AUTHOR	Södervik, Ilona; Hanski, Leena; Laakkonen, Eero; Katajavuori, Nina
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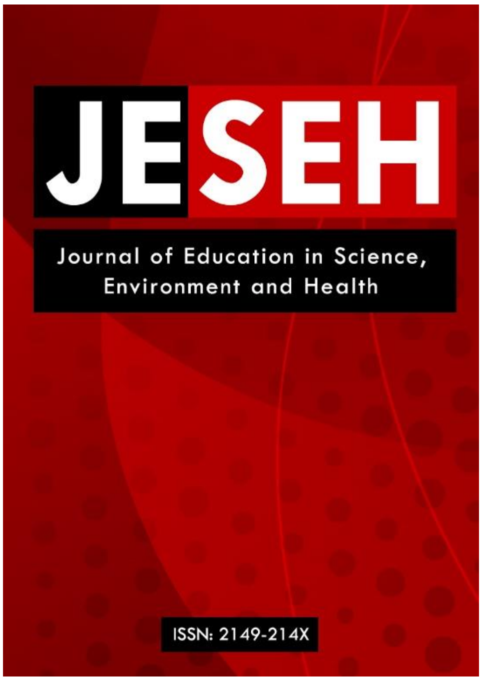

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Ilona Sodervik[1], Leena Hanski[1], Eero Laakkonen[2], Nina Katajavuori[1]

[1] University of Helsinki
[2] University of Turku

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Pharmacy Undergraduates' Epistemic Cognition and Medication Beliefs as Predictors of Conceptual Learning and Academic Progress

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Abstract

The importance of studies showing the impact of students' epistemic beliefs on their conceptual learning and academic progress is increasing. This study investigated pharmacy students' domain-specific epistemic cognition and topic-specific beliefs related to their level of conceptual prior knowledge, learning and study progress during the first academic year. Data were collected from 125 students using a pre-test/post-test design with a multiple-choice questionnaire, an open-ended case task and a measure of domain-specific epistemic cognition and topic-specific beliefs concerning medication. The results showed that students' prior knowledge predicted their academic performance and more sophisticated epistemic cognition was related to better conceptual understanding, faster study progress, and fewer anti-medication beliefs. Anti-medication beliefs hindered participants' success in the case task and were related to weaker study progress. Our study shows that epistemic cognition and topic-specific beliefs play a role in students' performance, learning, and study progress.

Introduction

A challenge in European universities is that although a large proportion of the students thrive in their studies, too many struggle to reach a high-level understanding of their discipline's substance and methodologies, achieve appropriate skill levels, and proceed through the programme at the suggested pace (Jia & Maloney, 2015; Korhonen & Rautopuro, 2019). Previous research highlights the particular importance of the first year in higher education to students' future academic performance and achievement (Araujo et al., 2019; Constantini & Vitale, 2011; European Education and Culture Executive Agency, 2017; Jenert et al., 2015; Mennen & van der Klink, 2017; Trautwein & Bosse, 2017). Consequently, there is growing interest in knowing the factors relevant to predicting and influencing academic performance during students' first study year in order to advance learning and teaching in higher education (see Tinto, 1993).

According to current understanding, investigating the factors that influence high-level learning requires a domain-specific approach (Boshuizen & Schmidt, 2018), but such research is still relatively scarce. Therefore, the aim of this study is to add to the understanding of cognitive cornerstones of students' study success and professional development by investigating undergraduates' conceptual and epistemic understanding together with their topic-specific beliefs from domain-specific perspective in the pharmacy context and to compare them with respect to study progress during the first academic study year.

Development of Conceptual Understanding

The single most significant aspect in students' knowledge building process and academic success, particularly in the early phases of study, is the level and quality of the students' prior knowledge (Binder et al., 2019; Bransford et al., 2000; Kuncel et al., 2001). The quality of prior knowledge has been shown to greatly influence how students interpret and learn from learning materials (e.g., Rittle-Johnson et al., 2009), how they use problem-solving strategies effectively (e.g. Koedinger & Roll, 2012), how they are able to use prior knowledge in novel contexts (e.g. Carpenter, et al., 1998), and how well they are prepared for future learning tasks (e.g., Bransford & Schwartz, 1999). Nevertheless, if students' prior knowledge contains information that is in conflict with current scientific understanding, learning requires profound changes in one's existing cognitive structures, i.e. conceptual change and becomes more laborious (Chi, 2013; Vosniadou, 2013). Furthermore, scientific concepts are often counterintuitive by nature and hence, learning of them requires intentional, high-level cognitive processing and sophisticated study strategies, particularly if misconceptions exist and conceptual change is needed. Based on extensive research, we now know that university students often have pre-existing, alternative conceptions and robust misinterpretations related to the central course content and concepts to be studied (e.g. Flaig et al., 2018; Södervik et al., 2015, 2017, 2020).

However, a tricky question has bothered researchers for a long time: why are some students more likely to revise their prior conceptions and undergo conceptual change as a result of instructional intervention or regular teaching, whereas others with similar naïve conceptions are more resistant to changing their conceptions? An important reason for this is assumed to lie in the interplay between students' ideas concerning the nature of knowledge and knowing, their topic-specific beliefs and conceptual understanding (Abendroth & Richter, 2021; Amin & Levrini, 2018; Murphy & Alexander, 2013). Studies have shown that individuals' ideas about knowledge and knowing, i.e. epistemic cognition have an impact on conceptual understanding, conceptual change, and their acceptance of controversial theories (Greene et al., 2016; Hofer, 2018; Mason et al., 2008). Furthermore, belief-consistent information is more easily and better comprehended compared to belief-inconsistent information (Abendroth & Richter, 2021). However, few studies investigate these aspects in relation to academic achievement from discipline- and topic-specific perspectives, partly due to the lack of appropriate methodological tools (see e.g. Bråten et al., 2009; Hofer, 2000; Muis et al., 2006; Merk et al., 2018).

Domain-Specific Epistemic Cognition

Researchers have argued that epistemic cognition is a key predictor of 21st-century learning outcomes (Cartiff et al., 2020: Greene et al., 2018, 1084). This is because in our society, scientific knowledge is growing faster than ever, and both students and professionals need to constantly evaluate the veracity and relevance of knowledge of their field. Individuals' domain-specific epistemic cognition, i.e. a set of mental processes that involve the development of one's conceptions of knowledge, plays a role in this, because it changes the premises on which students' knowledge and knowing are based (Hofer, 2016). Based on extensive earlier research, it influences reasoning, problem-solving, conceptual understanding, and argumentation and hence general academic performance (Greene et al., 2018; Hofer, 2016; Kuhn, 2005; Schommer-Aikins & Easter, 2006).

Whilst research related to epistemic cognition was previously conducted with an implicit assumption that these beliefs can be generalised across disciplines, it is now generally accepted that individuals hold both general, but also discipline- and even topic-specific beliefs about knowledge and knowing (see e.g. Bråten et al., 2008; Bråten et al., 2009; Hofer, 2000; Muis et al., 2006; Merk et al. 2018). This means that students may justify and construct knowledge in different ways depending on how they perceive the specific practices of the particular disciplines rather than general beliefs about knowledge, leading to a situation in which one may have beliefs about scientific knowledge in general that differ from one's beliefs on pharmaceutical knowledge and from their beliefs related to particular phenomenon. This may be true particularly in weighing information related to beliefs about complex and controversial issues, such as those related to drugs or vaccines in pharmaceutics that are developed in the academic context, but also influenced by larger social-cultural contexts (Kolstø, 2001; Merk et al., 2018; Sinatra et al., 2014). All in all, a growing body of empiric evidence supports the view that domain-specific epistemic beliefs deserve further exploration, particularly in relation to academic performance and conceptual understanding.

Discipline of Pharmacy as a Study Context

Pharmacy is a multidisciplinary field involving the natural sciences, health sciences and social sciences – disciplines that differ greatly in terms of research methodology. Furthermore, underlying theories related to health concepts are typically multifaceted, constantly evolving, and often disputed. Topics concerning unsettled or controversial issues related to people's health or safety may be well suited to eliciting epistemic cognition and topic-specific beliefs, because they often include disagreements regarding the validity or trustworthiness of the claims involved (Kolstø 2001; Sinatra et al., 2014).

Of all the scientific disciplines, knowledge related to health sciences has perhaps the greatest influence on individuals' daily lives and the choices that we make regarding nutrition, immunisation and medical treatment. Thus, pharmacists involved in patient-centred duties in pharmacies typically act as critical mediators and interpreters of scientific knowledge between the pharmaceutical industry, as drug developers, and customers, who may have adopted false or oversimplified information regarding drugs and their appropriate use (Kaufman et al., 2013). This is of particular concern when it comes to common medications such as vaccines and antibiotics, because the pharmacists need to be able to explain complex things plausibly to the customers. However, recent studies have shown severe problems in pharmacy students' understanding of elementary-level knowledge about antibiotics and antibiotic resistance mechanisms, and beliefs related to the factors promoting the emergence and spread of antibiotic resistance (Inacio et al., 2017; Södervik et al., 2020). Therefore, better discipline- and topic-specific understanding of these aspects and their interrelations are needed.

Students, also in pharmacy, typically struggle to apply basic knowledge in practical problem-solving situations (e.g. Boshuizen et al., 2020; Persky & Murphy, 2019; Södervik et al., 2023). According to our current understanding, knowledge and the associated skills to use the knowledge develop simultaneously and interdependently (Boshuizen & Schmidt, 2018), and hence learning activities that require mental activities and processes like those necessary in real work life would be beneficial (Brown et al., 1989). The use of authentic, discipline-specific case tasks can have the potential to support learning effectively, particularly in the early stages of education, when a great part of learners' cognitive capacity is laden with the processing of less integrated conceptual knowledge, and authentic problems can be too demanding (see e.g. Boshuizen et al., 2020).

The Study

Fostering the development of expertise in life sciences is a goal of the utmost importance in universities, since the rapidly changing society and the current global catastrophes and crises (such as pandemics and antibiotic resistance) challenge future experts to be able to evaluate and update their knowledge and skills in constantly evolving circumstances. Furthermore, the initial phase of study at university deserves more attention in terms of students' domain-specific conceptual and epistemic understanding. Therefore, in the present study we examined:

(1) How does first-year pharmacy students' conceptual understanding related to biosciences change during their first study year?

There is abundant evidence demonstrating the important role played by personal epistemology in students' academic performance, but rather limited understanding of this from domain- and topic-specific perspectives. Therefore, we also ask:

(2) How do students' domain-specific epistemic cognition and topic-specific beliefs predict their academic performance during the first study year?

Methods

Participants

Participating in this study was voluntary and informed consent was obtained from the participants in both data collection phases. The participants in the pre-test were 125 first-year pharmacy students (women n = 97; men n = 26; other n = 2) from the University of Helsinki, and 81 of those (women n = 64; men n = 16; other n = 1) took part in both data collection phases of the study.

Measures and Procedure

Design

A pre-test/post-test design was utilised. The pre-test measuring students' level and quality of prior knowledge was conducted at the beginning of the academic studies (September 2018) and the post-test six months later (February 2019). Students answered individually in a Moodle electronic exam environment in a regular lecture hall, and they had 40 minutes to complete the tasks.

Measures – Background Measures and Measure of Conceptual Understanding

Background questions, such as the students' gender and commencement year, were asked during the pre-test. Students' entrance examination scores and accumulated number of study credits (information obtained from the student register) at the end of the first study year were used as background variables. The measure of conceptual understanding in pre- and posttests consisted of 13 MCQs with the one-right/three-wrong answer model, and a case task with two related open-ended questions. The MCQs tested the students' basic knowledge of biochemistry, cell biology and molecular biology and referred to items in the phenomena to be handled in the case task. The MCQs were designed at a level that should have been mastered by the time students had completed Finnish high school. Students were permitted to leave the questions unanswered.

The case task was designed to require the application of conceptual knowledge, measuring conceptual change. It was the following 63-word description of a patient encounter with drug handling and antibiotic resistance (original task in Finnish): "A patient enters a pharmacy to pick up their prescribed broad-spectrum antibiotic. The patient tells you that this is their second prescribed antibiotic because the inflammation-relieving action of the first antibiotic was not effective, and in fact the symptoms got worse.

The patient seems dubious and tells you that he has heard several stories of the injurious side-effects of antibiotics, especially for intestinal bacteria. You suggest that the patient could take registered probiotics along with the antibiotics. Probiotics are used, for example, to prevent and alleviate antibiotic diarrhoea". After reading the case description, the following questions were asked: A) Name and define the essential science concepts which are related to this case (2–4 concepts). B) Describe the mechanisms related to this scientific phenomenon – both from the side of the human and the microbe. The case was designed to measure (A) the student's ability to identify and explain the central concepts regarding the phenomenon of drug-microbe interactions, covering antibiotic resistance and the effects of antibiotics on gut microbiota.

Table 1. Scoring of the case task

Case Task	**Concepts and Contents**	**Grading** Max: 16 points
Conceptual level Question A: Name and define the essential science concepts which are related to this case (up to four concepts)	<u>*Naming of the concept*</u> -Antibiotics (course), -Resistance/antibiotic resistance -Probiotics -Normal bacterial microbiota / intestinal microbiota -Microbe/bacterium/bacterial infection -Recombination/ genetic variation -Loss of microbiota -Superbug/ nosocomial infection; -Broad-spectrum / narrow spectrum antibiotics -Immunity -Antibiotic diarrhoea <u>*Defining of the concept*</u> Defining the concept	1 point for each correct concept and definition
Phenomenal level Question B: Describe the mechanisms underlying this scientific phenomenon – both from the side of human and the microbe	<u>*Microbe's point of view:*</u> -Resistance is a consequence of changes in genetic information -Resistance may occur as a structural change in the antibiotic target molecule -An ability of the microbe to cleave the antibiotic or to prevent it reaching its target -Under antibiotic pressure, mutations confer an advantage to the bacteria carrying them, leading to the flourishing of the mutated bacteria in the population <u>*Human body perspective:*</u> -Broad-spectrum antibiotics weaken the intestinal microbiota -Populations of *Clostridium difficile* and other non-susceptible microbes rise, causing antibiotic diarrhoea -Probiotics help to recover the normal microbiota -Probiotics mediate their action via their interactions with other microbes and the gut epithelium	1 point for each correct mechanism

Task (B) measured the student's understanding of the underlying scientific principles regarding the phenomenon, and the ability to apply and explain the causalities involved. Thus, success in the case task required a clear and profound understanding of the phenomenon on several conceptual levels. Misconceptions of these participants related to the case task have been published in a previous article (Södervik et al., 2020). This particular topic was chosen because antibiotics are commonly used to treat a range of diseases and resistance to antibiotics is a globally growing problem that presents real threats to public health and costs due to failure to treat and prevent infectious diseases (WHO, 2015). Thus, a comprehensive understanding of the safe use of antibiotics and their biomedical mechanisms is necessary for patient counselling. It was also anticipated that the topic would already be familiar to the students at the start of university. However, recent studies have shown severe problems and misconceptions in pharmacy students' understanding of elementary-level knowledge regarding antibiotics and antibiotic resistance mechanisms, and the factors that promote the emergence and spread of antibiotic resistance (Inacio et al., 2017; Södervik et al., 2020).

Measures of Epistemic Cognition and Beliefs regarding Medication

The participants' epistemic cognition (EC) was studied through a 5-point Likert scale measure. We adapted the epistemic cognition items from a topic-specific measure of climate change from Bråten and his colleagues (2009). However, to capture the original idea of items, certain modifications were made to tap on the phenomenon (see Hofer, 2000; Merk et al., 2018). Additionally, items regarding students' beliefs of medication were included in the questionnaire. The participants were given the following written instruction before answering the questionnaire: 'Please answer the following questions according to your current ideas. There is no right or wrong answers. All items are presented as an Appendix.

Data Analysis

Analysis of Conceptual Understanding

For the MCQs, the frequencies of correct answers were calculated and summated. The answers to the case task were analysed and scored by three researchers, one of whom is a biologist and two of whom are experts in pharmacy (see Table 1). Task A was scored by identifying and defining relevant concepts for the case (one score for each concept/definition, max. eight points) and question B based on the level and quality of the explanation of the underlying life science–related phenomena (max. eight points). An inter-rater analysis was performed with 15% of the data, and correlation was found to be $r = .82$ for the scoring of question A and $r = .91$ for the scoring of question B.

Analysis of Epistemic Cognition and Beliefs regarding Medication

Reliability analysis and principal components analysis were conducted using software IBM SPSS Statistics 27. First, the internal consistency of all 33 Likert scale items was evaluated with Cronbach alpha, and the item-total correlations were computed. The Cronbach alpha was .57 and six of the items had negative or low (less than .10) item-total correlations. These six items were left out of further analysis. With the remaining 27 items, the reliability analysis produced an alpha-coefficient of .70, indicating the inter-related dimensions of the epistemic beliefs. Next, principal component analyses were performed on the 27 EC items. The oblique rotation method was used (Promax with Kaiser Normalization), which allows calculation of the correlations between the components. The KMO measure showed that the sampling adequacy was at an acceptable level for PCA (KMO = .63). The number of components needed was first examined using the eigenvalues of the principal components. Nine of the components had an eigenvalue greater than 1.00 (Kaiser's criteria), with values ranging 4.11 to 1.09. Visual inspections of the Screen plot graph for the eigenvalues showed that the decrease of the eigenvalues flattened out slightly after three components and then after the fifth component (Cattell's criterion). Next, the five-component solution was extracted, which also corresponds to the number of the originally formulated dimensions.

However, the estimated solution with four main epistemic cognition components turned out to be unclear: many of the items loaded into the several components, with uniform and low loadings. In particular, the items of the Simplicity and Source dimensions did not perform consistently enough for the dimensions to be distinguishable in the solution. It is notable that, even in certain previous studies, it was somewhat problematic to distinguish the original factor structure and changes to the structure have been necessary (Bråten et al., 2009, Hofer, 2000;

Vančugovienė et al., 2024). Based on Hofer and Pintrich's original theory (1997), the measure consists of two larger entities, knowledge and knowing, and therefore the principal component analysis was next carried out with the number of components forced accordingly (two discipline-specific EC components plus one medication beliefs component). In this solution, there were five items in which the loadings were low (less than .30) or which loaded equally onto more than one component. These items were eliminated, and the solution was extracted again. With the remaining 22 items, the solution seemed clear and interpretable: all items loaded with a higher loading (greater than .39) into only one of the components, and the grouping of the items into the components was such that the components could be labelled as Justification, Certainty and Anti-medication beliefs. This solution explained 36.44 % of the total variance of the sample and the eigenvalues of the components were 3.66 for Justification, for 1.79 for Certainty and 2.57 for Anti-medication beliefs.

In sum, in the procedure described above, eleven of the 33 items were left out. The final dimensions and loadings, together with the items, are presented as an Appendix. Internal consistency measured with the Cronbach alpha for the three dimensions Justification, Certainty and Anti-medication beliefs were .73, .63 and .64 respectively. Based on this structure, the sum score variables were computed, and they were used in the subsequent analyses.

Statistical Analyses

More statistical analyses were performed using the structural equation modelling framework with Mplus 8.1 software. Epistemic cognition items and topic-specific beliefs together with learning and academic performance were analysed using path-modelling. Univariate distributions of the variables used and missing data were first analysed, and afterwards the hypothesised path-model was fitted to the data. In the model estimations, full information maximum likelihood estimation with robust standard errors were used, and the goodness of fit of the model was evaluated using $\chi 2$ test, comparative fit index (CFI), Tucker-Lewis index, RMSEA and SRMR. Model-fit evaluation was based on the recommendations by Hu & Bentler (1999).

Results

Students' Study Progress, Conceptual Understanding, Beliefs regarding Medication and Epistemic Cognition

During their first study year, the participants had completed 44.06 ECTS on average (Max: 67.00; Min: 18.00) by the end of their first academic study year (Table 2). In the pre-test, students received scores of approximately 6.67 out of 13.00 (Max: 12.00; Min: 1.00) from the MCQs measuring basic knowledge of biochemistry, cell biology and molecular biology, within a level that should have been mastered by the end of Finnish high school.

Table 2. Univariate descriptive statistics and correlations of the variables used in the path analysis model

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Correlations									
1. EC: Justification	1.00								
2. EC: Certainty	.22	1.00							
3. Anti-medication	-.26	.06	1.00						
4. Entrance Exam	.23	.01	-.17	1.00					
5. Case task Pre	.30	.04	-.01	.17	1.00				
6. MCQ Pre	.27	.21	-.06	.23	.48	1.00			
7. Case task Post	.18	.07	-.37	.11	.45	.28	1.00		
8. MCQ Post	.13	.10	-.10	.23	.25	.54	.43	1.00	
9. Academic achievement	.15	.16	-.24	.19	.23	.29	.31	.41	1.00
Descriptive Statistics									
M	4.24	3.67	1.96	16.28	3.08	6.67	5.95	9.96	44.06
SD	.43	.55	.49	4.31	2.14	2.55	2.37	2.03	8.85
Skewness	-.35	-.09	.51	.42	-.01	.57	.14	-1.50	-.60
Kurtosis	-.60	-.44	-.31	-.43	.01	-.79	-.70	3.80	.25

Note. EC: Epistemic Cognition, sumscore variables based on the principal components in PCA. Case task: Open ended case task related to antibiotic resistance. MCQ: Test score based on multiple choice questions related to biochemistry, cell biology, molecular biology and immunology. Correlations greater or equal than |.18|, |.23| and |.30| are significant at levels $p < .05$, $p < .01$ and $p < .001$, respectively.

In the post-test, students received an average score of 9.96 out of 13.00 (Max: 13.00; Min: 1.00); hence, students' scores improved significantly from the pre-test to post-test [$t(80) = -12.085$, $p < .001$, $d = 1.34$]. Scores on the case task in the pre-test were low, on average 3.79 out of 16.00 (Max: 10.00; Min: .00; SD: 2.15) and in the post-test on average 5.95 out of 16.00 (Max: 11.00; Min: 2.00). Thus, scores related to the case task improved significantly [$t(63) = -10.00$, $p < .001$, d = 1.25]. The scores from the multiple-choice questions correlated with the case task scores in the pre-test ($r = .48$, $p < .001$) and in the post-test ($r = .34$, $p = .003$). The pre-test MCQ scores / case task scores correlated with the post-test MCQ scores / case task scores ($r = .51$, $p < .001$ and $r = .41$, p = .001 respectively).

Students' scores related to sumscale of Justification of knowledge were quite high, averaging 4.24 (Max: 5.00, Min: 3.13), scores related to Certainty averaged 3.67 (Max: 5.00; Min: 2.43), whereas scores related to Anti-medication beliefs were relatively low, on average 1.96 (Max: 3.43; Min: 1.14). Sumscales of Justification and Certainty correlated strongly with each other, and both correlated with MCQ pretest scores. Justification scores also correlated positively with variables measuring general academic success (Table 2). On the other hand, Anti-medication beliefs correlated negatively with several variables: Justification, post-test case task scores and academic study achievement measured via accumulated number of study credits.

Epistemic Cognition and Beliefs regarding Medication in relation to Academic Performance

The interrelations of epistemic cognition, beliefs regarding medication and students' academic performance were studied using a longitudinal path-analysis model (Figure 1). At first, the distributions of the variables used were examined. According to visual evaluation (histograms and box-plots) and descriptive statistics (skewness and kurtosis), the distributional properties of the variables were within reasonable limits for the structural equation modelling (Curran, West & Finch, 1996). The missing data (assuming missing at random, MAR) was handled using the full information maximum likelihood method (MLR in Mplus) in the model estimations. The goodness-of-fit of the final path-model was good: $\chi2(6) = 7.68$; $p = .263$, CFI = .98, TLI = .91, RMSEA = .05 (90% CI: .00 - .13), SRMR = .03. In the model, Justification was significantly related to the pre-test of the case task and the MSQs. Other EC variables were not linked to the pre-test variables. EC variables were not significantly connected to the entrance exam scores either. Anti-medication beliefs significantly predicted success in the case task in the post-test. Effects from the pre-test to post-test were also significant in both the case test and the MCQs, with estimates ($\beta = .43$, $p = .001$ and $\beta = .52$, $p < .001$) indicating moderate stability in the test scores. Academic performance was associated significantly with the MCQs. Indirect effects from EC variables to the post-tests of the case task and MSQ and academic performance were significant from Justification to MCQ post-test (total indirect effect .15; $p = .025$), from Justification to the case task post-test (total indirect effect .14; $p = .039$) and from Justification to Academic performance via pre- and post-test variables (total indirect effect .06; $p = .043$).

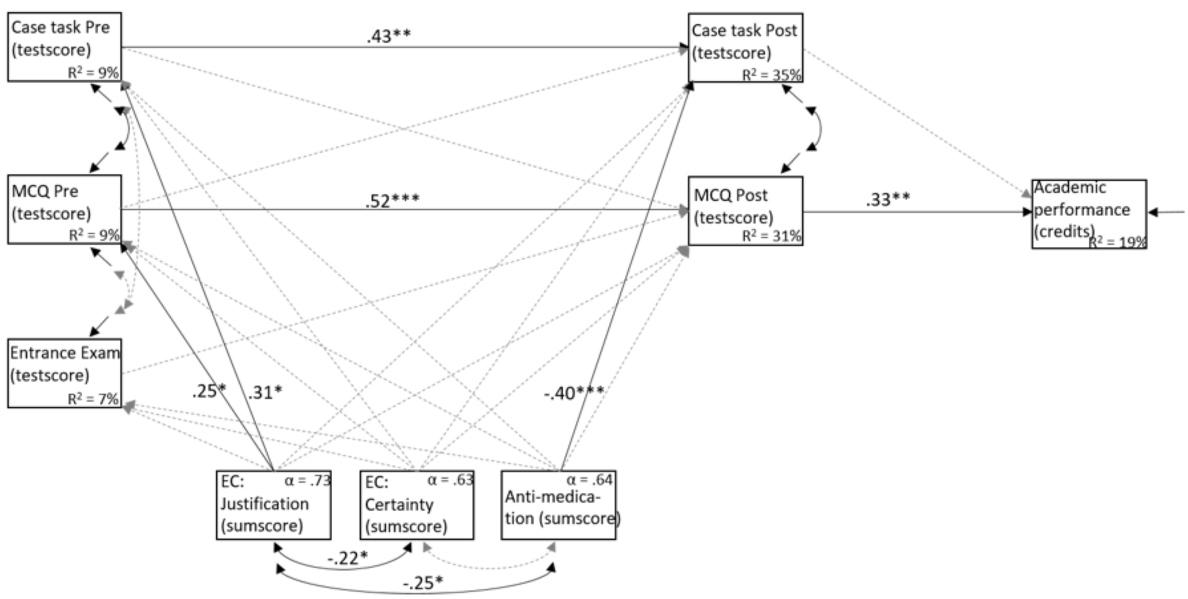

Figure 1. Path analysis model of epistemic cognition and medication beliefs predicting academic performance, with mediating effects of domain-specific conceptual understanding and entrance exam

Discussion

The first academic study year is largely recognised as laying the foundation for students' academic performance, and understanding the factors that promote or hinder students' academic success is of wide interest. Our study focused on conceptual and epistemic understanding related to pharmaceutical knowledge, to be precise, on antibiotic resistance and medication together with underlying biological knowledge. Therefore, the aim of this study was to add understanding of the development of university students' conceptual understanding during their first study year in relation to their beliefs, epistemic cognition and study progress from a domain-specific perspective. The results of this study revealed relatively serious challenges in students' conceptual understanding concerning elementary level knowledge. This is a worrying result considering that the multiple-choice questions were designed at a level that should have been mastered by the time of completing Finnish high school and challenges in basic conceptual understanding may have serious consequences during subsequent study (Södervik et al., 2020). However, the results of our study state that early identification of students with a higher risk of experiencing study delays or even dropping out is possible by using a relatively light prior knowledge test. These students would benefit from early support such as educational remediation. All in all, adequate first-year support should be provided, when necessary, because in the worst cases, delays may lead to dropping out from undergraduate education (Araujo et al., 2019).

We were also interested in students' underlying epistemic cognition of pharmaceutical knowledge and topic-specific beliefs on medication as such, and in relation to their conceptual understanding. The role of epistemic cognition in learning has been investigated extensively and it is suggested that it could be related to how learners integrate new knowledge with prior knowledge (Jacobson & Spiro, 1995). Therefore, a domain-specific epistemic cognition and beliefs measure was designed and tested. A new questionnaire was designed based on the assumption that pharmaceutical knowledge of medication, including antibiotics and vaccines, involves controversial and even disputed issues (Sinatra et al., 2014) and hence, measures that are more general might have failed to capture the phenomenon (Muis et al., 2006).

Our results showed that more sophisticated beliefs, particularly those related to justification of pharmaceutical knowledge, were related to general academic success, which was seen as a better score in the multiple choice questions and both in the baseline and in the follow-up measurement points in the case task and as a higher accumulated number of study credits after the first study year. This result is in line with previous findings highlighting the importance of justification in relation to academic achievement (for a review, see Cartiff et al., 2020). Conversely, a higher anti-medication beliefs score correlated with a lower accumulated number of study credits, less sophisticated beliefs related to justification of pharmaceutical knowledge, and weaker success in the problem-solving case task in the follow-up. Unscientific beliefs, such as anti-medication, presumably result in higher resistance towards conceptual change and reaching an adequate conceptual understanding among students, and further studies in higher education are needed. The results indicate that understanding how domain-specific knowledge claims can be warranted, how individuals evaluate the use of evidence, and how they assess the authority and expertise of science (Sinatra et al., 2014, 129) is an important factor influencing academic performance during the first study year (see also Bråten & Strømsø, 2009).

Limitations of the Study

This study is constrained by certain factors that need to be considered when the results outlined are interpreted and generalised. First, our study was conducted at one university, among one cohort of students, resulting in a quite small sample size. Additionally, the sample size was regrettably small in the post-test, which is typical problem in the studies with a follow-up design. Thus, it would be important to repeat the study with a larger sample in other contexts, as well as adapting the measures to other central topics. Additionally, the loadings of epistemic cognition items did not fully follow the theoretical assumption and we were able to distinguish only two dimensions instead of four. Several other previous studies have also found inconsistent results regarding earlier versions of epistemic cognition measures and have not been able to identify the four dimensions in Hofer and Pintrich's (1997) theoretical framework (see e.g. Bråten et al., 2009; Vančugovienė et al., 2024).

Conclusion

Our study showed that it may be possible to identify students at higher risk of delayed progress through their study with a relatively light prior knowledge test. Furthermore, our study adds to the empirical body of research, which states that domain-specific epistemic cognition and unscientific beliefs play a role in students' learning and study progress. Although this study was undertaken in pharmacy, the findings contribute to the larger-scale discussion about discipline-specific conceptual and epistemic understanding in higher education. The rapidly expanding amount of scientific knowledge and the continuous changes in work-related matters and society mean that we do not know the specific set of skills and knowledge today that will be necessary for future experts to succeed in the decades to come. However, we do know that students need support in learning to seek, evaluate and use scientific knowledge effectively and critically, and update their personal professional knowledge accordingly, to become adaptive experts with adaptive epistemic cognition.

Recommendations

To conclude, on one hand, students should understand that scientific explanations — such as theories and hypotheses — are subject to critical evaluation by the scientific community, in which explanations can be revised. At the same time, they also need to be able to discriminate, to know which findings have been well substantiated (Hofer, 2018). This requires students to understand the nature, foundations and principles underlying scientific research and the empirical grounds for acceptance. Thus, to improve the understanding of science, the students need to reconstruct both their conceptual understanding and their epistemic cognitive processes (Sinatra & Chinn, 2011). Hence, students' conceptual understanding requires not only the restructuring of students' alternative conceptions but also the restructuring of their modes of learning and reasoning (Vosniadou, 2013). For that, support from instruction is needed: university teachers should be aware that their students might hold unscientific beliefs, such as anti-medication beliefs among pharmacy students, that can have harmful consequences for students' learning and general study success – an aspect that may surprise many instructors, who may expect that beliefs of this type do not exist in their study programme. According to previous studies, even short interventions may be beneficial for supporting epistemic change (Cartiff et al., 2020). To be precise, instruction at universities should work towards building not only students' conceptual understanding, but also their epistemic competence, by supporting students to evaluate the source and worthiness of evidence (Hofer, 2016; Hofer, 2018; Kienhues, Jucks & Bromme, 2020; Murphy & Alexander, 2016).

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

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Authors Information

Ilona Södervik
Centre for University Teaching and Learning,
Siltavuorenpenger 5B, 00014,
University of Helsinki, Finland
Contact e-mail: ilona.sodervik@helsinki.fi
ORCID iD: https://orcid.org/0000-0001-8575-487X

Leena Hanski
Faculty of Pharmacy
Viikinkaari 5E, 00014,
University of Helsinki, Finland
ORCID iD: https://orcid.org/0000-0002-3121-8542

Eero Laakkonen
Department of Teacher Education,
Assistentinkatu 5, 20014
University of Turku, Finland
ORCID iD: https://orcid.org/0009-0000-6763-5877

Nina Katajavuori
Centre for University Teaching and Learning,
Viikinkaari 9, 00140,
University of Helsinki, Finland
ORCID iD: https://orcid.org/0000-0001-5093-2402