The Impact of Domain-Specific Training on Teacher Knowledge Familiarity: A Case Study of Teacher Training Colleges

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Abstract

This study investigates the impact of domain-specific training on the familiarity and proficiency of teacher knowledge among teacher education students. By comparing teacher education students with their non-teacher education peers, the study aims to explore the development of conditional knowledge-encompassing theoretical content knowledge, cognitive process knowledge, and problem condition knowledge-as foundational for effective teaching practices. Utilizing eye-tracking technology, we examine participants' visual attention patterns and cognitive processing efficiency, capturing metrics such as fixation times, saccades, and response accuracy. Results reveal that teacher education students display a significantly heightened familiarity with teaching-related domain knowledge, reflecting faster response times, higher accuracy rates, and greater confidence levels. These findings underscore the importance of teacher training programs in fostering essential cognitive tools and domain-specific knowledge structures that enhance future educators' preparedness for complex teaching environments. Insights from this study highlight the need for refined teacher training approaches to further strengthen essential knowledge areas, equipping educators with the competencies required for the demands of the modern classroom.

Keywords

Teacher Education Students, Teacher Education, Domain Knowledge, Conditional Knowledge, Eye Movement Research

1. Introduction

The intersection of cognitive science and education has long provided a fertile ground for exploring the complexities of learning and expertise. In the 1970s, the advent of domain knowledge in artificial intelligence marked a significant step forward by providing a framework for understanding how specialized information, skills, and understanding can be systematically applied to solve problems within specific fields [1]. This concept has since been instrumental in shaping our understanding of cognitive development and the acquisition of expertise across various domains.

In the field of teacher education, the relevance of domain knowledge is of paramount importance. Preservice teachers must develop a robust professional knowledge structure that encompasses not only subject matter expertise but also pedagogical content knowledge, which is the blend of content knowledge and pedagogy that enables effective teaching [2]. This body of knowledge is crucial for the next generation of educators, who must be adept at facilitating psychological development, employing interactive teaching methods, and assessing student achievement [3].

The uniqueness of teacher education lies in its focus on cultivating conditional knowledge, which is integral to the pedagogical strategies and psychological understanding necessary for effective classroom management and instruction. This domain-specific knowledge is the cornerstone of teacher education programs, which are designed to equip students with the competencies essential for effective teaching.

The relationship between domain knowledge and cognitive performance, however, is multifaceted. While extensive domain knowledge can enhance memory, comprehension, and problem-solving abilities [4,5], it can also impede performance under certain conditions [6,7]. This dichotomy underscores the need for a nuanced exploration of how domain knowledge influences cognitive tasks within an educational context.

Building on the seminal work of Hambrick and Engle [8], which delineated the interaction between domain knowledge and working memory, this study adopts a tripartite perspective to understand the interplay between these cognitive constructs. The compensation model, the independent influence model, and the rich-get-richer model offer distinct yet complementary insights into how individuals with varying levels of domain knowledge and working memory capacity perform cognitive tasks.

To delve into the intricacies of domain-specific knowledge acquisition among teacher education students, we designed a questionnaire to assess their conditional knowledge, which encompasses theoretical content knowledge, cognitive process knowledge, and problem condition knowledge [9]. Utilizing eye-tracking technology, we aimed to objectively measure the visual attention patterns and cognitive processing efficiency of teacher education students compared to their nonteacher education peers.

The findings from this study are expected to shed light on the effectiveness of teacher education programs in nurturing the development of essential knowledge domains. Moreover, these findings will provide insights into how these programs can be refined to better prepare future educators for the dynamic demands of the teaching profession.

2. Materials and Methods

2.1 Subjects

A total of 45 freshmen and sophomores (18 males and 27 females) were selected from a university in Fujian Province, comprising 24 teacher education students and 21 nonteacher education students. The participants' ages ranged from 19 to 24 years, with a mean age of 21.29 years (SD = 1.25). All participants received an explanation of informed consent and signed a written informed consent form. All participants had normal or corrected visual acuity, no color blindness, and no dyslexia. Before the experiment, participants were unaware of the experiment's purpose and had not participated in similar experiments. The experiment was reviewed by the Ethics Committee of the School of Psychology, and informed consent was obtained from all participants. After the experiment, participants were given a small gift.

2.2 Experimental Design

This experiment was designed to compare the differences in familiarity with teachers' conditional knowledge between teacher education students and nonteacher education students. The experimental design was a two-factor mixed design (2x3), with the between-group factor being the type of students (teacher education students and nonteacher education students). The within-group factors included the knowledge content of the test object, which were categorized as theoretical content knowledge, cognitive process knowledge, and problem condition knowledge. The dependent variables included test result scores, accuracy rate, response time, self-rating results, fixation times, blink times, and saccade times.

2.3 Experimental Instruments

In this study, the Eye-LINK2000 eye tracker, developed by SR Research (Canada), was used to present test materials on scientific content knowledge and cognitive process knowledge, and to collect data. The eye tracker consisted of three parts: the test machine, the main test machine, and the recording device. The 19-inch display of the NEC-FE2111SB was used to display the test materials with a resolution of 1024×768 pixels and a refresh rate of 120 Hz. The eye tracker had a sampling frequency of 1000 Hz, a refresh frequency of 120 Hz, and a resolution of 1024×768 pixels. Additionally, a paper-and-pen test of problem condition knowledge was conducted.

2.4 Experimental Materials

2.4.1 Test Content Questions

Based on the classification of domain knowledge, this study selected compulsory module textbooks for teacher education courses in Fujian universities: developmental and educational psychology, basic principles of education, and curriculum and teaching theory [10]. The study considered the system of teachers' conditional domain knowledge. The process of writing the test questions was as follows: First, thirty graduate students in psychology and education conducted a pretest before the formal experiment, assessing the chapters and modules of the teaching materials. Then, a public course teacher was invited to select the key chapters and determine the specific scope of the assessment content. Finally, three psychology and education graduate students were tasked with writing a set of conditional knowledge tests based on the division of domain knowledge, including theoretical content knowledge, cognitive process knowledge, and conditional problem knowledge. The preliminary questions included 20 multiple-choice questions on scientific knowledge content, 20 questions on cognitive process knowledge (learning materials + multiple-choice questions), and 4 essay questions on conditional problem knowledge. A correct answer on multiple-choice questions was worth 1 point, and each essay question was worth 10 points. Additionally, 16 non-teaching major undergraduate students and 23 graduate students in the School of Education at a university in Fujian were invited to participate in a pretest and were regarded as the high and low groups, respectively. Questions with a discrimination index of less than 0.3 were excluded or modified according to feedback. Finally, 12 multiple-choice questions on scientific knowledge content were retained. Twelve questions were included for cognitive process knowledge (learning materials + multiple-choice questions), and 2 questions were included for conditional problem knowledge (essay questions). The learning materials and responses for scientific and cognitive process knowledge were recorded using an eye tracker, while the conditional knowledge test was conducted on paper.

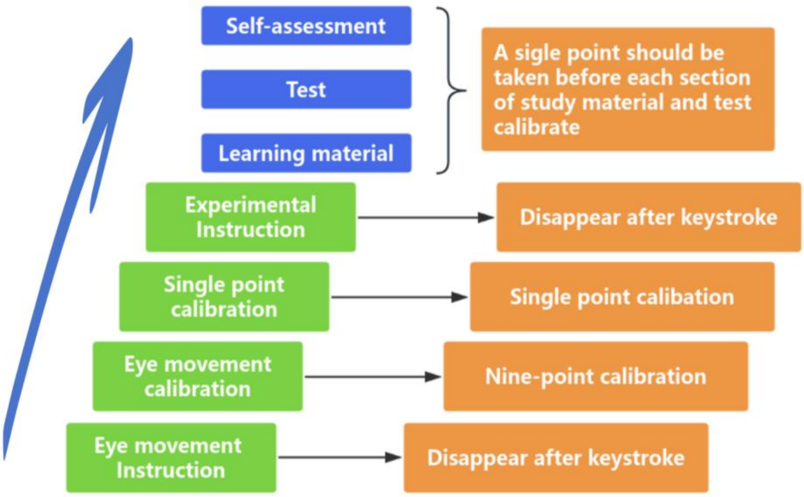
2.4.2 Self-Rating Scale

A self-rated Likert scale was developed, and the accuracy of the test results was also self-assessed. A 5-point scale was used. Participants were asked to choose a number from 1 to 5 that aligned with their confidence in their answer: 1 = sure, 2 = somewhat sure, 3 = unsure, 4 = somewhat unsure, 5 = not sure.

2.5 Experimental Process

The experiment was conducted individually, and participants were tested in a dedicated eye movement laboratory to minimize environmental distractions and ensure their comfort and relaxation. The specific procedure is illustrated in Figure 1 below.

Figure 1. formal experiment flow chart



3. Data Processing and Analysis

3.1. Eye Movement Area of Interest (Single-Point Calibration)

The area of interest (AOI) refers to the segments of the reading materials that the researcher designates as focus areas. Different classification methods are employed for various experimental purposes. In this experiment, the information in the test process materials was divided into five AOIs: the question part and the four option parts.

3.2. Results

SPSS 16.0 software was used to input and analyse the experimental data, and descriptive statistics and independent-sample t tests were performed on the data.

Table 1. T test of differences in academic content knowledge and cognitive process knowledge between normal college students and non-normal college students (*df*=43).

	Normal or not	*n*	Accuracy	Self-assessment *MD*	*tt*	Scientific knowledge	Cognitive process knowledge	Conditional problem knowledge	Learning section - Average saccade	Test - Average saccade	Total saccade
M±SD	N	21	0.37±0.14	2.54±0.80	646.11±108.10	4.20±2.68	4.86±1.86	4.81±0.71	52.93±30.52	16.05±5.24	510.18±169.67
	Y	24	0.65±0.15	2.10±0.56	456.88±83.49	8.92±1.86	6.58±2.74	11.67±0.83	39.07±17.02	11.09±3.79	367.50±89.59
t	N	21	-6.31^{***}	2.19^{*}	3.30^{**}	-6.94^{***}	-2.44^{*}	-6.18^{***}	1.91	3.76^{**}	2.49^{*}
	Y	24									

As illustrated in Table 1, the data revealed several notable findings that underscore the differences between teacher training students and nonteacher training students. The statistical analysis revealed a significant disparity in the performance of these two groups across various measures. Firstly, there was a marked distinction in the time taken to answer the questions ($p<0.01$), the accuracy of the responses ($p<0.001$), and the confidence in their correct judgments ($p<0.05$). These results indicated that teacher training students demonstrated a higher level of proficiency than their nonteacher training counterparts. Specifically, they completed the questionnaire more quickly, achieved a higher percentage of correct answers, and exhibited greater confidence in their ability to accurately assess their responses.

Delving further into the three domains of knowledge, the analysis revealed considerable differences between the teacher training and nonteacher training students, particularly in theoretical content knowledge and problem condition knowledge, which showed high statistical significance ($p<0.001$). This suggests that teacher training plays a substantial role in enhancing teachers' understanding and application of theoretical concepts and their ability to solve problems within their knowledge domain. Moreover, significant differences were also observed in the number of tests ($p<0.01$) and total saccades ($p<0.05$). During the learning stage, the p-value reached 0.063, indicating marginal significance. This implies that teacher education students demonstrated a greater familiarity with domain knowledge pertinent to teaching.

The use of eye-tracking technology, which measures saccades (quick, involuntary eye movements between points of interest), provided objective evidence that teacher education students were more adept at processing information related to their field of study. Overall, the results of this study underscore the value of teacher education in equipping students with essential cognitive tools to navigate the complexities of their chosen profession. It is evident that teacher training not only enhances the acquisition of knowledge but also strengthens confidence and cognitive efficiency in future educators.

Table 2. T test of the average time (s) spent reading questions and options and the difference in fixation points of normal college students and non-normal college students in scientific content knowledge and cognitive process knowledge tests.

	Normal or not	n	Scientific knowledge topic fixation time	Scientific knowledge topic fixation frequency	Problem condition knowledge topic fixation time	Problem condition knowledge topic fixation frequency	Scientific knowledge options fixation time	Scientific knowledge options fixation frequency	Conditional problem knowledge options fixation time	Conditional problem knowledge options fixation frequency
M±SD	N	21	75.26±30.91	60.04±23.37	65.63±25.26	53.29±18.35	6.76±2.33	32.29±10.63	8.93±3.39	42.95±15.47
	Y	24	43.13±21.25	34.13±14.13	51.25±18.83	41.43±13.44	3.90±1.86	18.66±7.07	7.07±2.46	33.55±10.95
d	N	21	4.11***	4.57***	2.18*	2.49*	4.58***	5.13***	2.13*	2.38*
	Y	24								

Table 3. T test of the difference between normal college students and non-normal college students in the average percentage (%) of correct choices in the test of academic content knowledge and cognitive process knowledge.

	Normal or not	*n*	*M±SD*	*df*	*t*
Scientific knowledge-The percentage of time spent on correct options	N	21	29.19±6.74	43	-.2.93**
	Y	24	34.30±4.88		
Scientific knowledge-The percentage of the correct option's fixation points	N	21	27.87±6.27	43	-3.45**
	Y	24	34.01±5.69		
Problem condition knowledge-The percentage of time spent on correct options	N	21	24.46±3.93	43	-2.45*
	Y	24	28.78±5.10		
Problem condition knowledge-The percentage of the correct option's fixation points	N	21	25.31±4.09	43	-3.15*
	Y	24	28.72±5.09		

Note that the rows indicate the starting areas, and the columns indicate the target areas.

$^{*}p < 0.05$. $^{**}p < 0.01$. $^{***}p < 0.001$.

The data presented in Tables 2 and 3 reveal intriguing insights into the cognitive processes of teacher education students compared to their nonteacher education peers. The findings illustrate that during the examination, those undergoing teacher training devoted less time and attention to reading the questions. This suggests a heightened familiarity with the subject matter, likely attributable to their educational training. Significant disparities were observed between the two groups in their overall performance levels. These differences underscore the relative advantage that teacher education students possess in conditional knowledge questions specific to teaching practices.

The variance in knowledge of theoretical content surpassed that of cognitive process knowledge, indicating that while both are important, theoretical knowledge may hold greater significance or present more complexity for the students. Teacher education students demonstrated a more efficient approach in processing response options. They required less time and focused less on reading the available choices, demonstrating a significant difference compared to their counterparts. Furthermore, the reaction of teacher education students to theoretical content knowledge was notably swifter and more sensitive than their response to cognitive process knowledge ($p<0.01$ versus $p<0.05$), suggesting a deeper grasp of theoretical concepts than the application of such theories.

Additionally, teacher education students displayed greater accuracy and decisiveness in their judgments. They spent a greater percentage of time focusing on the correct answers and concentrated their attention on the correct options. This implies that teacher education not only provides students with a solid foundation in theoretical knowledge but also enhances their capacity to make accurate and confident judgments-a crucial skill in the teaching profession. These results corroborate that teacher education plays a pivotal role in shaping the cognitive frameworks and knowledge acquisition of future educators. These findings highlight the importance of theoretical content knowledge and demonstrate that teacher training programs effectively prepare students for the complex tasks inherent in the teaching environment.

4. Discussion

Studies of students with varying knowledge levels across different fields have shown significant differences in the processing of key, confusing, and redundant information [11]. According to Wolfe [12], an effective visual search is governed by two factors: the ability to direct attention to relevant cues and the speed of rejecting distractions.

An efficient search means that attention is immediately directed to the target item, thus making the remaining scene irrelevant. This model is based on the information simplification hypothesis proposed by Haider and Frensch [13]. Eye movements are expected to have longer durations and longer gaze/stay times in relevant areas and shorter durations and shorter gaze/stay times in disturbed areas, resulting in highly selective attention allocation [14]. If the subject directs attention in a top-down manner based on the target, distractors containing bottom-up signals will be ignored [15-20] This process can be modulated by experience, and the presence of a familiar target makes the subject quicker and more likely to find the same target again. In the assessment of teachers' conditional knowledge, our study revealed a marked distinction between teacher education students and nonteacher education students in terms of their attention to and processing of correct responses. Teacher education students exhibited heightened sensitivity and acuity in their reactions to accurate answers. The observation of shorter response times and fewer fixation points indicates accelerated cognitive processing among these individuals, suggesting that well-trodden domain knowledge plays a pivotal role in refining and enhancing the learning experience. Moreover, it was noted that teacher training college students displayed a significantly greater degree of self-confidence in self-assessment than their counterparts. Such confidence could be construed as an indication of superior metacognitive monitoring-a facet of cognition that enables learners to evaluate their knowledge and comprehension effectively. This enhanced self-evaluation capability may be reflective of the comprehensive instruction received through teacher education programs, equipping students not only with subject matter expertise but also with advanced cognitive skills crucial for teaching professionals.

The theory of long-term working memory, posited by Ericsson and Kintsch [21], suggests that memories can be swiftly retrieved from specific contexts, significantly impacting our perception. According to the theory, through repetition and practice, domain-specific knowledge becomes well-entrenched within our long-term memory reserves. Consequently, when confronted with tasks requiring such knowledge, the information is readily accessible, facilitating efficient task completion. This process is facilitated by working memory's ability to extract pertinent information necessary for the immediate demands of a task. The ability to rapidly draw upon long-term memory results in an effortless and coherent output of fundamental, task-oriented information.

In line with this, Gegenfurtner [14] assert that due to the rapid acquisition of foundational details, eye movement metrics would show shorter and fewer fixations across different locations, indicating improved efficiency in visual search processes. This finding aligns with Rayner's [22] hypothesis, which interprets these eye-tracking measures as indicative of superior efficiency in visual search. Our investigation into the performance of teacher education students versus their nonteacher education peers on tests of teachers' conditional knowledge revealed significant differences. These differences were evident not only in the test outcomes but also in the eye-tracking measures, including fixation duration, gaze times, and saccade counts for both questions and options. These findings highlight that teacher education students possess a significantly higher level of familiarity and comprehension regarding teachers' conditional knowledge than their counterparts. This disparity suggests that teacher education plays a crucial role in fostering the development and construction of conditional knowledge among individuals preparing to enter the teaching profession.

In essence, the data obtained from our study corroborate the assertions posited by the theory of long-term working memory. The ability to rapidly and accurately access domain-specific information seems to stem from repeated exposure and practice within a specific field, as observed among teacher education students. Their advanced preparation and mastery of the subject matter are reflected in their cognitive processing abilities, which manifest in shorter response times, reduced eye movements, and increased accuracy during testing scenarios.These findings underscore the importance of specialized educational training in developing the cognitive frameworks essential for effective teaching practices.

In the context of our empirical investigation, it has become evident that among the various dimensions of pedagogical knowledge assessed, the most significant disparity was observed in the domain of problem condition knowledge among teacher education students. This facet was followed by their understanding of academic rationale and cognitive processes in terms of significance. The stratification of these results is not without precedent, as the existing literature has consistently highlighted the correlation between commendable academic performance and the adaptable application of knowledge by students. As elucidated by previous research [10,23], students who excel in their academic endeavors demonstrate the ability to adeptly analyze specific problem scenarios. These scholars suggest that effective learning is reflected in the flexible and accurate deployment of knowledge, which serves as a cornerstone for successful cognitive processing and decision-making. It appears that individuals undergoing teacher education benefit from a curriculum that both emphasizes and refines this particular skill set, enabling them to better grapple with the complexities of pedagogical challenges. The data obtained from our study underscore the paramount importance of fostering a nuanced understanding of problem condition knowledge within teacher education programs. Such an emphasis not only equips prospective educators with the necessary tools to navigate the multifaceted nature of teaching but also ensures a more profound grasp of the cognitive and conceptual frameworks that underpin academic disciplines.

5. Conclusions

The comparative analysis between teacher education students and their counterparts without teacher education across the three types of knowledge-assessed through eye movement data and behavioral metrics-reveals a marked disparity. The findings indicate that teacher education students exhibit a heightened familiarity with and mastery of teachers' conditional knowledge. This advanced understanding is rooted in a solid grasp of fundamental principles and concepts that form the foundation for the straightforward application of knowledge. Furthermore, this knowledge foundation facilitates sophisticated analytical discourse within real-world contexts. Notably, lacking a well-established domain-specific knowledge framework, students from institutions without teacher training struggle to swiftly assimilate material to the same degree of proficiency as those undergoing teacher training. In conclusion, the results of our study underscore the influential role of teacher education in shaping the development of teachers' conditional knowledge. The pedagogical training received by students in teacher education programs not only enhances their cognitive processing abilities but also significantly improves their overall performance in applying and articulating domain-specific knowledge.

In the context of our empirical investigation, it has become evident that among the various dimensions of pedagogical knowledge assessed, the most significant disparity exists in the domain of problem condition knowledge among teacher education students. Following this, their understanding of academic rationale and cognitive processes was of significance. The stratification of these results is not unprecedented, as the existing literature has consistently highlighted the correlation between commendable academic performance and the adaptable application of knowledge by students. As shown in previous studies, students who excel in their academic endeavors demonstrate the ability to analyze specific problem scenarios adeptly. With this analytical skill, they can make judicious selections and evaluations, thereby facilitating a comprehensive interpretation of the underlying principles and concepts inherent in the subject matter. These scholars posit that effective learning is reflected in the flexible and accurate deployment of knowledge, which is a cornerstone for successful cognitive processing and decision-making. The outcomes of our current experiment resonate with these previous findings, reinforcing the notion that the capacity to handle problem condition knowledge is a critical determinant in differentiating students' mastery and understanding of educational material.

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