachers' professional competence" in *Cognitive activation in the mathematics classroom and professional competence of teachers: results from the COACTIV project*. eds. M. Kunter, J. Baumert, W. Blum, U. Klusmann, S. Krauss and M. Neubrand (Boston, MA: Springer US), 25–48.

Blömeke, S., Gustafsson, J.-E., and Shavelson, R. J. (2015). Beyond dichotomies: competence viewed as a continuum. *Z. Psychol.* 223, 3–13. doi: 10.1027/2151-2604/a000194

Bloom, B. S. (1978). New views of the learner: implications for instruction and curriculum. *Educ. Leadersh.* 35, 563–576.

Bologna Process Committee. (1999). Joint declaration of the European ministers of education convened in Bologna on 19 June 1999. Bologna Declaration.

Borg, S. (2010). Language teacher research engagement. *Lang. Teach.* 43, 391–429. doi: 10.1017/S0261444810000170

Böttcher, F., and Thiel, F. (2017). *Ergebnisse der Evaluation der Forschungsorientierten Lehre (FoL) an der Freien Universität Berlin [Results of the evaluation of research-oriented teaching (FoL) at Freie Universität Berlin]*. (Berlin: Freien Universität Berlin).

Böttcher, F., and Thiel, F. (2018). Evaluating research-oriented teaching: a new instrument to assess university students' research competences. *High. Educ.* 75, 91–110. doi: 10.1007/s10734-017-0128-y

Braguglia, K. H., and Jackson, K. A. (2012). Teaching research methodology using a project-based three course sequence critical reflections on practice. *Am. J. Bus. Educ.* 5, 347–352. doi: 10.19030/ajbe.v5i3.7007

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale, MI: Lawrence Erlbaum Associates.

Deicke, W., Gess, C., and Ruess, J. (2014). Increasing students' research interest through research-based learning. *CUR Quart.* 35, 27–34.

DeVellis, R. F., and Thorpe, C. T. (2022). *Scale development. Theory and applications*. Thousand Oaks, CA: SAGE Publications, Inc.

Earley, M. A. (2014). A synthesis of the literature on research methods education. *Teach. High. Educ.* 19, 242–253. doi: 10.1080/13562517.2013.860105

Eckes, A., Großmann, N., and Wilde, M. (2018). Studies on the effects of structure in the context of autonomy-supportive or controlling teacher behavior on students' intrinsic motivation. *Learn. Individ. Differ.* 62, 69–78. doi: 10.1016/j.lindif.2018.01.011

Fichten, W. (2010a). "Forschendes Lernen in der Lehrerbildung [Inquiry-based learning in teacher education]" in *Neue Impulse in der Hochschuldidaktik*. ed. U. Eberhardt (Wiesbaden: VS Verlag für Sozialwissenschaften), 127–182.

Fichten, W. (2010b). "Konzepte und Wirkungen forschungsorientierter Lehrerbildung [Concepts and effects of research-oriented teacher education]" in *Wirkt Lehrerbildung? Antworten aus der empirischen Forschung*. eds. J. Abel and G. Faust (Münster: Waxmann), 271–281.

Fichten, W., and Meyer, H. (2014). "Skizze einer Theorie forschenden Lernens in der Lehrer_innenbildung [Outline of a theory of inquiry-based learning in teacher education]" in *Last oder Lust? Forschung und Lehrer_innenbildung*. eds. E. Feyerer, K. Hirschenhauser and K. Soukup-Altrichter (Münster: Waxmann), 11–42.

Gess, C., Deicke, W., and Reichow, I. (2017). "Kompetenzentwicklung durch Forschendes Lernen [Competence development through inquiry-based learning]" in *Forschendes Lernen. Wie die Lehre in Universität und Fachhochschule erneuert werden kann*. eds. H. A. Mieg and J. Lehmann (Frankfurt/New York: Campus Verlag), 79–90.

Gess, C., Ruess, J., and Blömeke, S. (2019). Ein fach- und paradigmenübergreifendes Modell der Forschungskompetenz in den Sozialwissenschaften [A cross-disciplinary and cross-paradigm model of research competence in the social sciences]. *ZeHf – Zeitschrift für empirische Hochschulforschung* 3, 7–27. doi: 10.3224/zehf.v3i1.02

Hochschulrektorenkonferenz (HRK), Kultusministerkonferenz (KMK), Bundesministerium für Bildung und Forschung (BMBF). (2017). Qualifications framework for German higher education degrees. *German Rectors' Conference, Secretariat of the Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany, and Federal Ministry of Education and Research*. Available at: https://www.hrk.de/fileadmin/redaktion/hrk/02-Dokumente/02-03-Studium/02-03-02-Qualifikationsrahmen/HQR_EN.pdf

Heissel, A., Pietrek, A., Flunger, B., Fydrich, T., Rapp, M. A., Heinzel, S., et al. (2018). The validation of the German basic psychological need satisfaction and frustration scale in the context of mental health. *Eur. J. Health Psychol.* 25, 119–132. doi: 10.1027/2512-8442/a000017

Humpert, W., Hauser, B., and Nagl, W. (2006). Was (zukünftige) Lehrpersonen über wissenschaftliche Methoden und Statistik Wissen sollen und wollen [What (future) teachers should and want to know about scientific methods and statistics]. *Beiträge zur Lehrerbildung* 24, 231–244. doi: 10.25656/01:13627

Jang, H., Reeve, J., and Deci, E. L. (2010). Engaging students in learning activities: it is not autonomy support or structure but autonomy support and structure. *J. Educ. Psychol.* 102, 588–600. doi: 10.1037/a0019682

Johnson, L., Adams Becker, S., Estrada, V., Freeman, A., Kampylis, P., Vuorikari, R., et al. (2014). Horizon report Europe: 2014 schools edition. Luxembourg: Publications Office of the European Union, and Austin, Texas: The New Media Consortium.

Katz, I., and Assor, A. (2007). When choice motivates and when it does not. *Educ. Psychol. Rev.* 19, 429–442. doi: 10.1007/s10648-006-9027-y

Klieme, E., and Leutner, D. (2006). Kompetenzmodelle zur Erfassung individueller Lernergebnisse und zur Bilanzierung von Bildungsprozessen. Beschreibung eines neu eingerichteten Schwerpunktprogramms der DFG [Competence models for recording individual learning outcomes and for balancing educational processes. Description of a newly established priority program of the DFG.]. *Z. für Pädagog.* 52, 876–903. doi: 10.25656/01:4493

Koeppen, K., Hartig, J., Klieme, E., and Leutner, D. (2008). Current issues in competence modeling and assessment. *Z. für Psychol./J. Psychol.* 216, 61–73. doi: 10.1027/0044-3409.216.2.61

Krapp, A. (2005). Basic needs and the development of interest and intrinsic motivational orientations. *Learn. Instr.* 15, 381–395. doi: 10.1016/j.learninstruc.2005.07.007

Kunter, M. (2011). Theorie meets praxis in der Lehrerbildung – Kommentar [Theory meets practice in teacher education – commentary]. *Erziehungswissenschaft* 22, 107–112. doi: 10.25656/01:5434

Kunter, M., Kleickmann, T., Klusmann, U., and Richter, D. (2013). "The development of teachers' professional competence" in *Cognitive activation in the mathematics classroom and professional competence of teachers: Results from the COACTIV project*. eds. M. Kunter, J. Baumert, W. Blum, U. Klusmann, S. Krauss and M. Neubrand (Boston, MA: Springer US), 63–77.

Kunter, M., Pohlmann, B., and Decker, A.-T. (2020). "Lehrkräfte [Teachers]" in *Pädagogische Psychologie*. eds. E. Wild and J. Möller (Berlin, Heidelberg: Springer), 269–288.

Lienert, G. A., and Raatz, U. (1998). *Testaufbau und Testanalyse [Test setup and test analysis]*. Weinheim: Psychologie Verlags Union.

Mandinach, E. B., and Gummer, E. S. (2016). Every teacher should succeed with data literacy. *Phi Delta Kappan* 97, 43–46. doi: 10.1177/0031721716647018

Meyer-Ahrens, I., and Wilde, M. (2013). Der Einfluss von Schülerwahl und der Interessantheit des Unterrichtsgegenstandes auf die Lernmotivation im Biologieunterricht [The influence of student choice and the interestingness of the subject matter on motivation to learn in biology classes]. *Unterrichtswissenschaft* 41, 57–71.

Ministerium für Schule und Weiterbildung des Landes NRW [MSW NRW]. (2010). Rahmenkonzeption zur strukturellen und inhaltlichen Ausgestaltung des Praxissemesters im lehramtsbezogenen Masterstudiengang [Framework concept for the structural and content-related design of the internship semester in the teaching-related Master's program]. Available at: https://www.zfsl.nrw.de/system/files/media/document/file/obh_ps_rahmenkonzept.pdf

Mkrttchian, V., and Belyanina, L. (2018). *Handbook of research on students' research competence in modern educational contexts*. Hershey, PA: IGI Global.

Naidu, S. (2017). How flexible is flexible learning, who is to decide and what are its implications? *Distance Educ.* 38, 269–272. doi: 10.1080/01587919.2017.1371831

Organisation for Economic Cooperation and Development [OECD]. (2005). *Teachers matter: attracting, developing and retaining effective teachers*. Paris: OECD Publishing.

Reeve, J., and Jang, H. (2006). What teachers say and do to support students' autonomy during a learning activity. *J. Educ. Psychol.* 98, 209–218. doi: 10.1037/0022-0663.98.1.209

Reeve, J., Nix, G., and Hamm, D. (2003). Testing models of the experience of self-determination in intrinsic motivation and the conundrum of choice. *J. Educ. Psychol.* 95, 375–392. doi: 10.1037/0022-0663.95.2.375

Riewerts, K., Weiß, P., Wimmelmann, S., Saunders, C., Beyerlin, S., Gotzen, S., et al. (2018). Forschendes Lernen entdecken, entwickeln, erforschen und evaluieren [Discover, develop, explore, and evaluate inquiry-based learning]. *die hochschullehre* 4, 389–406.

Ryan, R. M., and Deci, E. L. (2002). "Overview of self-determination theory: an organismic dialectical perspective" in *Handbook of self-determination research*. eds. E. L. Deci and R. M. Ryan (New York: University of Rochester Press), 3–33.

Ryan, R. M., and Deci, E. L. (2017). *Self-determination theory: basic psychological needs in motivation, development, and wellness*. New York, NY: The Guilford Press.

Ryan, R. M., and Deci, E. L. (2020). Intrinsic and extrinsic motivation from a self-determination theory perspective: definitions, theory, practices, and future directions. *Contemp. Educ. Psychol.* 61:101860. doi: 10.1016/j.cedpsych.2020.101860

Schumacher, F. (2020). Konstruktivistisch, forschend-reflexiv und digital. Hochschuldidaktische Maßnahmen zur Entwicklung der professionellen Handlungskompetenz angehender Biologielehrkräfte [Constructivist, research-reflexive and digital. University education measures for developing the professional competence of prospective biology teachers] Bielefeld: Universität Bielefeld. doi: 10.4119/unibi/2950000

Secretariat of the Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany [KMK]. (2019a). Ländergemeinsame inhaltliche Anforderungen für die Fachwissenschaften und Fachdidaktiken in der Lehrerbildung [Content requirements for subject-related studies and subject-related education in teacher training which apply to all Länder]. Available at: https://www.kmk.org/fileadmin/Dateien/veroeffentlichungen_beschluesse/2008/2008_10_16-Fachprofile-Lehrerbildung.pdf

Secretariat of the Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany [KMK]. (2019b). Standards für die Lehrerbildung: Bildungswissenschaften [Standards for teacher training in the educational sciences]. Available at: https://www.kmk.org/fileadmin/veroeffentlichungen_beschluesse/2004/2004_12_16-Standards-Lehrerbildung-Bildungswissenschaften.pdf

Sizemore, O. J., and Lewandowski, G. W. (2009). Learning might not equal liking: research methods course changes knowledge but not attitudes. *Teach. Psychol.* 36, 90–95. doi: 10.1080/00986280902739727

Spronken-Smith, R. (2005). Implementing a problem-based learning approach for teaching research methods in geography. *J. Geogr. High. Educ.* 29, 203–221. doi: 10.1080/03098260500130403

Stark, R., and Mandl, H. (2000). "Training in empirical research methods: analysis of problems and intervention from a motivational perspective" in *Advances in psychology*. ed. J. Heckhausen (Amsterdam: Elsevier), 165–183.

The German Science and Humanities Council. (2006). *Empfehlungen zur zukünftigen Rolle der Universitäten im Wissenschaftssystem [Recommendations on the future role of universities in the science system]*. (Berlin/Köln: The German Science and Humanities Council).

Thiel, F., and Böttcher, F. (2014). "Modellierung fächerübergreifender Forschungskompetenzen: das RMKR-W-Modell als Grundlage der Planung und evaluation von Formaten forschungsorientierter Lehre [modeling interdisciplinary research competencies: the RMKR-W model as a basis for planning and evaluating formats of research-oriented teaching]" in *Neues Handbuch Hochschullehre*. eds. B. Berendt, A. Fleischmann, J. Wildt, N. Schaper and B. Szczyrba (Berlin: Raabe), 109–124.

van Loon, A.-M., Ros, A., and Martens, R. (2012). Motivated learning with digital learning tasks: what about autonomy and structure? *Educ. Technol. Res. Dev.* 60, 1015–1032. doi: 10.1007/s11423-012-9267-0

Vittengl, J., Bosley, C., Brescia, S., Eckardt, E., Neidig, J., Shelver, K., et al. (2004). Why are some undergraduates more (and others less) interested in psychological research? *Teach. Psychol.* 31, 91–97. doi: 10.1207/s15328023top3102_3

Weinert, F. E. (2001). "Concept of competence: a conceptual clarification" in *Defining and selecting key competencies*. eds. D. S. Rychen and L. H. Salganik (Seattle, WA: Hogrefe and Huber Publishers), 45–65.

Wessels, I., Rueß, J., Gess, C., Deicke, W., and Ziegler, M. (2020). Is research-based learning effective? Evidence from a pre–post analysis in the social sciences. *Stud. High. Educ.* 46, 2595–2609. doi: 10.1080/03075079.2020.1739014

Wessels, I., Rueß, J., Jenßen, L., Gess, C., and Deicke, W. (2018). Beyond cognition: experts' views on affective-motivational research dispositions in the social sciences. *Front. Psychol.* 9, 1–10. doi: 10.3389/fpsyg.2018.01300

Zlatkin-Troitschanskaia, O., Shavelson, R. J., and Kuhn, C. (2015). The international state of research on measurement of competency in higher education. *Stud. High. Educ.* 40, 393–411. doi: 10.1080/03075079.2015.1004241