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THE COGNITIVE-EMOTIONAL PROCESSES AND THEIR IMPLICATIONS FOR TEACHER EDUCATION RESEARCH

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Abstract
Cognition and emotion are intertwined structures. Emotions experienced by all stakeholders in the educational environment affect cognitive processes, learning and teaching performances. The purpose of this review is to explore the interactions of different cognitive and emotional stimuli related to emotional processing and cognitive processes in various brain regions and to provide a basis for their use in the context of teacher education research. Experimental studies addressing this interaction of cognition and emotion were examined and brain regions related to cognitive and emotional functions were synthesized. It was pointed out that the effects of emotion on cognitive processes are context-specific and personal; positive emotions do not always have positive effects on cognitive processes or negative emotions do not affect these processes negatively. In light of these findings, suggestions were made for educational researchers.

Keywords: cognition; emotion; teacher training; pre-service teachers; neuropsychological correlates

Introduction

Teaching is a process surrounded by emotional experiences (Cowie, 2011; Hargreaves, 1998; Zembylas, 2005). Studies in the literature show that designing the learning environment by considering emotional situations bring

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positive results such as increasing engagement (Linnenbrink-Garcia, Patall, & Pekrun, 2016) and improving learning (O'Regan, 2003). On the other hand, it is often emphasized that teaching is a multifaceted profession that requires constant interactions with different stakeholders. This subsequent interaction of teachers, especially of teachers who have just started their professional life, with students, parents, and school administrators, makes them experience different and/or constant change in emotions.

Uitto, Jokikokko, and Estola (2015) conducted a content analysis over 70 research on teacher emotions between 1985 and 2014. They summarized those studies basically in seven different categories: (1) feelings about teacher identity and professional development, (2) teachers' emotional burnout, (3) teachers' feelings and relationships, (4) teachers' effects on student feelings, (5) teachers' emotional intelligence-skills-knowledge, (6) teachers' emotions and (7) regulation of emotions. Although the majority of those studies were qualitative in design, some of them were also designed as either in quantitative or in mixed methods. The participants in those reviewed studies were mainly preservice (prospective) teachers, primary, secondary and high school teachers, teacher educators, and administrators. In most of the studies, observation, interview and self-reporting data collection methods were preferred. Uitto, Jokikokko, and Estola (2015) reported that the factors related to teachers' emotional states were focused on social factors such as school climate, interpersonal relations, workload, and individual factors such as cognitive self-regulation, assertiveness, target orientation, and job satisfaction. They further added that majority of those studies focused on emotional intelligence and emotional competence, but not directly on teacher feelings. As a result, they have concluded that it would be beneficial to examine teacher emotions more in-depth. They have also drawn attention to the weaknesses of existing data collection tools which had been mainly observations, interviews, and questionnaires, suggesting that innovative methods to detect emotional situations in daily educational settings are needed.

Fried, Mansfield, and Dobozy (2015) examined 82 studies published between 2003 and 2013 to explain how teacher emotions were conceptualized. The researchers concluded that (1) teacher emotions and appraisals are shaped by social, political and cultural factors within and between individuals; and, (2) emotional experiences of teachers have an effect on students' motivation and cognitive processes. In the future studies, in addition to the use of measurement tools to record the emotional state of the teachers in a longitudinal way and instant, the researchers also recommended the use of methods (*e.i.,* self-reporting and storytelling) that would reveal certain dimensions of emotion. They went further to state that there was a need for research to be carried out with psychological measures that would help understand the different dimensions of emotion.

Emotions are known to play an important role in improving the quality of teaching and learning in teacher education (Day & Leitch, 2001). Hargreaves (2000) suggests that emotions be evaluated together with cognitive and behavioral situations during teaching and learning process, considering the multidimensional, dynamic and contextual structure of emotions (Pekrun & Schutz, 2007). However, some researchers criticize the majority of educational research in that instead of focusing directly on teacher emotions, many researchers study emotions in the context of emotional intelligence, emotional burnout, emotional competence, and teacher-student relationships (*e.i.,* Fried, Mansfield, & Dobozy, 2015). This may simply be due to the fact that changes in emotions heavily depend on time and context (Meyer & Turner, 2006), have a multidimensional complex structure (Sutton & Wheatley, 2003) and are specific to the individual (Hargreaves, 1998). This complexity can however be approached with a cognitive-emotional framework on how teacher emotions should be handled with a focus on cognitive dimension (Fried, Mansfield, & Dobozy, 2015). Therefore, the aim of this study is to reveal the interactions of different cognitive and emotional stimuli related to emotional processing and cognitive processes in various brain regions and to provide a basis for their use in the context of teacher education research. In what follows, the interaction of cognitive and emotional processes will be scrutinized under the following headings: (1) Executive functions and emotions (2) Language processing and emotions (3) Visual-Spatial information processing and emotions (4) Memory and emotions. Finally, suggestions will be made on the basis of this interaction for further research on teacher emotions.

Interaction of cognitive and emotional functions

Executive functions and emotions

The executive function is the ability to sustain attention, improve reasoning, support problem solving along with integrating past experiences and planning for the future (Zelazo, Blair, & Willoughby, 2016). Early definition are ambiguous in that executive function had been related to attention, planning and self-regulation skills (Zelazo et al., 2016). Yet, with the recent research findings, researchers have extented this scope and redefined executive functions as a set of attention-regulating skills, conscious targeted problem-solving skills (Zalezo et al., 2016; Kamkar & Morton, 2017), inhibitory control (inhibition), cognitive flexibility (update), and working memory components (Zalezo et al., 2016; Gijselaers, Meijs, Neroni, Kirschner, & de Groot, 2017). Researchers and educators agree on the fact that executive functions associated with prefrontal cortex activities should be utilized in educational contexts and be placed among teacher competences, since they involve deeper understanding and control of cognitive processes (Anderson, 2002).

Philliphs, Bull, Adams, and Frazer (2002) investigated the effect of positive mood on executive functions and fluency based on the finding that positive moods improve cognitive processes associated with the anterior cortex. Executive functions of 36 participants were evaluated with Stroop test and fluency performance of 60 participants were evaluated with three different fluency tasks. The results showed that positive mood had a negative effect on fluency performance during the change condition in the Stroop test and improved the performance in the fluency test.

Tang and Schmeichel (2014) examined the effect of individuals' inhibitory control capacity on an emotional process when recalling autobiographical memories. Participants' inhibitory control capacity was determined by using stop-signal test, in a procedure that could cause anger, anxiety and neutral emotions. The results showed that individuals with low inhibitory control had significantly experienced higher arousal (*i.e.*, emotion intensity) during the induction and anger-inducing processes than those with high inhibitory control.

Shields, Moons, Tewell, and Yonelinas (2016) aimed to explore the effect of negative emotions such as anxiety and anger on executive functions. 153 healthy participants were asked to write down their angry and anxious situations in order to understand their anger and anxiety conditions. Data on emotion states were obtained by self-report and data on executive functions were obtained by Wisconsin Card Sorting test. The results showed that anger had no disruptive effect on executive functions, but anxiety had disruptive effect.

Sperduti, Makowski, Arcangeli, Wantzen, Zalla, Lemaire, Dokic, Pelletier, and Piolino (2017) had aimed to investigate the effects of executive functions on implicit emotion regulation strategies that has been thought to be more effective in daily life. In order to down regulation the emotions of 34 healthy participants, the fictional or real short texts were presented to the participants with negative emotion valence at different intensities. Participants reported a sense of subjective arousal based on their electrodermal activity measurement scores. There was no difference reported in their electrodermal activity scores between fictional and real short texts. In negative fictional conditions with high emotion intensity, the suppression of emotion differed depending on the update performance only. The results indicated that there was a relationship between update performance and implicit suppression of intense emotions.

Wang, Chen and Yue (2017) investigated the effects of positive emotions on cognitive flexibility and its associated neural mechanisms on the basis of the task change paradigm along with neuroimaging screening. 19 healthy participants were presented with positive, negative and neutral images of different valance. Then, they were asked to determine whether the number of a given color was odd or even. After a series of experiments, the target stimulus was discolored. According to the task change performance results, the reaction time was shortened in the positive stimuli compared to the neutral conditions, while the reaction time was prolonged in the negative stimuli. According to the neuroimaging results, more activation was observed in dorsal anterior cingulate cortex (dACC) under repeated conditions. Activation in dACC was decreased in participants with positive emotion under changing conditions, whereas activation in participants with negative emotion increased significantly compared to neutral ones. Activation in dACC did not differ significantly if the condition did not change. It was concluded that positive emotions decreased the activation of dACC, reduced conflict, and increased cognitive flexibility.

In summary, existing research explored the effects of the complex relationship between emotional states and the various components of executive functions. Also, there are limited number of studies investigating the effects of cognitive skills on emotional processes and behavioral responses (*e.g.,* Tang & Schmeichel, 2014). In some studies, it was observed that emotions were studied based either on valence dimension (*e.g.*, positive and negative) or on discrete emotions (Shields et al., 2016). While positive moods and anxiety has been found to have negatively affected executive functions (Philliphs et al., 2002; Shields et al., 2016), positive moods have yielded more cognitive flexibility (Wang et al., 2017). In other words, as individuals had higher performances in updating, they regulated their emotions easier (Sperduti et al., 2017), whereas as they failed to control their inhibition, their emotion intensities increased (Tang & Schmeichel, 2014).

Language processing and emotions

Language processing is associated with inferior frontal gyrus, superior temporal gyrus, and middle temporal gyrus. Trauer, Andersen, Kotz, and Müller (2012) examined the effects of distracting activities and lexical semantic processing on words with emotion-based activities. 23 participants followed a series of randomly moving squares superimposed on positive, neutral, or negative valued words. The results showed that the deviations of P2 and N400 for negative words had increased and the word containing negative emotion had modulated lexical-semantic processing. However, when behavioral data and evoked potentials were examined, it was observed that distracting emotional words did not affect task performance. This distinction of emotional effects on early perceptual and lexical processing stages has shown that written emotional words may not lead to attention modulation in early visual fields.

Rodriguez-Ferreiro and Davies (2018) explored the effects of valence and arousal on word recognition reaction time based on the finding that positive words were processed faster than negative words compared to neutral words. Positive, negative and neutral words were drawn from the Spanish lexical decision dataset. Results showed that valence had an effect on reaction time, but no significant effect of arousal had been observed. According to reaction times, positive words were recognized in a shorter time than neutral words, while negative words were recognized in a longer period than neutral words. In addition, the effect of valence was found to be more pronounced in lexical decision than in pronunciation.

Positive mood improves semantic memory activation during word rendering process compared to negative mood (Ogawa & Nittono, 2019). In their research, Ogawa and Nittono (2019) examined the effect of participants' current mood on subjective word imagination score along with event related potential components on a single word. A single imaginable word was selected and presented to 41 participants. The results showed that participants' self-reported mood did not affect neither their subjective imagery scores nor their N700 amplitude. In addition, the researchers claimed that the effects of mood on language processing, where the relationship between words in semantic memory changed power, might not occur at the level of one-word processing.

To summarize, researchers explored the effects of valance on word recognition, word rendering, and semantic processes. The research results showed that emotions did not affect subjective imagination, semantic processing for a single word, and that the valence dimension of emotion (positive-negative) had an effect on word recognition time.

Visual spatial information processing and emotions

Visual spatial information processing includes cognitive functions that enable the individual to perceive the stimuli in the environment along with his / her own physical position. The visual-spatial properties of the objects (such as where and what they are) are processed by various areas of the occipital, temporal, parietal regions and are integrated all in the prefrontal cortex.

De Sonneville, Verschoor, Njiokiktjien, Op het Veld, Toorenaar, and Vranken (2002) examined the accuracy and speed of face recognition and emotion recognition in abstract visual spatial processing in children (7-10 years old) and adults (21-29 years old). 106 children and 26 adults participated in the study. Participants performed five tasks in the Amsterdam Neuropsychological Tasks and Recognition of Facial Expressions Test. In the age range of 7-10, the accuracy of facial processing almost did not increase as the age increased, while the processing speed increased significantly with age. In all tasks, adults performed faster and more accurate processing than children. The results showed that speed in visual spatial processing was more sensitive to the developmental process.

Ferstl and von Cramon (2007) emphasize that understanding a story requires readers a representation of the story in their minds with questions such as who, when, and how. From this point of view, researchers investigated the activation of emotional, temporal and spatial processing in the brain with fMRI. 20 participants read stories, some of which were inconsistent in terms of emotional, temporal and spatial information. The results of the study showed that the anterior lateral prefrontal cortex / orbito-frontal cortex was involved in the processing of temporal information, the left anterior temporal lobe was involved in the processing of emotional information, and the visual-spatial information was involved in the posterior cingulate cortex.

Kaltner and Jansen (2014) examined the effects of fear and anxiety during mental rotation performance based on participants' egocentric and object-oriented rotation strategies. In this study, 86 participants were presented with either a fear stimulus or a neutral stimulus, which was expected to awaken after each mental rotation task. Particularly in the egocentric rotation strategy, in which the participant changed his / her perspective during mental rotation, it was concluded that fear increased the mental rotation performance. In addition, participants with high scores on anxiety scale showed poor results both in reaction time and mental rotation rate.

Herrmann, Neueder, Troeller, and Schulz (2016) explored the effect of competition in working memory on emotional facial expression based on the dual task paradigm. In addition, fNIRS and EEG were simultaneously recorded from 36 participants to reveal brain regions associated with this task. The corsi block test, the face identification task and the dual task in which both tasks were presented together were used in the experiment. High activation was observed in the prefrontal cortex during the dual task compared to single tasks. Furthermore, a decrease in P100 was observed, while the expected level of P300 did not decrease. The results show that some aspects of emotional processing are not fully automatic, are dependent on prefrontal control, and are therefore influenced by the sources of visual-spatial working memory.

To sum up, research examining the interaction between visual-spatial information processing and emotion has mainly focused on understanding the differences related to development (De Sonneville et al., 2002), discrete emotions (Kaltner & Jansen, 2014) and working memory performances (Herrmann et al., 2016). One could conclude that (1) as the age of individuals increased, the speed of processing emotional expressions increased, (2) fear improved mental rotating performance and anxiety had negative effects on it, and (3) emotional processing was not fully automatic. Physiologically, anterior lateral prefrontal cortex and orbitofrontal cortex are the brain regions associated with visuospatial information processing and emotion interaction.

Memory and emotions

Memory is a structure in which the stimulus is encoded, processed, stored, and retrieved. In their study, Zembylas, Charalambous, and Charalambous (2014) investigated the relationship between memories and emotional states during the pedagogical practices of teachers. They concluded that political and cultural norms shape emotional situations in their classroom practices.

Kensinger, Garoff-Eaten, and Schacter (2007) examined the remembering central emotional element and non-emotional element in visual scenes. According to the researchers, the relationship between negative emotional stimuli and memory could be explained by how the main idea and visual details of the emotional stimulus is remembered. Therefore, in their research, 16 participants were asked to remember the main ideas and visual details of the objects in these scenes -with negative and neutral objects placed in the background- through four different experimental processes. They have found that central emotional elements in scenes are better remembered than environmental non-emotional elements. The results also indicated that emotion did not facilitate the storage of all aspects of the presented stimuli in memory.

Luo, Qin, Fernandez, Zhang, Klumpers, and Li (2014) examined the effects of emotional stimuli on working memory performance with fMRI. 25 participants received an n-back task with fear and neutral stimuli. The participants made more errors in the fear stimuli in the 0-back task than the neutral stimuli. In the 2-back task, they made more mistakes in neutral stimuli than fear stimuli. The dorsal anterior insula (dAI) and dorsal cingulate cortex (dACC) were more active in the 0-back task of fear stimuli than neutral stimuli. In the 2-back task, there was a decreased activation of dAI, increased activation of the temporaloccipital cortex and amygdala in fear stimuli.

Plancher, Massol, Dorel, and Chainay (2019) aimed to examine the effect of negative emotional content on working memory. In two different experiments under acoustic suppression, five-letter sequences with negative and neutral images were shown to the participants. In both experiments, negative images were processed longer than neutral images, and lower working memory performance was observed during the negative stimulus.

In summary, it is noted that the interaction between memory and emotion is rarely discussed in educational research. Although it is emphasized that emotional stimuli are better remembered than neutral stimuli, it is known that this may change depending on whether the stimulus is environmental or central (Kensinger et al., 2007). While the effect of emotional stimuli on long-term memory is clear; It is obvious that the effects of emotional stimuli on working memory differ. Furthermore, it should be noted that negative emotions have negative effects on working memory performances (Levine & Edelstein, 2009; Plancher et al., 2019), there are also studies showing that individual differences can differentiate this interaction in memory and emotion process. Edelstein (2006) once emphasized that the working memory capacity was higher for the positive and negative words than the neutral ones, yet she further emphasized that the working memory capacity of a group of participants with avoidant attachment style was higher for the neutral words.

Dorsal anterior insula (dAI), dorsal cingulate cortex (dACC), temporooccipital cortex and amygdala are activated in memory and emotion related functions (Luo et al., 2014). The amygdala processes emotional stimuli in the hippocampus. The amygdala regulates both the coding and storage of hippocampus-dependent memory fragments. When the hippocampus encounters an emotional stimulus, it forms representations of the emotional significance and interpretation of the stimulus (Phelps, 2004).

Table 1 summarizes the brain regions and their functions involved in the processing and response of emotional and cognitive processes that are independent but interactive in nature. According to neuroscience studies, cognitive functions associated with learning are directly related to PFC, working memory, long-term memory where target information are selected and manipulated (Guy & Byrne, 2013). Specialized areas for controlling the learning process in PFC are DLPFC, OFC, APFC, VLPFC and MPFC. The control component of the working memory is associated with the DLPFC. OPFC is especially activated in learning situations involving reward. APFC is responsible for high-level cognitive skills, the increase in gray matter in this region has positive effects on learning. For metacognition, APFC and VLPFC are important. MPFC is closely related with hippocampus, and IFG, STG, V2, TP regions are related to language processing, visual spatial processing, memory and executive function skills.

Table 1. Neuropsychological Correlates of Cognitive-Emotional Processes

Regions/ Brodmann Areas	Cognitive Processes	Emotional Processes
DLPFC (Dorsolateral Prefrontal korteks) 9,46	Working memory and selective attention (Curtis & D'Esposito, 2003). Memory functions including coding and organizing, visual spatial reasoning processes (Çakır et al., 2011).	Left DLPFC is responsible for processing emotions during decision making. Right DLPFC is responsible for keeping information about the value of emotional information in the working memory (Ashby & Isen, 1999; Rilling & Sanfey, 2009).
OFC (Orbitofrontal korteks) 11	Award-winning decision-making processes (Hsu et al., 2005; Stalnaker et al., 2018). Learning using positive reinforcement (Rolls, 2014).	Judgment and response to emotional processes (Northoff et al., 2000).

Table 1. Neuropsychological Correlates of Cognitive-Emotional Processes – *continued*

Regions/ Brodmann Areas	Cognitive Processes	Emotional Processes
APFC (Anterior Prefrontal korteks) 10	Coding and retrieval functions (Ranganath & Blumenfeld, 2008). Executive functions, high-level cognitive skills such as sharing of attention among resources, problem solving (Koechlin, 1999).	Control of social-emotional behavior by regulating rule selection and automatic evaluation of emotions (Volman et al., 2011).
VLPFC (Ventrolateral prefrontal korteks) 44,45	Semantic processing (Démonet et al., 1992). Right VLPFC visual spatial processing (Kuhl & Wagner, 2009). Coding function of memory and inhibition (Ranganath & Blumenfeld, 2008; Aron, Robbins, & Poldrack, 2004).	Perception and evaluation of emotional information (Ochsner & Gross, 2005). Regulation emotions with Amygdala and Insula (Phillips et al., 2003).
MPFC (Medial prefrontal korteks) 25,32	Memory and decision-making functions. Empowering memory with the hippocampus and supporting learning (Euston, Gruber, & McNaughton, 2012).	Evaluation of negative emotions (Etkin, Egner, & Kalisch, 2011). Regulation of fear (Morgan, Romanski, & LeDoux, 1993).
IFG (Inferior frontal gyrus) 47	Language-related functions such as semantic coding and retrieval (Zevin, 2009).	Appraisal process of intentions, regulation of social emotions (Grecucci et al., 2013).
V2 (Secondary Visual korteks) 18	Visual spatial information processing, object recognition and storage in memory (TCT, 2012).	Processing of emotional elements in the visual spatial processing (TCT, 2012).
STG (Superior Temporal Gyrus) 22	Language and speech processing functions (Zaidel, 2001).	Processing emotional facial expresion (Manfredi et al., 2017).
TP (Temporopolar Area) 38	Executive functions and retrieval of multimodal memory elements (TCT, 2012).	Visual processing of stimuli, especially fear (TCT, 2012).

Conclusions and suggestions for future research

Teaching is a process in which three basic functions of the nervous system, namely perception, processing and response, are performed in a dynamic and complex way (Rodriguez, 2013). Emotions affect the teaching process by influencing and shaping motivation, beliefs, goals and cognitive processes (Pekrun, Goetz, Titz, & Perry, 2002). This paper scrutinizes existing literature to uncover emotion as a structure that shapes cognitive processes in learning-teaching environments (Immordino-Yang, 2015). It is emphasized that negative teacher emotions trigger negative student emotions, as classes characterized by positive feelings about teaching and learning can provide the best conditions for student development and success (Frenzel, Goetz, Lüdtke, Pekrun, & Sutton, 2009; Yan, Evans, & Harvey, 2011). Research findings also indicate that negative emotions lead students to process shallow and surface level information (Linnenbrink & Pintrich, 2002). In addition, positive emotions in the learning environment play facilitative role in impeding learning and support academic achievement by increasing motivation toward and satisfaction with learning material and teaching (Um, Plass, Hayward, & Homer, 2012).

There is, however, some irregularities to be noted. For example, feeling positive and negative emotions may not bring about positive and negative cognitive processes in all cases. Positive emotions negatively affect executive functions (Philliphs et al., 2002; Shields et al., 2016), working memory performance (Eysenck & Calco, 1992), and attention (Forgas, 1998). It is also noteworthy that negative emotions improve mental rotation performance and enable individuals to be more focused, more analytical and more organized in information processing (Bless, Bohner, Schwarz, & Strack, 1990; Clark & Isen, 1982). Further research is needed to explore whether those statements regarding emotions and cognitive processes would be valid across different contexts.

Similarly, it is needed to include individual differences as another variable to address in order to provide more solid background for teacher training programs. Negative and mild emotions are shown to affect cognitive performance positively, while excessive and chronic emotions may cause negative results (Tyng, Amin, Saad, & Malik, 2017). Indeed, D’Mello and Graesser (2012) concluded that negative emotions in the teaching environment positively affected focused attention and improved learning outcomes. On the other hand, Tettegah and Gartmeier (2016) state that the effects of emotions may vary according to the physiological excitation thresholds, developmental states, and self-regulation skills of individuals. For example, negative emotions affect individuals in a highly self-regulated way, while this ability may cause negative effects in individuals with low self-regulation. Personality, gender and genetic differences greatly alter the neural basis of emotional processing in prefrontal, limbic, and other brain regions (Hamann & Canli, 2004). More research is needed in authentic settings to show the importance of emergent emotions and their effects on learning outcomes. Teacher training programs address such differences from a global perspective in that prospective teachers are needed to develop positive attitudes toward teaching and more tolerant toward their students; yet, research would be needed to explore how teachers develop those skills through their professional development.

In this dynamic and complex process, it is thought that it is an important competence for teachers to have emotion awareness skills including the processes of recognizing, differentiating and labeling the emotions of teachers both for themselves and for their students. Awareness of how emotions emerge in which context is seen as one of the basic components of emotion regulation (Barrett, Gross, Christensen, & Benvenuto, 2001). While examining cognitive-emotional functions in educational studies, it is emphasized that certain aspects of both emotions and cognitive processes can be improved and developed depending on maturation and experience (Immordino-Yang, 2015). Considering the existing literature as a base to develop intervention programs, researchers are urged to experiment various and viable intervention programs to help teachers develop their emotion awareness in authentic settings.

Conducting research from an interdisciplinary perspective will be beneficial when examining the interaction of emotion and cognitive structures in teacher education research. Computer based simulation and serious games for classroom teaching practice should be utilized to be used in teacher training programs. Incorporating computers in teachers' classroom practices can even be more powerful if such systems could have intelligent recommendation systems covering the recognition, separation and labeling of emotion according to individual differences and context. Such simulation-based and serious gaming tasks could help teachers experience such complex yet quite influential experiences from first hand before going into real classroom settings.

To conclude, one limitation of this study should be noted in that this study covers only the interaction between limited numbers of cognitive functions and emotion types. The interaction of various emotional experiences with different cognitive and sub-cognitive skills such as attention, perception, auditory processing, and knowledge representations can also be examined within the domain of teacher education.

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