



# Interactions of Feelings of Competence and Motivation of Pre-Service Science Teachers in Their Laboratory Course: A Dynamic Multilevel Modeling Approach

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Dynamic structural equation modeling was applied to examine feelings of competence and in the moment motivation among pre-service science teachers ( $N = 101$ ) enrolled in a course on practical biology during their second semester. The student teachers completed a short questionnaire 18 times, and the interaction between their feelings of competence and momentary motivation over time was examined in relation to control-value theory. The autoregressive values of both variables were significant, and a pattern was observed of low competence at the beginning of the course session, combined with low motivation in the moment. Feelings of competence increased by the end of each course session but returned to a low level at the beginning of the next session. Momentary motivation followed this back-and-forth shifting somewhat but showed more carryover effects. The student teachers' motivation depended on their feelings of competence from the previous moment in the biology course session, but feelings of competence did not depend on their motivation.

**Keywords:** trait-state affect, competence, situational motivation, science teacher education, dynamic structural equation modeling

## INTRODUCTION

A teacher's competence is viewed as a multitude of cognitive abilities and affect motivation states that change throughout the teaching process (Blömeke et al., 2015). The assessment of competence development during a higher-education course presents substantive and methodological challenges. According to Blömeke et al. (2015), it should include the examination of developmental trajectories of competence and its latent cognitive and affective-motivational underpinning of domain-specific performance in varying situations. For example, when student teachers experience success in learning situations during a course, they feel in control of their studies and exert volitional effort or persist in their career. Research indicates that affective experiences, such as feeling confident, are highly relevant for the development of pre-service teachers' strong beliefs in their competence during their education (Hong, 2012; Tobin and Ritchie, 2012). One could argue that pride and enjoyment are more typical affects or emotions than feelings of competence and motivation in the moment; however, based on our experience, student teachers report experiencing these emotions less often during academic course sessions. Course-related tasks to be completed are not self-selected; their purpose is to promote skills acquisition related to work (not

pleasure), and are often linked to exams. Our assumptions are supported by studies indicating that intrinsic motivation is not the primary influencer of pre-service teachers' learning (Malmberg, 2006; König and Rothland, 2012).

A crucial point of our study is the distinction between state and trait in the characterization of affects. Rosenberg (1998) describes an affective trait as a typical way of responding to a situation that is different for each person but does not change much over time. For example, a student teacher might have a fondness for mathematics (affective trait) and indicate general enjoyment of mathematics. Meanwhile, an affective state (e.g., motivation in the moment) delineates a response to a shifting environment based on the situation and changes over time. In the present study, the focus was on affective states, although we also investigated relationships between related states and traits. For example, the feeling of satisfaction with one's competence during a physical-education task might serve as a source of self-efficacy (Raven and Pels, 2021). Similarly, repeated experiences of a certain situational motivation may influence the development of a stable motivational disposition (Dietrich et al., 2015). According to Turner and Patrick (2008), much of motivation research so far has separated individuals from their contexts, and failed to capture the dynamic and situational nature of motivation.

Meyer and Turner (2006) state that the feeling of being in control of one's learning might influence how a student perceives the learning experience, and thus, change their motivation to learn. Goudas et al. (1995) showed that perceptions of competence among university physical-education students at the beginning of a course were predictive of their intrinsic motivation at the end of the course, which was mediated by their performance. When undergraduate science students experience learning tasks that correspond to their level of competence as personally meaningful and interesting, frustration and boredom are prevented, and motivation in the moment (e.g., momentary enjoyment or flow) is stimulated (DeHaan, 2005). In addition, there is a clear connection between the experience of feeling competent in a given subject area and success in learning that subject. Ruys et al. (2010) showed that student teachers' feelings of competence in the implementation of an instructional innovation was associated with their higher rating of their perceived value of the innovation, their expectancy of success, and lower rating of their perceived costs of implementation. This finding indicates that momentary feelings of competence and motivation in the moment are connected in a timely manner when learners are actively engaged with their learning tasks. It is unclear how these two variables regulate each other over a longer period, for example, over a typical semester at a university.

The present study is novel in that it treats pre-service teacher affective experiences in a science laboratory course as longitudinal momentary data, and compares the bidirectional cross-lagged effects between repeated individual outcomes of feelings of competence and state motivation simultaneously in a unified autoregressive model. According to the control-value theory of Pekrun (2006), such affective experiences are linked by reciprocal causation over time within individuals. Hence, the

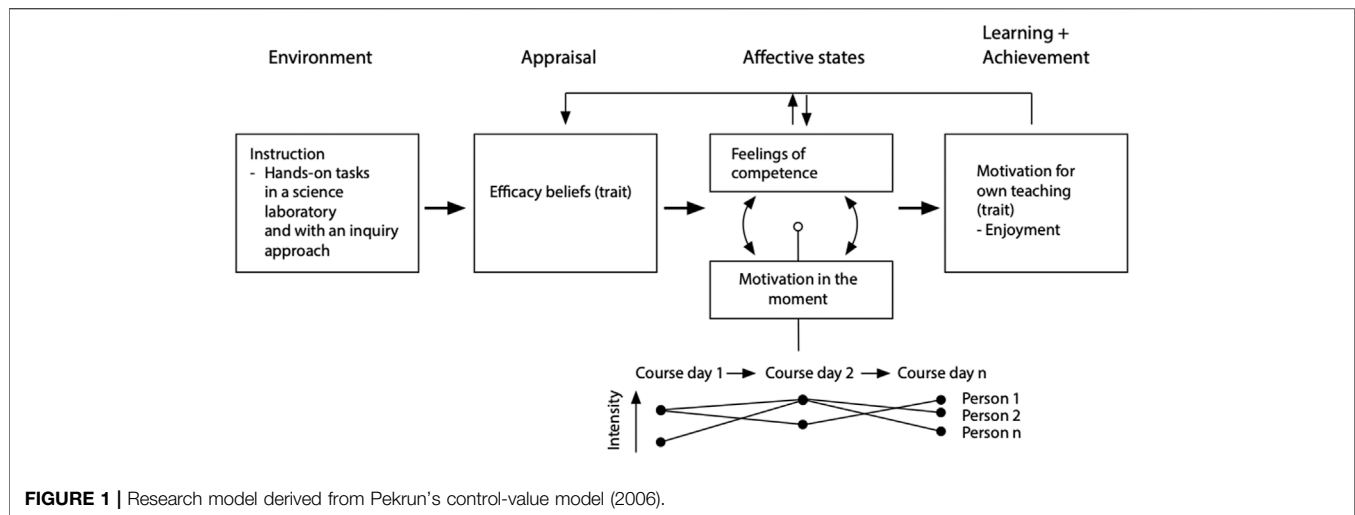
underlying research question is whether increases in preceding momentary feelings of competence predict increases in state motivation at the next measurement, and whether state motivation predicts subsequent measurements of feeling competent over time.

## Affective Traits and States and Their Regulation Over Time

Affect refers to consciously accessible feelings. An affective state, such as feeling competent in the moment, arises in response to particular stimuli and is characterized by a situation-specific appraisal function (Fiedler and Beier, 2014). Affective states evolve from feelings when accompanied by specific thoughts, such as one's judgment of an event (Zembylas, 2003; Scherer, 2005; Frenzel et al., 2016). An emotion, which is distinct from an affect is relatively more object-oriented and short-lived (Fredrickson, 2001). Nevertheless, all references to affective states in this study, which are short-lived and situation-based, include emotions (Linnenbrink, 2006; Ainley and Hidi, 2014). This approach to affect is in line with Ainley (2006), who studied the role of affect in students' learning about how they are feeling as they work through tasks in university courses. Each state has an antecedent in the form of the disposition (trait) the student teacher brings to the learning experience and consequences of the student teachers' performance, as postulated in latent state-trait theory (Steyer et al., 2015). In the following paragraph, we briefly describe our two constructs of interest before explaining their interactions over time in more detail.

The view we have of ourselves is not determined only by our cognition; it is also influenced by our affect and how we feel about ourselves. A self-esteem trait, such as feeling competent, is, in part, a stable trait over time; however, self-esteem is also a state that varies from day to day and even hour to hour. Students pursuing teacher education, experience mastery with each success, which builds their confidence, until eventually, they feel totally competent and confident in their teaching performance (Bandura, 1977). Overlaps have been found between self-esteem and affective states (Brown and Marshall, 2001). As part of the development of their state self-esteem instrument, Heatherton and Polivy (1991) measured self-confidence in one's abilities.

Although motivation is mostly defined as a trait, it also has aspects of a state in learning situations. Ainley and Hidi (2014) proposed that situational interest, a construct similar to motivation (Krapp, 1999), can be viewed as an in-the-moment experience or an affective state in performance situations. Furthermore, motivational intensity, which refers to the strength of the motivation, is defined as a dimension of affect. Within a given motivational direction (e.g., approach), motivation can range from low to high intensity (Gable and Harmon-Jones, 2010). Finally, students' motivation can be contextualized in particular activities, persons, discourse, and materials at specific places and times, and it can change from one situation to the next (Turner and Patrick, 2008). A situated approach to motivation, such as this study's method, seeks to understand how learners' motivation develops over time.



Following the control-value theory of Pekrun (2006), some of the affects experienced during scientific activities in laboratory courses are considered achievement emotions. **Figure 1** shows the influence of the learning environment on the affect experienced by student teachers: when more self-determination or self-regulation is involved in activities, for instance, feelings of competence will be more likely to develop. Pekrun further assumes that achievement emotions are determined by control and value appraisals. For example, a student teacher who finds an experiment to be pleasant and going well is likely to enjoy the activity. Furthermore, cognitive appraisals, such as self-efficacy (control) and perceptions of usefulness (value) are antecedents of emotions, although emotions can have a reciprocal effect on these appraisals. If the lab activity (e.g., animal dissection) and the material to which it relates (e.g., a fish) are positively valued (e.g., is interesting), and if the activity is perceived to be sufficiently controllable by the individual, motivation in the moment is assumed to be instigated, and feelings of competence will emerge (*see Figure 1*). As for outcomes, the affective state can induce and modulate the student teachers' motivation to learn. A positive affective state, such as motivation in the moment, is assumed to strengthen habitual intrinsic motivation. The individual and social antecedents of affective states or emotions and their effects are linked by reciprocal causation over time. For example, motivational outcomes, such as habitual enjoyment, are part of a teacher's motivation to use specific instructional practices that are part of the teacher's valued appraisals (Ryan and Deci, 2000; Lam et al., 2008). Overall, success in the completion of lab tasks influences student teachers' control appraisals, values, and habitual self-efficacy beliefs. It also influences their future goals and instructional methods for teaching (Wang et al., 2017). Reciprocal causation can also include positive feedback loops of affective states (e.g., the mutual reinforcement of feeling motivated [enjoyment] and feeling competent). The dynamics of the feedback loops occur during various stages of the lab task, the course day, the entire semester, and throughout the 4-year study period. Typically, the

affect or emotion regulation increases positive emotions. Pre-service teachers can regulate their achievement emotions by 1) coping with emotions (using relaxation techniques, sharing their experiences with others); 2) addressing the control and value antecedents of emotions (e.g., changing the value: the experiment learned is not useful for classroom practice); 3) improving knowledge and skills to gain more control (e.g., asking peers to repeat explanations); and 4) changing the situational circumstances with respect to control and value (e.g., dropping out of a course). We will address some of these aspects in the discussion section.

No empirical findings on the interaction over time of feelings of competence and state motivation were available in the current literature; however, research closely related to our constructs was found. Malmberg et al. (2013) explored the effects of situation-specific competence beliefs operationalized as the amount of task-related success and understanding. These momentary measurements of day-to-day competence beliefs have been shown to be differentially and negatively related to task difficulty, and differentially and positively related to situation-specific effort exertion (Malmberg et al., 2013). Dietrich et al. (2015) reported that student teachers with higher dispositional success expectations (control beliefs) were more likely to experience states of high motivation during a lecture. Glowinski and Bayrhuber (2011) studied the development of situational interest in a lab-visit program. In such activity-based learning environments with a high proportion of hands-on activities, the experience of competence can be assumed to be critical to the development of students' interest. The study showed that for upper secondary students, the experience of competence was a crucial factor in predicting students' momentary interest. The authors state that this result indicates the importance of prior subject knowledge and being in control while engaged in practical work in student labs (Glowinski and Bayrhuber, 2011).

In a completely different context, namely HIV medication adherence, higher momentary control belief values, which are comparable to feelings of competence, predicted higher in-the-

moment motivation (Cook et al., 2018). Similarly, in a study by Malmberg and Martin (2019), a strong belief in the momentary competence of primary school students led to a diminished belief in their momentary autonomous motivation. Salanova et al. (2014) showed that collective task-specific self-efficacy beliefs (i.e., confidence, competence, and ability) predicted collective momentary flow for motivation (e.g., enjoyment) over time, both of which were reciprocally related. Finally, Niemivirta and Tapola. (2007) studied the dynamic interplay of task-specific self-efficacy and situational interest in secondary school classes using latent growth curve modeling. Although self-efficacy beliefs developed positively while conducting problem-based tasks, interest remained at initial levels. They further found that an increase/decrease in self-efficacy during the task was related to an increase/decrease in interest (and vice versa), which indicated a parallel change over time. However, the causal order could not be clarified. Hence, although the direction of the action is mostly from feelings of competence to motivation in the moment, reciprocal effects might exist, and the interaction requires further clarification.

## Research Model to Disentangle the Temporal and Causal Relations of Affects

To investigate the dynamic interactions of variables over time, researchers have often turned to cross-lagged models. As part of this procedure, at least two variables are measured repeatedly. Then, the cross-lagged relations are compared, and at the same time, they need to be controlled for the effects that the variables at the preceding time points have on themselves (Schuurman et al., 2016). The repeated measurements and the fitting of these measurements in a cross-lagged model allow for the examination of associations between variables while concurrently considering the time pattern of the process.

Momentary or experience sampling data can be analyzed as longitudinal data if the time order remains intact, meaning that the longitudinal data are not condensed to achieve a single estimate of affect for each student teacher. This process makes it possible to analyze the bidirectional nature of affect (e.g., “Do feelings of competence predict momentary motivation and vice versa?”). This combination of the cross-lagged model and time series makes it possible to investigate the tendency of a variable to persist in a particular state. Such stability or “inertia” can be described as the “carryover” of a variable. It is defined as the autoregression of that variable; in other words, it is one occasion that predicts the subsequent occasion (Schuurman et al., 2016). In our study, the appropriate question was: “Does the last feeling of competence in a biology course predict a momentary feeling of competence?” In situations where data consist of repeated measurements from the same person, it is necessary to account for this carryover or stability before bidirectional effects or external predictors can be considered (Hamaker and Wichers, 2017). This is done by modeling the autoregression. Hence, it is essential to ask: “Does the momentary feeling of competence predict the next time’s motivation in the moment above and beyond the motivation in the moment?” Dynamic structural equation modeling (DSEM) consists of multilevel

analyses while allowing for the examination of paths typical of cross-lagged autoregressive models (Hamaker et al., 2018). The DSEM framework merges multilevel modeling, structural equation modeling, time-series modeling, and time-varying effect modeling.

## Research Questions

Our research questions were:

1. a) Is pre-service teachers’ subsequent trait self-efficacy in conducting experiments predicted by their state feelings of competence? and b) are their state feelings of competence predicted by previous trait self-efficacy?
2. a) Is pre-service teachers’ subsequent trait enjoyment (intrinsic motivation) predicted by their state motivation? and b) is their state motivation predicted by their previous trait enjoyment?
3. Do previous feelings of competence in the biology course predict subsequent state motivation of pre-service teachers and vice versa?
4. Do pre-service teachers differ in their feelings of competence and motivation in the moment over time?

## METHODS

### Research Design, Data Collection, and Sample

This study used an intensive, non-experimental, longitudinal pretest-posttest design. “Intensive” implies that we collected repeated measurements frequently to allow us to characterize a separate development process for each subject (Bolger and Laurenceau, 2013). “Characterizing” refers to our examination of developmental patterns.

Experience sampling is a group of data collection methods for collecting self-reports of experiences related to a connected event. In this study, the experience sampling method (ESM) was used for the momentary assessment of student teachers in lab situations. Hence, it allows for repeated measurements of affects occurring in a prospective and ecologically valid manner (Csikszentmihalyi and Larson, 1987; Peeters et al., 2003). Unlike retrospective questionnaires and interviews, ESM has several benefits: 1) reliability is enhanced because the student teachers’ experiences are assessed repeatedly; 2) retrospective bias is minimized because student teachers’ experiences are assessed in the moment; and 3) ecological validity is enhanced because the student teachers are assessed in their daily (normal) university environment.

The data for this study were collected during two secondary pre-service teacher-training courses on performing practical tasks and experiments in biology during the autumn semester in either 2018 or 2019 at the St. Gallen University of Teacher Education. Practical work is an inherent feature of science subjects, firmly embedded “inside” the science’s subject domains. Secondary science teachers in Switzerland are prepared to teach science, technology, engineering, and mathematics (STEM) subjects as well as non-STEM subjects. The science course is required of every secondary pre-service science teacher in the second

**TABLE 1** | Unstandardized parameter estimates for the multilevel autoregressive model explaining the effects of feelings of competence (state) on pre-service teachers' self-efficacy for conducting biology experiments (trait variable on the between level).

Parameters	Estimate	Posterior SD	95% CI LL	95% CI UL
<i>Fixed effects</i>				
Competence (state) intercept	3.15 <sup>a</sup>	0.42	2.33	3.96
Self-efficacy t2 (trait) intercept	2.65 <sup>a</sup>	0.62	1.39	3.83
Autoregressive effects $Comp_{t-1} \rightarrow Comp_t$	-0.08	0.04	-0.15	0.01
Competence (state) $\rightarrow$ Self-efficacy t2 (trait)	0.42 <sup>a</sup>	0.16	0.10	0.75
Self-efficacy t1 (trait) $\rightarrow$ Competence (state)	0.12	0.10	-0.007	0.31
<i>Random effects</i>				
$Comp_{t-1} \rightarrow Comp_t$	0.07 <sup>a</sup>	0.02	0.04	0.11
Competence (state)	0.35 <sup>a</sup>	0.06	0.25	0.49
Self-efficacy t2 (trait)	0.58 <sup>a</sup>	0.10	0.43	0.80

<sup>a</sup>Significance was based on the credible interval (CI) not containing zero. LL, lower limit; UL, upper limit.

semester of studies at the university. One aim of the course is to provide an explicit model of how experiments are designed and conducted as part of teaching scientific inquiry. There is a special focus on applying the control-of-variables strategy. As the demands of the course for pre-service teacher lab skills are high, the inquiry process is structured (Banchi and Bell, 2008). To promote fruitful learning exchanges, the course was offered to small groups of approximately eight students, each of whom completed a short electronic questionnaire on tablets or mobile devices during each course session. Before and after the course, a longer survey was conducted to measure students' attitudes. Finally, an oral test related to the course content was administered by two course lecturers.

Our study included all participants listed in two consecutive first-year science experimentation courses ( $N = 101$ ). All secondary pre-service teachers in our institution must study four school subjects to earn a Master of Science in secondary education. The school subject "science and technology" consists of biology, chemistry, and physics content. In their second semester, the students take a course in practical biology. In this course, the student teachers worked on experiments in the field of human physiology or microbiology during the nine lessons ( $9 \times 2$  h). Men and women were equally distributed among the sample. The mean age of the pre-service teachers was 23 years ( $SD = 4.6$ ).

## Instruments

### Momentary Affects (States)

Self-reporting takes time, and as such, it is not optimally suited to assess the real-time dynamics of affective states in a classroom (Pekrun, 2016). One strategy is to reduce the number of questionnaire items to avoid compromising the assessment of momentary or in-the-moment affects (Goetz et al., 2016). The use of a few single items has been successful in other research to avoid overly intrusive state-based questionnaires in studies (Goetz et al., 2010; Becker et al., 2014).

In the present study, a short online questionnaire on handheld devices was administered during each lesson of the course, with two items related to the momentary feelings of competence and motivation. These are typical affects in the emotional life of novice teachers (Bullough, 2009), and are important in relation to lab work (Itzek-Greulich and Vollmer, 2017). The

exact wording was: "Please state how you feel right now: 1) I am motivated, 2) I feel competent."

The participants were asked to complete this short survey twice during each lesson: immediately before they started conducting experiments, and immediately after they conducted the last experiment. We used a 6-point Likert scale to assess student's level of agreement/disagreement with the item's statements indicating a certain feeling at that time (6 = *absolutely agree*, 5 = *agree*, 4 = *somewhat agree*, 3 = *somewhat disagree*, 2 = *disagree*, and 1 = *absolutely disagree*). The measurement of an item twice (beginning and end) during each course session yielded 18 measurements for each student and item over time. Means and standard deviations are reported in **Tables 1, 2**.

### Attitudes (Traits)

Before and at the end of the semester, the student teachers completed a longer questionnaire measuring their self-reported attitudes and affects. The items related to self-efficacy that were analyzed in this study were adapted from the Science Teaching Efficacy Belief Instrument-B (Bleicher, 2004). The responses to the five items (see **Table 3**) were rated on a 6-point Likert scale, and the reliability indices for both time points (Cronbach's alphas = 0.79 and 0.83) were computed. No significant difference in the students' mean self-efficacy for conducting experiments was found between the two time points ( $t_1$ :  $M = 4.24$ ,  $SD = 0.68$ ;  $t_2$ :  $M = 4.14$ ,  $SD = 0.81$ ;  $F = 0.78$ ,  $df = 79$ ,  $p = 0.38$ ,  $r_{tt2} = 0.15$ ). We measured the students' general enjoyment (trait) of conducting experiments during class, using a three-item scale (**Table 4**) (Cronbach's alphas = 0.75 and 0.91), which was adapted from the instrument developed by van Aalderen-Smeets and van der Molen (2013). The items on enjoyment based on intrinsic motivation were formulated to reflect students' future self-determined situations as teachers in practice, which differs from the externally determined course situation at the university. However, this does not mean that student teachers at the university do not show behavior that is intrinsically motivated, in part (Ryan and Deci, 2000). The students' mean enjoyment of conducting experiments in class was not significantly different between the two time points ( $t_1$ :  $M = 4.87$ ,  $SD = 0.80$ ;  $t_2$ :  $M = 4.79$ ,  $SD = 1.03$ ;  $F = 0.44$ ,  $df = 77$ ,  $p = 0.51$ ,  $r_{tt2} = 0.20$ ).

**TABLE 2 |** Unstandardized parameter estimates for the multilevel autoregressive model explaining the effects of momentary motivation (state) on pre-service teachers' general enjoyment of conducting experiments in class (trait variable on the between level).

Parameters	Estimate	Posterior SD	95% CI LL	95% CI UL
<i>Fixed effects</i>				
Motivation (state) intercept	2.90 <sup>a</sup>	0.47	1.98	3.84
Enjoyment t2 (trait) intercept	3.41 <sup>a</sup>	0.85	1.72	5.04
Autoregressive effects Mot <sub>t-1</sub> →Mot <sub>t</sub>	0.17 <sup>a</sup>	0.03	0.10	0.24
Motivation (state) → Enjoyment t2 (trait)	0.43 <sup>a</sup>	0.24	0.03	0.94
Enjoyment t1 (trait) → Motivation (state)	0.22 <sup>a</sup>	0.10	0.03	0.41
<i>Random effects</i>				
Mot <sub>t-1</sub> →Mot <sub>t</sub>	0.03 <sup>a</sup>	0.02	0.01	0.07
Motivation (state)	0.41 <sup>a</sup>	0.08	0.27	0.60
Enjoyment t2 (trait)	0.91 <sup>a</sup>	0.19	0.52	1.28

<sup>a</sup>Significance was based on credible interval (CI) not containing zero. LL, lower limit; UL, upper limit.

**TABLE 3 |** Scale for the pre-service teachers' self-efficacy in conducting experiments (trait).

Item	Statement
Selefe 1	I'm good with equipment when I'm experimenting
Selefe 2	I'm good at conducting experiments in courses
Selefe 3	I like to volunteer in the course when it comes to conducting experiments
Selefe 4	I know exactly what to do when I conduct experiments in training
Selefe 5	In a course, I understand exactly what the respective experiment is about

Adapted from Bleicher (2004). 6-point Likert scale (6 = absolutely agree, 5 = agree, 4 = somewhat agree, 3 = somewhat disagree, 2 = disagree, and 1 = absolutely disagree).

**TABLE 4 |** Scale for the pre-service teachers' general enjoyment of conducting experiments in class (trait).

Item	Statement
Enjoy 1	I really enjoy the use of experiments in class
Enjoy 2	When I can use experiments in class, I am always very happy
Enjoy 3	I experience teaching in which experiments are carried out as the climax of my teaching job

Adapted from van Aalderen-Smeets and van der Molen (2013). 6-point Likert scale (6 = absolutely agree, 5 = agree, 4 = somewhat agree, 3 = somewhat disagree, 2 = disagree, and 1 = absolutely disagree).

## Data Analysis

We used the DSEM framework to establish a multilevel bivariate autoregressive cross-lagged model as a basis for investigating the development of the relationship between feelings of competence and motivation of pre-service teachers in a science course. The model consisted of a time-series model at Level 1, which presented the within-person processes, and one at Level 2, which presented the between-person differences (Hamaker and Wichers, 2017). In the first step, two autoregressive models were created to determine whether pre-service teachers' self-efficacy beliefs and general enjoyment of conducting experiments (traits) were related to the subjective experience of their feelings of competence and in-the-moment motivation (states). We could thereby gain information on the assumed relatedness of the state and trait constructs. We assumed that states, for example, feeling competent, are antecedents of traits, such as self-efficacy, and that these traits were, to some extent, affected by

our pre-service teacher course. In addition, we included previous measurements of the same traits as antecedents of states, as outlined in the control-value theory of achievement emotions by Pekrun (2006).

SPSS (Version 25) was used to calculate the descriptive statistics. DSEM was applied in Mplus (Version 8.3) and executed using a Bayes full-information estimator with non-informative priors. With this procedure, we achieved results comparable to full information maximum likelihood. As part of the iteration process, we ran 50,000 Markov chain Monte Carlo computations. Every 10th iteration was saved for estimation. Bayesian estimation is flexible in terms of the specification of a model and allows the bivariate model to be run at the same time (Schuurman et al., 2016). Furthermore, with the help of Bayesian modeling, it is possible to calculate standardized regression coefficients that account for uncertainty about the new quantities (Hamaker et al., 2018). Regarding the study's sample size, we followed the recommendations of Schultzberg and Muthén (2018). With  $N = 101$  and  $T = 18$  ( $N \times T = 1818$ ), we reached an acceptable level of performance for our simple model, and power was not an issue. However, the sample size did not provide sufficient power for models that were more complex (Schultzberg and Muthén, 2018). We collected data for two cohorts (2018 and 2019). Two additional years would have produced a larger sample size but our project was financed for only 2 years. Our events were, in principle, continuous successive lessons of 2 h duration. There was a 1-week break between each lesson, but no further events were possible during that time. If we were to model the missing hours in between, the data set would be increased by 92% by imputation of data, which would have led to problems regarding the convergence of the estimation. For this reason, and with reference to a valid representation of reality, we assumed a regular interval of 1 h for the modeling. This is equivalent to using the Mplus option, where the  $T$  interval = 1. We also applied residual dynamic equation modeling (RDSEM), which is more robust against misspecifications (Asparouhov and Muthén, 2020). The values of the RDSEM and DSEM models compared very well. The DSEM model showed better deviance information criteria (DIC) values, and was preferred in the following analyses. All missing data were due to illness or other responsibilities of the students. Thus, in our study, the data were assumed to be randomly missing. All missing

data were included as additional unknown quantities for which it was possible to estimate a subsequent distribution. Variables with repeated measurements were decomposed into latent within- and between-person parts, and lagged to control and estimate the effect of the previous measurements on the subsequent ones (Hamaker and Wichers, 2017).

## Autoregressive Effects

A multilevel AR-1 model makes it possible to calculate the mean “inertia” of a variable in the sample population of all pre-service teachers, and for the individual student teacher (Suls et al., 1998). “Inertia” is the correlation of a variable with itself related to the preceding measurement (lag 1). For an autoregressive value close to zero, it can be assumed that a strong attraction dynamic exists. This implies that after a low or high score, the pre-service teacher will return to the equilibrium or “set point” (i.e., the typical level of motivation or feeling of competence). In the other case, if the autoregressive value is close to 1, more carryover from one moment to the next is presumed. This reflects a regulatory weakness. For example, a pre-service teacher showing an autoregressive value near 1 for feelings of competence would be expected to show several successive feelings in a row with high or low competence values above or below their set-point/equilibrium. In the case of negative values of the autoregressive term, they need to be interpreted differently. Negative autoregressive values imply reflexive back-and-forth shifting between experienced emotions above and below the equilibrium (called anti-persistence) (De Haan-Rietdijk et al., 2016). Anti-persistence might show a zigzag pattern where feelings of low competence are followed by feelings of competence that are higher than the student’s typical feelings of competence.

## RESULTS

### Relations of State and Trait Variables

Two first-order autoregressive lag-1 (AR-1) multilevel models were used to model the trait variables as predictors and outcomes of the state variables. In the first model, we regressed subsequent self-efficacy for conducting experiments (trait) on feelings of competence (state) during the experimental course in biology. Prior self-efficacy for conducting experiments was included as a predictor of feelings of competence (state). A model with an additional path from trait t1 to trait t2 was also tested, but the DIC values were considerably higher. The multilevel model’s unstandardized effects and variances are presented in **Table 1**. The fixed effect of feelings of competence is the average effect over all student teachers, expressed as the regression coefficient. The random effects are the variances of the fixed-effects parameters. A second autoregressive multilevel model was established for the effects of momentary motivation (state) on the pre-service teachers’ subsequent enjoyment of conducting experiments in class (trait), including prior enjoyment of conducting experiments in class as a predictor of state motivation. The unstandardized results of the second model are presented in **Table 2**.

In both models, the means of the state over time significantly predicted trait outcomes. For self-efficacy beliefs, there was a standardized regression coefficient of  $\beta = 0.30$  (unstandardized  $B = 0.42$ ) with feelings of competence as a predictor on the between level. The standardized values of feelings of competence are the within-person standardized coefficients averaged over the cluster (Schuurman et al., 2016). Previous self-efficacy beliefs before the course did not predict significant feelings of competence  $\beta = 0.10$  ( $B = 0.12$ ) within the course. Similarly, mean state motivation across the pre-service teachers predicted significant enjoyment, with an effect of  $\beta = 0.27$  ( $B = 0.43$ ). However, previous habitual enjoyment before the course predicted motivation in the moment  $\beta = 0.18$  ( $B = 0.22$ ) within the course.

Autoregressive values appeared to be significant only for motivation. For feelings of competence, the value was negative and not significant,  $\beta = -0.09$  ( $B = -0.07$ ) (see **Table 1**,  $\text{Comp}_{t-1} \rightarrow \text{Comp}_t$ ), indicating back-and-forth shifting of feelings of competence around the equilibrium (called anti-persistence). A line plot of our data showed that each course session started with rather low feelings of competence and ended with feelings of competence above the mean over the entire course. However, the magnitude of this value was low, indicating only minor anti-persistence (Velicer and Fava, 2003). In the case of state motivation, the autoregressive value was positive,  $\beta = 0.23$  ( $B = 0.17$ ) (see **Table 2**,  $\text{Mot}_{t-1} \rightarrow \text{Mot}_t$ ), indicating a low carryover and no anti-persistence. More specifically, motivation in the moment appeared to have the properties of an attractor dynamic. This means that after a situation in the course with high or low momentary motivation, a pre-service teacher was likely to return in a short time to his/her set point or equilibrium of typical momentary motivation. There were also significant individual differences (variance) between the mean of the pre-service teachers’ feelings of competence and momentary motivation.

### Interplay of Feelings of Competence and Momentary Motivation

To analyze the interplay of the pre-service teachers’ feelings of competence and momentary motivation, an autoregressive lag-1 (AR-1) multilevel model was applied. It is essential to discuss the meaning of previous and current occasions when we consider the inherent lagged relations between feelings of competence and motivation. For example, if the current feeling of competence (i.e., at time  $t$ ) is defined as the feeling of competence when the student teacher has just finished the experiment in the biology course, the previous feeling of competence would be the moment when the student teacher had just started the experiment in the same course session ( $t-1$ ; lag 1). Similarly, to estimate the effects of momentary motivation on subsequent momentary motivation, motivation at time  $t$  (lag 2; e.g., at the beginning of the next session) is regressed on the current  $t-1$  (at the end of the current session). To estimate the cross-lagged effects of competence on motivation, current motivation (time  $t$ ) is regressed on the previous occasion of competence ( $t-1$ ; lag 1). For cross-lagged effects of motivation on competence, it would simply be the other way around.

**TABLE 5** | Unstandardized parameter estimates or the multilevel bivariate autoregressive model's analysis of the associations between feelings of competence and momentary motivation in pre-service teachers conducting science experiments.

Parameters	Estimate	Posterior SD	95% CI LL	95% CI UL
<i>Fixed effects</i>				
Competence intercept	3.66 <sup>a</sup>	0.07	3.52	3.79
Motivation intercept	3.98 <sup>a</sup>	0.08	3.82	4.14
<i>Autoregressive effects</i>				
Comp <sub>t-1</sub> →Comp <sub>t</sub>	-0.09	0.04	-0.17	0.00
Mot <sub>t-1</sub> →Mot <sub>t</sub>	0.23 <sup>a</sup>	0.04	0.15	0.30
<i>Cross-lagged effects</i>				
Motivation <sub>t-1</sub> →Competence <sub>t</sub>	0.03	0.03	-0.04	0.10
Competence <sub>t-1</sub> →Motivation <sub>t</sub>	-0.15 <sup>a</sup>	0.04	-0.23	-0.07
<i>Random effects</i>				
Competence	0.39 <sup>a</sup>	0.07	0.27	0.56
Motivation	0.47 <sup>a</sup>	0.10	0.31	0.70
Comp <sub>t-1</sub> →Comp <sub>t</sub>	0.08 <sup>a</sup>	0.03	0.05	0.14
Mot <sub>t-1</sub> →Mot <sub>t</sub>	0.04 <sup>a</sup>	0.02	0.02	0.09
Motivation <sub>t-1</sub> →Competence <sub>t</sub>	0.04 <sup>a</sup>	0.02	0.02	0.08
Competence <sub>t-1</sub> →Motivation <sub>t</sub>	0.07 <sup>a</sup>	0.03	0.03	0.13

<sup>a</sup>Significance was based on the credible interval (CI) not containing zero. LL, lower limit; UL, upper limit.

The unstandardized effects and variances of the multilevel model are presented in **Table 5**. The random effects are the variances of the fixed-effects parameters. The current model explained 11.1% of the within-person variability for feelings of competence and 12.5% of the within-person variance for momentary motivation. There was considerable variation among the student-teachers' individual *r*-square values.

The autoregressive values for feelings of competence and momentary motivation are discussed in the previous section. Feelings of competence appeared to have a negative value, indicating anti-persistence. The value was positive for momentary motivation, indicating low carryover and signs of an attractor dynamic. Cross-lagged values revealed that, on average, when comparing across individuals, a pre-service teacher who showed high (or low) actual feelings of competence in the practical biology course showed low (or high) momentary motivation in the subsequent measurement ( $B = -0.15$ ,  $\beta = -0.56$ ) (see Comp<sub>t-1</sub>→Mot<sub>t</sub>, **Table 5**). Conversely, momentary motivation did not predict significant feelings of competence in a person ( $B = 0.03$ ,  $\beta = 0.14$ ) (see Mot<sub>t-1</sub>→Comp<sub>t</sub>, **Table 5**). For both cross-lagged paths, there were significant but small variances.

Overall, a moderate correlation was found between the student teachers' intercepts of feelings of competence and momentary motivation ( $r = 0.54$ , see **Table 6**). **Table 6** further shows that students with feelings of greater competence showed higher negative cross-lagged values for state competence on previous state motivation, indicating a higher dynamic interplay between the two affective states ( $r = -0.45$ ). The student teachers with feelings of low competence were only slightly affected by previous motivational intensity, and student teachers with more inertia or carryover of feelings of competence showed higher cross-lagged values for state motivation on previous state competence ( $r = 0.45$ ).

## DISCUSSION

The first aim of the present study was to investigate the relationship between state and trait affects (research questions 1 and 2). The results showed that the state variables of feelings of competence and motivation in the moment were predictors of the theoretically related trait variables of self-efficacy and intrinsic motivation (enjoyment). Hence, the momentary measurement of competence and motivation seemed to be a reliable procedure for capturing the situational aspects of the pre-service teachers' learning process. At first glance, the trait variables before and after the semester course on practical biology showed no significant development, whereas observation of the development of the state variables over time revealed a more detailed picture. Based on the autoregressive values, we were able to describe a sawtooth pattern of feelings of competence in which low competence was followed by subsequent feelings of competence that were higher or lower than that of the students' mean or typical feelings of competence, which exemplified anti-persistence. Each session seemed to represent a new challenge that made it difficult for the student teachers to develop feelings of competence that were more stable. Meanwhile, momentary motivation appeared to be more persistent; there was some carryover, and the motivation values varied around the students' equilibrium.

In the bidirectional model, we explored the relationship between feelings of competence and motivation among pre-service teachers to demonstrate the value of using a multilevel model to study cross-lagged relations between outcomes. In accordance with the previous literature, the results suggest a bidirectional relationship between feelings of competence and momentary motivation (Salanova et al., 2014; Malmberg & Martin, 2019). Previous studies linking feelings of competence to motivation in the moment within the context of science teacher education have often relied on trait measurements (Fazio et al., 2010; Riegle-Crumb et al., 2015). The current study builds on these results by using related state measures. It shows that



**TABLE 6 |** Standardized between-person correlations for the random effects from the bivariate autoregressive model.

		1	2	3	4	5	6
1	Competence intercept	-					
2	Motivation intercept	0.54 <sup>a</sup>	-				
3	Comp <sub>t-1</sub> →Comp <sub>t</sub>	0.30	0.10	-			
4	Mot <sub>t-1</sub> →Mot <sub>t</sub>	-0.28	0.07	-0.39	-		
5	Motivation <sub>t-1</sub> →Competence <sub>t</sub>	-0.45 <sup>a</sup>	-0.12	-0.30	0.48	-	
6	Competence <sub>t-1</sub> →Motivation <sub>t</sub>	0.07	-0.15	0.45 <sup>a</sup>	-0.26	0.35	-

<sup>a</sup>Significance was based on the credible interval (CI) not containing zero.

momentary motivation in a teacher education course depends on the student teachers' subjective experience of their moment-to-moment course activities. This finding indicated that when pre-service teachers experienced decreased motivation at one moment, they were likely to experience some carryover in the next moment, but then returned to their baseline level of motivation rather quickly. Furthermore, momentary motivation was influenced by the feelings of competence from the previously measured moment in the biology course session, but momentary motivation did not predict subsequent feelings of competence (research question 3). Although this was not the case for some student teachers with high mean feelings of competence, their feelings of competence were more affected by their previous motivation in the moment. In addition, a significant but small between-person random variability in the strength of the carryover effects indicated that not all pre-service teachers in the sample returned to their typical level of motivation at the same rate (research question 4). Some student teachers had more carryover from one moment to the next. For these student teachers, a moment in the course session with low/high motivation was followed by continued moments of low/high motivation before eventually returning to the baseline level.

The current study built on intensive longitudinal models, as presented in Malmberg and Martin (2019) for primary students. Similar to Malmberg and Martin (2019), the current study examined state competence and motivation (autonomous motivation in Malmberg and Martin) and modeled within- and between-person variability. However, we applied DSEM, which yielded a slightly different set of the results. Nevertheless, the current study made it possible to compare some of their study's findings on primary students with our results on university students enrolled in teacher education. Their study is broader because we limited our study to two constructs and one specific subject. Although both feelings of competence and momentary motivation in the Malmberg and Martin (2019) study seemed to possess a small amount of inertia, this was the case for only momentary motivation in our study. With respect to cross-lagged effects, no dynamic interaction effects were found between feelings of competence and momentary motivation in their study, whereas previous feelings of competence predicted momentary motivation in our study. However, Malmberg and Martin (2019) found that previously controlled motivation predicted feelings of competence and autonomous motivation.

We limited our study to two affects that we thought were appropriate to our situation, and because of the small sample size, we restricted our model to two affects. However, other important

academic effects could have been examined in our research (see e.g. Pekrun et al., 2002). These restrictions made comparisons with the results of other studies less simple. Nevertheless, considering an open question in a paper by Niemivirta and Tapola (2007) about causality, based on our results, it is possible that situated self-efficacy beliefs would have predicted situated interest in their study. We cannot rule out the possibility that other affects or the operationalization of their constructs would have led to different results than we achieved. A further limitation is that we used a small convenience sample of students and a small number of repeated measurements, which jeopardizes the replicability and generalizability of our findings and could compromise its internal validity (Pekrun, 2019). However, the limited number of course days was based on the academic calendar and course schedule of a real institution of higher education. The semester course lasted only 10–12 course days. Hence, a multi-institutional study, as suggested by Pekrun (2019), would certainly be desirable, but would not be easy to implement given the institutional context.

Future research can use the DSEM technique to pose questions about the magnitude or length of typical patterns (i.e., which course sessions show the largest differences in feelings of competence?) and questions about individual differences related to persistence (i.e., what attributes are associated with a pre-service teacher who shows pronounced anti-persistence of feelings of competence?). Itzek-Greulich and Vollmer (2017) identified further predictors of inquiry-based lab work, such as gender and prior knowledge. We would like to mention that a previous study with the same sample showed that neither gender nor age predicted self-efficacy beliefs or enjoyment; only subsequent test results explained differences in these two variables (Smit et al., 2021). The inclusion of further variables in our dynamic model would require a larger number of observations to achieve reasonable estimates, as such models become more complex.

Our study implies that state competence and motivation are dynamically linked. As a suggestion for teacher education, actions to encourage future science teachers to implement practical work in their teaching should consider the development of competence within science courses. First, it should be noted that student teachers are also extrinsically motivated, in part, by the educator reminding them that the task they are working on is relevant for the final exam. Next, as individuals master the challenges of an activity, they develop higher levels of competence, and the activity ceases to be as motivating as before because it has become too easy. To continue experiencing motivation, pre-service teachers

must identify challenges of greater difficulty. If the challenge is not too difficult, even feelings of low competence might lead to developing (emergent) motivation (Csikszentmihalyi et al., 2005). The intrinsic motivation to persist in an activity can arise from the experience itself. Thus, over time, the balance between challenges and feelings of competence enhances general self-efficacy beliefs (Csikszentmihalyi et al., 2005). Overall, feelings of competence did not develop negatively in our study, and the course content was not overwhelming. Despite these characteristics, each of the experimental tasks seemed to be a new challenge; feelings of competence were always a little lower in the beginning than at the end of the lessons, so that the student teachers were able to develop their competence beliefs only to a limited extent. For example, the control-of-variable strategy was discussed each time as a typical aspect of scientific inquiry, but new science content knowledge was the main focus, which seemed to have been an issue. Furthermore, lab work is time-consuming. Often, there is little or no time to clarify open questions or uncertainties after part of an experiment is completed. Among uncertain students, this lack of time can lead to feelings of having an inability to follow the course content and to understand it. For some student teachers, this problem could lead to lack of self-efficacy. In the long term, it might result in disinterest in using scientific inquiry practices in one's own teaching. This begs the question, "based on the level of learning, what is the

extent to which independent learning with a differentiated approach is possible here?" As Pekrun (2006, p. 334) noted: "the relative match between demands and individual capabilities can influence the student's valuing of the material." Furthermore, Dennis et al. (2016) suggested that educators use personalized performance feedback and emotional support to foster learners' momentary motivation. This advice relates to one of the four suggestions for emotion regulation by Pekrun (2006): competence-oriented emotion regulation and treatment. Future interventions should focus on educators using constructive feedback to strengthen pre-service teachers' cognitive abilities and affect-motivation states for practical science work. This could enhance the development of student teachers' competence in teaching science.

## DATA AVAILABILITY STATEMENT

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

## AUTHOR CONTRIBUTIONS

RS: Project head and data analysis. FR and NR: Lecturers and data sampling.

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