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EPISTEMIC EMOTIONS: INTERRELATIONSHIPS AND CHANGES DURING TASK PROCESSING

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Abstract: This study focused on five epistemic emotions, namely surprise, curiosity, confusion, interest, and wonder. The aim was to investigate their change during task processing, their interrelations as well as their relations with metacognitive experiences in problem solving. Participants were 108 undergraduate students of psychology. They responded to three scenarios of varying difficulty describing learning situations. Performance on the tasks was followed by external feedback on the correctness of the response. The feedback created conditions eliciting epistemic emotions. The epistemic emotions were measured at three different times during task processing. There were also two measures of metacognitive experiences. The results showed that epistemic emotions differed in the three tasks, depending on the discrepancy between the initial schema that guided performance and the feedback. Furthermore, their intensity decreased as task processing progressed. There were also interrelations of epistemic emotions between them, particularly between confusion and wonder, and between surprise and all the other emotions. Finally, there were relationships between epistemic emotions and metacognitive feelings.

Key words: Confusion, Curiosity, Epistemic emotions, Interest, Metacognitive experiences, Surprise, Wonder

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INTRODUCTION

Epistemic emotions constitute an important category of human emotions. They arise when the object of attention is knowledge and the processes of knowing (Morton, 2010; Muis, Psaradellis, Lajoie, Leo, & Chevrier, 2015; Pekrun & Linnenbrick-Garcia, 2012; Pekrun & Stephens, 2012). Although studied by philosophers, they have been neglected in psychological research (Brun, Doguoglu, & Kuenzle, 2008; Morton, 2010). From an evolutionary point of view, epistemic emotions serve the acquisition of new knowledge by focusing attention onto one's own knowledge states and/or their relationships with the world (Brun et al., 2008; Elgin, 2008; Morton, 2010). In learning, epistemic emotions are important because they can facilitate the directing of attention to cognitive discrepancies or interruptions in cognitive processing and the search for new information that can restore the flow of processing (Efklides, 2017; Touroutoglou & Efklides, 2010). The aim of the present study was to investigate the role of cognitive discrepancy on the triggering of epistemic emotions, their development during task processing as new information changes the cognitive state that gave rise to them, and their interrelations.

Surprise, curiosity and confusion are epistemic emotions par excellence because their focus is always knowledge states. According to Graesser, Ozuru, and Sullins (2010), they usually arise in complex learning tasks. Complex learning is often associated with cognitive interruption (Kang et al., 2009; Mandler, 1975) that triggers surprise if the interruption is unexpected (Muis, Psaradellis et al., 2015; Touroutoglou & Efklides, 2010). It is also associated with awareness of uncertainty or lack of needed information that give rise to curiosity (Efklides, 2017). It may also give rise to confusion if the interruption is due to conflict (e.g., in response or pieces of information) that cannot be resolved (Muis, Psaradellis et al., 2015).

On the other hand, there are emotions such as wonder that is manifested in learning situations and are "caused by something new, unusual, strange, or marvelous" (Lewis, Canby, & Brown, 1946). Wonder is epistemic in nature because it denotes a desire to know and speculation about the nature of the object of wonder. It may also denote doubt about, e.g., the meaning of an unusual or strange event, possible ways to deal with it, amazement, or even astonishment. From this point of view, wonder is related to surprise and curiosity (Lewis et al., 1946) but also to interest (Izard, 1977). Presumably, it is also related to confusion when the source of wonder cannot be resolved and there is conflicting information.

A broader conceptualization of epistemic emotions includes any emotion caused by properties of cognitive processing (Pekrun & Linnenbrink-Garcia, 2012). Specifically, achievement emotions can act as epistemic depending on their object

(Muis, Psaradellis et al., 2015; Muis, Pekrun, Sinatra, Azevedo, Trevors, Meier, & Heddy, 2015). For example, interest has been associated in the past with surprise and curiosity (Izard & Ackerman, 2000; Stein & Levine, 1991). In such a case interest is triggered by knowledge states that give rise to epistemic emotions, such as discrepancy and/or interruption of processing. This assumption, however, has not been tested in the past.

This study aimed to investigate, firstly, the effect of task-specific factors such as discrepancy between one's knowledge schemas and congruent (or discrepant) feedback on the triggering and change of epistemic emotions as new information is acquired. Secondly, to examine the interrelations between surprise, curiosity, confusion, wonder, and interest. Thirdly, to delimit the possible relations between epistemic emotions and metacognitive experiences, which also arise in response to cognitive processing and knowledge states (Efklides, 2006, 2008; Touroutoglou & Efklides, 2010).

In what follows, after the overview of research on epistemic emotions, we shall present evidence associating them with metacognitive experiences. Then the study will be presented and discussed.

Epistemic emotions

Surprise

Surprise is a short-lived emotional reaction, activated when the individual faces unexpected events of all kinds (Izard, 1977; Kagan, 2002; Reisenzein, 2000). Surprise serves important adaptive functions and for many researchers belongs to basic emotions (Ekman, 1992; Izard, 1977; Meyer, Reisenzein, & Schützwohl, 1997). According to the cognitive-evolutionary model of Meyer et al. (1997), the emotion of surprise is a built-in information-processing tool that constantly compares, at an unconscious level, the active cognitive schema with newly acquired information. When detecting a discrepancy between existing cognitive schemas and new information, surprise immediately triggers an interruption of processing that allows the individual to analyze and evaluate the unexpected event and to update and review existing relevant schemas (Topolinski & Strack, 2015). This serves short- but also long-term adaptation and learning. Surprise helps the individual to revise their beliefs, adapt to the environment, and be prepared to face similar situations in the future. On the other hand, surprise is terminated if new information about the discrepant event is provided or figured out. Presumably, this will impact the relations of surprise with the other epistemic emotions that are associated with it such as curiosity or confusion.

Curiosity

Curiosity is considered basic emotion (Berlyne, 1960; Izard, 1977) and serves adaptation to the environment by facilitating exploratory behavior that increases the range of stimuli/information available to the person. According to Berlyne (1960), there are two kinds of curiosity: perceptual and epistemic. Perceptual curiosity is triggered by complex or ambiguous sensory stimuli (Collins, Litman, & Spielberger, 2004). Epistemic curiosity is the desire for new knowledge. It guides the person to learn new things, fill in cognitive gaps and solve mental problems (Litman, 2008). Epistemic curiosity is one of the most important emotions for cognitive development (Sternberg, 1994), for personal development (Kashdan, Rose, & Fincham, 2004) and for school and learning (Day, 1982).

Curiosity occurs when there is a gap between the information the individual already has and the information one would like to have (Loewenstein, 1994). It is triggered by interest and the desire to increase information on a topic/issue which is a positive emotional state , or by the detection of gap in one's knowledge that needs to be filled in. In the latter case, curiosity is associated with negative affect, such as uncertainty, due to lack of information (Litman, 2008; Litman & Jimerson, 2004). This entails that when one has sufficient knowledge about a topic curiosity is not triggered. Also, curiosity is not necessarily triggered if the person has no information about something. Evidently, if the gap between one's current knowledge and the desired one is overcome because new information fills in the gap, curiosity is satisfied and terminated. Finally, according to Muis, Psaradellis et al. (2015), when one experiences surprise, the emotion of curiosity or the emotion of confusion follows.

Confusion

Confusion is triggered when the individual is confronted with ideas and events that are inconsistent with existing cognitive patterns and one does not know how to proceed (Stein & Levine, 1991). Specifically, confusion is likely to arise when there is an enduring mismatch between incoming information and prior knowledge, which cannot be resolved directly and automatically. Also, when new information cannot be assimilated into existing schemas, or when the information flow is interrupted due to inconsistencies in the information being processed. Situations involving inconsistency, discrepancy, or conflict cause a stalemate in cognitive processing and lead to a state of cognitive imbalance, which is associated with increased physiological arousal and a need for more thinking (Muis, Psaradellis et al., 2015).

When the person feels confused, they begin to engage in problem-solving activities to restore balance. The individual tries to resolve the problem by evaluating the source of information, by adapting one's strategies and following a solution path (Muis,

Pekrun et al., 2015). These activities lead to deeper processing of information, increased attention and more successful information retrieval (Craik & Tulving, 1975). In this way, confusion facilitates comprehension processes, as the individual needs to establish new and deeper links between ideas or knowledge schemas and engage in carefully guided cognitive activities. If comprehension is restored, confusion is terminated.

However, it is important to note that confusion by itself does not necessarily lead to learning benefits. Under certain conditions it may promote learning, but there are occasions that lead to opposite results. For example, when a student is "confused" while trying to solve a difficult problem and gives up after some unsuccessful attempts, confusion is not expected to lead to learning gains. Likewise, confusion that remains, without finding a solution, does not lead to learning (D 'Mello & Graesser, 2010; D'Mello, Lehman, Pekrun, & Graesser, 2014).

Wonder

Wonder as an emotion has a double face: (a) doubt or speculation about something novel or unexpected and (b) astonishment, admiration, marvel (Lewis et al., 1946). The Greek word for wonder is "aporia", which means lack of way out, difficulty to figure out the meaning of something, embarrassment, or surprise accompanied by doubt (Μανδαλά, 2007). Thus, the epistemic aspect of wonder is the one related to the desire to know about a new, strange or unexpected, surprising, object or event but this cannot be achieved because there is no obvious or direct way to deal with it. The person feels overwhelmed by something that is incomprehensible or difficult to understand (Ekman, 1992; Izard, 1977). This causes doubt, speculation, or even curiosity (Lewis et al., 1946). Thus, wonder is related to both surprise and curiosity but also to interest (Izard & Ackerman, 2000; Schmitt & Lahroodi, 2008).

The closest relationship, however, is between curiosity and wonder. The two feelings are reactions to seemingly unexplainable events. Despite wonder sharing features with curiosity, the two emotions also have differences. Specifically, curiosity is accompanied by energetic effort and exploration of the environment, while wonder is more passive and often leads to intellectual reasoning rather than action. Moreover, whereas curiosity urges the person to analyze in depth the object of curiosity, in wonder the person tries to find the fullest meaning of the unexpected event (Fuller, 2006).

The question is if wonder is also related to confusion. It is plausible that when one wonders about the meaning of something unexpected they come across dead ends or conflicting viewpoints. In such a case, wonder would be related to confusion. However, there is no empirical evidence, to our knowledge, connecting wonder with confusion.

Interest

Interest is an emotion that allows the person to focus on and actively engage with an object, event or process (Krapp, 2005; see also Izard, 1977; Sansone & Smith, 2000). It is characterized by high stimulation and positive valence. Interest arises in environments that are appraised by the individual as safe, but at the same time offer challenges due to novel or unknown information, and/or complexity (Berlyne, 1960). The condition, however, for the triggering of interest is that one feels they can understand and cope with the challenges (Csikszentmihalyi, 1990). Interest can be a relatively stable person characteristic, a trait, that is, an orientation towards a field (e.g., mathematics). It can also be triggered by task or situational features; in the latter case, it is called state or situational interest (Hidi & Renninger, 2006). State interest can very soon decrease once the person realizes that the stimulus/event that caused it has limited value for ensued processing. Presumably, if interest is triggered by a discrepant event that gave rise to surprise, it will decrease when surprise is terminated due to new incoming information. However, if the new information requires further processing to fit in with prior knowledge, then interest may remain active because there is still challenge, albeit manageable.

Interest is considered source of intrinsic motivation, necessary for the development of knowledge and experience (Kashdan, 2004). It motivates the individual to explore new environments (as curiosity does), focus on new opportunities, and acquire experiences without any obvious reward (Fredrickson, 1998; Izard & Ackerman, 2000). Therefore, interest can be related to both surprise and curiosity. The question is if it is also related to wonder and confusion.

To sum up, the research overview shows that epistemic emotions are short-lived and serve important adaptation functions. Because they are triggered by cognitive states that share features such as discrepancy, interruption or conflict it is plausible to assume that there are interrelations between them, particularly between surprise and curiosity, on the one hand, and surprise and confusion on the other.

Epistemic emotions and metacognition

Epistemic emotions are associated with learning processes (D'Mello & Graesser, 2012), motivation (Kang et al., 2009), learning strategies (Muis, Pekrun et al., 2015), and learning outcomes (D'Mello et al., 2014). Specifically, activation of positive academic emotions, such as enjoyment and curiosity, are related to adoption of appropriate learning strategies (Pekrun & Stephens, 2012). Confusion, if resolved, positively predicts the use of learning strategies (Muis, Psaradellis et al., 2015).

However, cognitive states such as interruption of processing or discrepancies

between incoming information and activated schemas give rise to both epistemic emotions, namely surprise, and metacognitive feelings tapping lack of fluency such as feeling of difficulty (Touroutoglou & Efklides, 2010). Also, epistemic curiosity is an emotion that occurs in situations in which there is gap in one's knowledge, and hence uncertainty (low confidence) (Efklides, 2017) or desire for more information. Curiosity presupposes that there is potential that the missing information can be retrieved or recovered after exploration. Loewenstein (1994) associated curiosity with metacognitive experiences such as the tip-of-the-tongue (TOT) state and feeling of knowing. That is, one needs to be aware that the missing information can be accessed if one is to actively search for it, as in TOT. In situations in which there is no prior knowledge curiosity is not triggered because one does not know what to search for. It can be hypothesized then that epistemic curiosity will be negatively related to feelings of confidence and knowing.

In the case of confusion and wonder there is no prior research connecting them to metacognitive experiences. However, both wonder and confusion are associated with impasses in the meaning-making process. Specifically, wonder occurs when one tries to figure out why something unexpected happened and there is no immediately available explanation. This means that the person feel that they cannot make sense of the situation. From this point of view, wonder should be negatively related to feeling of confidence that one knows the answer and to feeling that one makes sense of the situation (i.e., comprehension of the available information). Confusion, on the other hand, is associated with discrepant, inconsistent or conflicting information that prevents fluent cognitive processing. Therefore, it should be negatively related to feeling of confidence and feeling of comprehension.

In so far as the relationship of interest with the metacognitive experiences is concerned, there should be no relationship between them to the extent interest is not epistemic in nature and serves engagement with a task.

To sum up, there is evidence suggesting relations between epistemic emotions and metacognitive experiences such as feeling of confidence or feeling of comprehension. Interest is not expected to be related to metacognitive experiences.

The present study: Aims and design

A within subject design was followed. The present study used three scenarios regarding memory and learning. The independent variable was the level of difficulty of the scenarios, in terms of compatibility of the schema that guided response and feedback on the accuracy of response. The dependent variables were performance, epistemic emotions (three measurements), and metacognitive feelings (feeling of confidence and feeling of comprehension).

Scenarios differed in difficulty. Specifically, the easy scenario was about a highly predictable learning situation; the difficult scenario was about a phenomenon that runs contrary to lay beliefs about learning, and the moderate difficulty scenario was about a relatively less well-known learning phenomenon (see McCabe, 2011). The presentation order of the scenarios was randomized. After participants had answered to the question regarding the scenario (performance measure) and judgment of confidence about the correctness of the answer, corrective feedback was provided. This was the trigger of epistemic emotions. Then, the first measurement of epistemic emotions took place. At the next step, explanation of the psychological principle underlying the feedback was provided. A judgment of comprehension of the explanation of the principle followed, and after it the second measurement of the epistemic emotions took place. Questions about possible strategies one would use when coming across a similar learning situation were then presented to probe the understanding of the implications of the psychological principle explained. Immediately afterwards the third measurement of epistemic emotions took place.

Hypotheses

1. Performance in the scenarios will be negatively related to the epistemic emotions, except for interest, since surprise, curiosity, wonder and confusion are likely to arise when the person faces unexpected, discrepant, or conflicting information to the schema that guided performance (Hypothesis 1).
2. Epistemic emotions will vary as a function of scenario difficulty (Hypothesis 2a). The more difficult the scenario, and hence lower the performance, the higher the level of epistemic emotions. Moreover, the intensity of the epistemic emotions will decrease after explanation of the principles underlying the phenomenon depicted in the scenarios (second and third measurement time) (Hypothesis 2b).
3. The epistemic emotions will be interrelated. Surprise will be related to curiosity, confusion and wonder, and curiosity to wonder. Surprise and curiosity are also expected to be related to interest (Hypothesis 3).
4. Feeling of confidence and feeling of comprehension will be negatively associated to epistemic emotions (Hypothesis 4), since the epistemic emotions occur when the person feel that they do not make sense (comprehend) a situation.

METHOD

Participants

The sample consisted of 108 undergraduate students of the School of Psychology of Aristotle University of Thessaloniki. Ninety-six of them (88.9%) were women. Their average age was 19 years. All of them attended the first semester in their studies and had limited theoretical knowledge on memory and learning.

Since two of the scenarios referred to the use of pictures or videos during their study, participants were asked how many hours they usually spent working on PC or used a cell phone. All participants used computer at least one hour per day. Ninety-seven percent of the sample had a picture and camera cell phone.

Materials

Scenarios

There were three scenarios (Exams, Diagram, Brain), which were created for this study. The scenarios were based on McCabe's (2011) research on learning and study strategies. Each scenario described two psychology students, who studied for the same course, had the same learning material, but used different learning strategies. Specifically, the Exams scenario presented two students who studied to pass an exam. The first student mass studied the course material whereas the second student followed spaced study. In the Diagram scenario, two psychology students studied the course material. The first student studied a science video in which there was a diagram and a speaker explaining verbally the diagram, while the second student studied the same video with the same diagram, but the information was presented in text form next to the diagram. Finally, in the Brain scenario, two psychology students studied the structures and functions of the human brain. The first student studied a multimedia video showing, through movement and color change, how blood circulates in the brain during information processing; the second student used the same material, but in the form of black and white photographs. In all scenarios participants were asked which student will perform better in the exams: Student A, Student B, or Both Students. Only one response was correct (Student A or Student B).

The scenarios were constructed so they differed in their difficulty. The "Exams" scenario was expected to be the easiest, as it was in line with the participants' study experiences, that is, spaced studying as contrasted to massed (at least when there is plenty of time before exams, Rohrer & Pashler, 2007). The "Brain" scenario was expected to be the most difficult, as the multimedia learning theory, that underlies this

scenario, is in complete contrast to the naïve beliefs about multimedia effects on learning. The Diagram scenario was expected to be of moderate difficulty.

To test the assumption about the scenario difficulty, a post hoc comparison of performance scores was carried out. A within-subject ANOVA was applied. Since the condition of sphericity was not met, Mauchly's $W = .607$, $\chi^2(2) = 52.860$, the Greenhouse-Greisser correction was used. There was a statistically significant difference in performance between the three scenarios, $F(1.436, 153.662) = 193.922$, $p < .001$, $\eta_p^2 = .644$. The Bonferroni paired comparison test showed that performance in the Exams scenario ($M = .926$) was significantly higher ($p < .001$) than performance in the Diagram scenario ($M = .537$) and significantly higher ($p < .001$) than in the Brain scenario ($M = .028$). Also, scores in the Diagram scenario were significantly higher ($p < .001$) than the Brain scenario.

Metacognitive feelings

Feeling of confidence. Right after the answer to the scenario, participants were asked to state how confident they were that the response they had given was correct. Responses were on a 4-point Likert- type scale, ranging from 1 = not at all confident to 4 = very confident.

Feeling of comprehension. After the presentation of the scientific explanation of the correct response, participants were asked to respond how well they understood the explanation provided. The question was: "How well did you understand why A / B (student) will do better than A / B?" Responses were on a 4-point Likert- type scale ranging from 1 = not at all to 4 = very well.

Strategies

After the explanation of the principle underlying the feedback, and in order to probe participants' understanding of the principle, they were asked to respond the extent to which they use each of seven strategies that were relevant to the content of each scenario when they study. Responses were on a 4-point Likert-type scale, ranging from 1 = never to 4 = always. In the Exams scenario, the strategies were about the spaced or mass studying; for example, "I divide the material into sections and study one section at a time". In the Diagram scenario, the strategies referred to the processing of tasks with diagrams (i.e., use of dual vs. single mode processing); for example, "I see the diagram, then I read the corresponding part of the text, and then return to the diagram". Finally, in the Brain scenario, the strategies were about the static or animated mode of presentation; for example, "I prefer to examine each picture separately for as long as it needs and not use videos".

Epistemic emotions

The epistemic emotions, namely, surprise, wonder, confusion, curiosity, and interest, were measured at three different time points: (a) after the feedback about the correct answer, (b) after the explanation of the correct answer, and (c) after the questions on the strategies participants would use to study in the situation depicted in the scenario. Responses were on a 4-point Likert-type scale ranging from 1 = not at all to 4 = very much. Participants were asked to respond to the following prompt: "What emotions do you experience now that you were given the correct answer and to what degree?" In the second measurement, the question was: "Now that you have read the explanation, what emotions do you have at this moment and to what degree?" In the third measurement, after the questions on strategies, the question was: "What emotion do you have now and to what degree?" The order of presentation of the emotions was as follows: surprise, wonder, confusion, curiosity, interest.

Procedure

Testing took place in groups of about 25 individuals. Participation was voluntary. Participants could stop working on the tasks any moment they felt doing so. They were also assured that anonymity was preserved. The order of presentation of the scenarios was counterbalanced.

RESULTS

The mean scores and standard deviations of the epistemic emotions in the three measurement points are presented in Table 1.

Relations between performance and epistemic emotions

To test Hypothesis 1, according to which performance on the scenarios would be negatively related to the epistemic emotions of surprise, wonder, confusion and curiosity, and positively to interest Pearson's correlations in each scenario in each of the three measurements were performed. The alpha level was set to .05 / 6 = .008.

In the *Exams* scenario, performance was significantly and negatively correlated only with epistemic emotions of the first measurement: surprise, $r = -.36$, $p < .001$, wonder, $r = -.269$, $p = .005$, confusion, $r = -.427$, $p < .001$, and curiosity, $r = -.267$, $p = .005$. The correlation with interest was nonsignificant. In the second and third measurements, there were no statistically significant correlations, presumably due to the low stimulation of epistemic emotions in the easy scenario.

Table 1. Means and standard deviations for epistemic emotions in the three scenarios

Scenario	Exams		Diagram		Brain	
	M	*SD*	*M*	*SD*	*M*	*SD*
Surprise[a]	1.19	.54	1.87	.99	3.25	.76
Surprise[b]	1.34	.67	1.87	.87	2.79	.89
Surprise[c]	1.27	.66	1.41	.68	2.00	.97
Wonder[a]	1.20	.58	2.01	1.05	3.24	.82
Wonder[b]	1.14	.46	1.52	1.16	1.92	.89
Wonder[c]	1.12	.43	1.33	.67	1.47	.69
Confusion[a]	1.11	.43	1.76	.98	2.68	.94
Confusion[b]	1.07	.46	1.40	.68	1.61	.78
Confusion[c]	1.11	.39	1.29	.56	1.36	.62
Curiosity[a]	1.52	.78	2.36	1.03	3.16	.98
Curiosity[b]	1.49	.75	1.81	.86	2.27	.99
Curiosity[c]	1.46	1.14	1.75	.86	1.92	.93
Interest[a]	2.52	.92	2.94	.84	3.29	.79
Interest[b]	2.50	.93	2.81	.93	3.14	.83
Interest[c]	2.37	.98	2.57	.93	2.92	.84

In the *Diagram* scenario, performance was negatively associated with all epistemic emotions. Specifically, performance was significantly and negatively correlated with all the epistemic emotions of the first measurement: surprise, $r = -.596$, $p < .001$, wonder, $r = -.688$, $p < .001$, confusion, $r = -.645$, $p < .001$, curiosity, $r = -.526$, $p < .001$, and interest, $r = -.350$, $p < .001$. It also correlated significantly and negatively with the epistemic emotions of the second measurement point: surprise, $r = -.312$, $p = .001$, wonder, $r = -.356$, $p < .001$, confusion, $r = -.412$, $p < .001$, and curiosity, $r = -.333$, $p < .001$. Negative correlations were maintained in the third measurement but only for wonder, $r = -288$, $p = .003$, and confusion, $r = -385$, $p < .001$.

In the *Brain* scenario, performance was significantly and negatively correlated only with two of the epistemic emotions of the first measurement point: surprise, $r = -.278$, $p = .004$, and wonder, $r = -.396$, $p < .001$. There were no correlations with the epistemic emotions of the second and third measurement points. This suggests that the changes in epistemic emotions after the explanation of the answer and at the end of task processing were not in line with the initial performance.

Overall, epistemic emotions were significantly and negatively associated to performance mainly in the first measurement time when responses about epistemic emotions were aligned to the schema that guided performance. The associations in the easy and difficult scenarios in the second and third measurement points were not significant because of the limited variability of the performance scores and the fact that changes in the epistemic emotions scores occurred independently of the initial performance schema, that is, reflected the impact of the feedback provided. In the

moderately difficult scenario, the associations between performance and epistemic emotions were maintained likely because the feedback provided was partly in line with the initial schema that guided performance.

Task difficulty and measurement time effect

According to Hypothesis 2a, the intensity of epistemic emotions would increase as a function of scenario difficulty. Moreover, the intensity of epistemic emotions would change from the first to the following measurement times (Hypothesis 2b). To test Hypothesis 2a, a 3(Task) by 3(Measurement time) within subject ANOVAs was carried out for each epistemic emotion. The statistical indices are given in Table 2.

Table 2. Task difficulty effect and measurement time effect on epistemic emotions

	Main effect of task difficulty	**Main effect of measurement time**	**Interaction of task difficulty with measurement time**
Surprise	Pillai's = .809, $F(2, 106)$ = 224.637, $p < .001$, $\eta_p^2 = .809$	Pillai's = .571, $F(2, 106)$ = 71.701, $p < .001$, $\eta_p^2 = .571$	Pillai's = .606, $F(4, 104)$ = 39.924, $p < .001$, $\eta_p^2 = .606$
Wonder	Pillai's = .722, $F(2, 106)$ = 137.844, $p < .001$, $\eta_p^2 = .722$	Pillai's = .673, $F(2, 106)$ = 109.076, $p < .001$, $\eta_p^2 = .673$	Pillai's = .731, $F(4, 104)$ = 70.750, $p < .001$, $\eta_p^2 = .731$
Confusion	Pillai's = .603, $F(2, 106)$ = 80.489, $p < .001$, $\eta_p^2 = .603$	Pillai's = .608, $F(2, 106)$ = 82.370, $p < .001$, $\eta_p^2 = .608$	Pillai's = .627, $F(4, 104)$ = 43.727, $p < .001$, $\eta_p^2 = .627$
Curiosity	Pillai's = .578, $F(2, 106)$ = 72.733, $p < .001$, $\eta_p^2 = .578$	Pillai's = .426, $F(2, 106)$ = 39.256, $p < .001$, $\eta_p^2 = .426$	Pillai's = .428, $F(4, 104)$ = 19.440, $p < .001$, $\eta_p^2 = .428$
Interest	Pillai's = .408, $F(2, 106)$ = 36.513, $p < .001$, $\eta_p^2 = .408$	Pillai's = .207, $F(2, 106)$ = 13.808, $p < .001$, $\eta_p^2 = .408$	*nonsignificant*

In all cases epistemic emotions were higher in the difficult scenario compared to the easy and the moderate difficulty scenarios as the Bonferroni paired comparisons showed ($p < .001$). Moreover, the measurement time effect suggests that the intensity of the epistemic emotions was higher in the first compared to the second and third measurement time. The interaction effect indicates that the changes in the easy scenario were not as pronounced as in the other two scenarios, particularly the difficult one.

Interrelations between epistemic emotions

To test Hypothesis 3 Pearson's correlation was applied to the responses on epistemic emotions in each scenario in the three measurement points. The α level was set to: .05 / 15 = .003 (See Table 3a, 3b, and 3c for each scenario, respectively.)

Table 3a. Pearson correlations between epistemic emotions in the Exams scenario

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.Surprise[a]	-													
2.Wonder[a]	.505**	-												
3.Confusion[a]	.720**	.706**	-											
4.Curiosity[a]	.293**	.574**	.398**	-										
5.Interest[a]				.325**	-									
6. Surprise[b]	.603**	.480**	.370**			-								
7. Wonder[b]	.679**	.699*	.772**	.369**		.579**	-							
8.Confusion[b]	.611**	.613**	.869**	.334**		.412**	.849**	-						
9. Curiosity[b]	.384**	.456**	.333**	.437**		.618**	.499**	.387**	-					
10. Interest[c]					.517**					-				
11. Surprise[c]	.481**	.369**	.328**			.664**	.546**	.392**	.499**		-			
12. Wonder[c]	.509**	.584**	.543**	.317**		.518**	.720**	.684**	.483**		.545**	-		
13.Confusion[c]	.382**	.557**	.537**	.388**		.428**	.631**	.743**	.380**		.456**	.698**		
14.Curiosity[c]		.282**		.338**			.285**		.451**			.365**		
15. Interest[c]					.498**					.667**				

Note: ** $p <$ .003. The symbols a, b, c, stand for first, second, and third measurement, respectively.

Exams. As shown in Table 3a the correlations between epistemic emotions ranged from $r = .282$, $p < .001$ to $r = .849$, $p < .001$. The epistemic emotions of the first measurement significantly correlated between them, except for interest. The highest *r*s were between surprise and confusion, $r = .720$, $p < .001$, and between wonder and confusion, $r = .706$, $p < .001$. This pattern of correlations was retained in the second measurement time for surprise, wonder and confusion, with the highest *r* between wonder and confusion, $r = .849$, $p < .001$; at the third measurement, there were correlations between surprise, wonder and confusion, with the highest *r* being between wonder and confusion, $r = .698$, $p < .001$.

The epistemic emotions of the first measurement also correlated with the respective emotions of the second measurement with highest *r*s for wonder, $r = .772$, $p < .001$, and confusion, $r = .869$, $p < .001$. The epistemic emotions of the first measurement were also associated, to a lesser extent, with the epistemic emotions of the third measurement; the highest *r*s were between confusion of the first measurement and wonder, $r = .543$, $p < .001$, and confusion, $r = .537$, $p < .001$, of the third measurement. Finally, the epistemic emotions of the second measurement were highly correlated with the respective emotions of the third measurement. Interest was the only emotion that was not related to other epistemic emotions.

In conclusion, the intercorrelations between epistemic emotions in the easy scenario were maintained at the three measurement points, probably because the easiness of the task did not lead to overturning of the epistemic emotions when feedback and explanation of the correct answer were provided.

Table 3b. Pearson correlations between epistemic emotions in the Diagram scenario

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.Surprise[a]	-													
2.Wonder[a]	.690**	-												
3.Confusion[a]	.641**	.810**	-											
4.Curiosity[a]	.415**	.588**	530**	-										
5.Interest[a]	.430**	.521**	413**	.532**	-									
6. Surprise[b]	.615**	.456**	.380**	.305**	.375**	-								
7. Wonder[b]	.338**	.414**	.398**	.289**		.357**	-							
8.Confusion[b]	.327**	.440**	.436**			.436**		-						
9. Curiosity[b]			.462**	.587**	.310**	409**	.364**	.511**	-					
10. Interest[c]					.561**	412**				-				
11. Surprise[c]	.467**		.327**			.611**			.322**		-			
12. Wonder[c]		.409**	.420**			.381**	.378**	.627**	.451**		.394**	-		
13.Confusion[c]		.407**	.512**	.303**		.345**		.549**	.518**		.396**	.634**	-	
14.Curiosity[c]		.348**	.339**	.434**		.385**		.460**	.703**		.351**	.690**	537**	-
15. Interest[c]					.448**	.349**			.358**	.612**	364**	.320**	.289**	.476**

Note: ** $p \leq .003$. The symbols a, b, c, stand for first, second, and third measurement, respectively.

Diagram. As shown in Table 3b, the correlations between epistemic emotions ranged from $r = .289$, $p < .001$ to $r = .810$, $p < .001$. The epistemic emotions of the first measurement were all intercorrelated, with the greatest correlations occurring between surprise and wonder, $r = .690$, $p < .001$, and surprise with confusion, $r = .641$, $p < .001$. Wonder also correlated highly with confusion, $r = .810$, $p < .001$. The intercorrelations were not maintained in the second measurement, except for surprise that was associated with all other epistemic emotions. The number of intercorrelations between epistemic emotions increased in the third measurement. However, *r*s were lower than in the first measurement.

Moreover, the epistemic emotions of the first measurement were associated with almost all the epistemic emotions of the second and third measurement. This was particularly true for wonder and confusion of the first measurement, which correlated with almost all epistemic emotions of the other two measurements. Furthermore, the epistemic emotions of the second measurement correlated with the epistemic emotions of the third measurement.

Summing up, there were close interrelations between epistemic emotions in the first measurement. There were fewer interrelations in the second measurement, but their strength increased again in the third measurement.

Brain scenario. As shown in Table 3c, the correlations between epistemic emotions ranged from $r = .283$, $p < .001$ to $r = .701$, $p < .001$. In the first measurement, surprise was associated with wonder, $r = .681$, $p < .001$, and confusion,

Table 3c. Pearson correlations between epistemic emotions in the Brain scenario

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.Surprise[a]	-													
2.Wonder[a]	.681**	.609**												
3.Confusion[a]	.502**	.559**	-											
4.Curiosity[a]	.460**	.356**	.409**	-										
5.Interest[a]	.300**	.445**		.464**	-									
6. Surprise[b]	.522**	.311**	396**	.287**		-								
7. Wonder[b]	.307**		.446**			.476**	-							
8.Confusion[b]			.383**				.571**	-						
9. Curiosity[b]			.303**	.361**		.416**	.546**	.509**	-					
10. Interest[c]		.283**			.442**					-				
11. Surprise[c]	.330**			.297**		.523**	392**	.296**	.370**	.281**	-			
12. Wonder[c]						.334**	.508**	.568**	.496**		.434**	-		
13.Confusion[c]			.282**			.312**	.532**	.543**	.389**		.375**	.648**	-	
14.Curiosity[c]		.609**				.364**	.432**		.516**		.559**	.562**	.483**	-
15. Interest[c]					.389**	.351**			.306**	.701**	.458**	.		.324**

Note: ** $p \leq .003$. The symbols a, b, c, stand for first, second, and third measurement, respectively.

$r = .609$, $p < .001$. The number of interrelations dropped in the second measurement, but increased again in the third measurement, when all epistemic emotions were associated, at low level, with surprise and wonder.

The epistemic emotions of the first measurement were less closely associated to the epistemic emotions of the second measurement, and even less to the epistemic emotions of the third measurement, suggesting that the epistemic emotions were highly impacted by the feedback and explanation of the principle underlying the phenomenon described. Exception was the emotion of confusion of the first measurement that was related to almost all the epistemic emotions of the second measurement. On the contrary, the epistemic emotions of the second measurement displayed a dense network of relationships with the epistemic emotions of the third measurement, which reflects the change of emotions after the explanation.

In conclusion, despite the variability of interrelations between epistemic emotions in the three scenarios there were some notable consistencies. Specifically, (a) each epistemic emotion correlated with its counterpart in the three measurements; (b) surprise correlated with all the epistemic emotions, but the strongest relations were with wonder and confusion; less strong were the relations of surprise with curiosity and interest; c) wonder was highly associated with confusion and moderately with curiosity; d) confusion was associated moderately to low with curiosity, and e) curiosity was occasionally associated with interest.

Relations between metacognitive experiences and epistemic emotions

To test Hypothesis 4, which regarded the relations of metacognitive feelings confidence and comprehension with epistemic emotions, Pearson's correlations were computed in the three measurement times separately for each scenario. Because of the large number of variables, the Bonferroni correction was applied, and the alpha level was set at .05 / 6 = .008.

Feeling of confidence

There were no significant correlations between feeling of confidence and epistemic emotions in the Exams and the Diagram scenarios. In the Brain scenario, confidence was significantly and *positively* related with the epistemic emotions of the first measurement time, that is, right after feedback: surprise, $r = .396$, $p < .001$, wonder, $r = .406$, $p < .001$, and confusion, $r = .290$, $p = .002$. No correlations were found with the epistemic emotions of the second and third measurements. This attests to the claim made previously that the greater the confidence the greater the conflict with the discrepant feedback provided. Hence, the relationship was positive rather than negative as one would expect in the case of feedback that was congruent with the initial response.

Feeling of comprehension

In the easy scenario (Exams), no statistically significant relationship was found. In the moderately difficult scenario (Diagram), feeling of comprehension was negatively related to wonder of the first measurement, $r = -.327$, $p = .001$, and marginally to curiosity, $r = -249$, $p = .009$. In the second measurement, feeling of comprehension was negatively related to confusion, $r = -.409$, $p = .001$, and in the third measurement to wonder, $r = -.356$, $p = .001$. This means that the better the participants comprehended the explanation provided the lower the confusion and wonder, as one would expect.

In the Brain scenario, feeling of comprehension was significantly and negatively correlated with wonder, $r = -.273$, $p = .004$, and confusion, $r = -.308$, $p = .001$ of the first measurement and the same emotions of the second measurement: wonder, $r = -.301$, $p = .002$, and confusion, $r = -.356$, $p < .001$. That is, the better the participants understood the feedback and explanation the lower the wonder and confusion they reported.

To sum up, the feedback and explanation created conflict in the participants who had answered incorrectly but were highly confident in their response. This increased wonder and confusion. On the contrary, the better the participants understood the explanation of the scientific principle underlying the phenomenon depicted in the scenario, the lower the wonder and confusion.

DISCUSSION

This study aimed to investigate the relationships of five epistemic emotions (surprise, wonder, confusion, curiosity, interest) between them and with metacognitive experiences in cognitive problem solving.

Performance and epistemic emotions

Hypothesis 1 predicted that the relationship of performance with epistemic emotions would be negative. This was confirmed in the easy and moderate difficulty scenario, but not in the difficult one, in which almost all participants had responded incorrectly. These findings suggest, firstly, that the epistemic emotions were triggered by the feedback rather than performance per se. In the easy scenario the feedback was consistent with the prevalent cognitive schema and, for his reason the intensity of epistemic emotions was low. Obviously, in the few cases in which the prior schema was not so strong (e.g., response "Both students"), there was some triggering of epistemic emotions caused by the feedback. This suggests that assimilation of the new information to the extant schema was taking place. In the moderately difficult task, the discrepant feedback to the prior schema required revision of the schema. The epistemic emotions reflected such a revision processes.

Secondly, in the difficult scenario, where there was also discrepancy of the feedback from the extant cognitive schema, there was no relationship of performance with epistemic emotions, contrary to what had happened with the easy and moderately difficult scenarios. This suggests that epistemic emotions presuppose availability of alternative cognitive schemas against which the information provided by the feedback is judged. If there are no such alternative schemas (i.e., correct vs. incorrect or partially correct schemas), then no assimilation or revision processes can be implemented. The person needs to build a new schema dictated by the feedback and its explanation. Hence, the epistemic emotions were controlled not by prior cognitive schemas but by the explanation provided to justify the feedback. In this case, a new schema was established, and the epistemic emotions reflected the processes involved in the construction of the new schema.

Interrelations between epistemic emotions

Hypothesis 3 regarded the interrelations between epistemic emotions. The hypothesis was partly confirmed. Firstly, there were interrelations between surprise, wonder, confusion and curiosity. There were also relations between wonder and confusion,

and in a few cases between curiosity and interest, particularly in the moderately difficult scenario. Interest was hardly related to any of the epistemic emotions.

Secondly, there were relations between epistemic emotions in each measurement time and across measurements. In the difficult scenario, the relations of the epistemic emotions of the first measurement with those of the second and third measurement were limited. This reflects the effect of the explanation of the correct response and probably the difficulty to assimilate the new information into prior schemas. What is worth noting is that in the difficult scenario surprise and wonder were associated with curiosity and interest. Confusion was also associated with curiosity but not with interest. The relationship of wonder and confusion with curiosity was not expected. It may reflect deprivation-type curiosity rather than interest-type as in the moderately difficult scenario.

Thirdly, despite the differences in the interrelations between epistemic emotions in the three scenarios, what was consistent was that the highest correlations were between wonder and confusion, which confirms the assumption that wonder is conceptually closer to confusion than to curiosity and interest. However, wonder cannot be equated with confusion because it has different pattern of relations with the other epistemic emotions than confusion does.

Relations between metacognitive feelings and epistemic emotions

Another significant finding of this study was the limited number of correlations of metacognitive feelings with the epistemic emotions, contrary to Hypothesis 4. This suggests that, despite metacognitive feelings and epistemic emotions focusing on cognitive processing, they are differentiated between them. A noteworthy finding was that confidence in the difficult scenario was positively associated to surprise, wonder and confusion of the first measurement rather than negatively. This suggests that the more confident one is in an incorrect response the greater the surprise, wonder and confusion when negative feedback is provided. Furthermore, feeling of confidence was not related to curiosity, as Lowenstein (1994; see also Efklides, 2017) had proposed. Further research is needed to clarify the conditions under which feeling of confidence is associated with curiosity.

On the other hand, feeling of comprehension was negatively related to epistemic emotions in the moderately difficult and difficult scenarios suggesting that the better one understood the explanation of the feedback the lower the surprise, wonder or confusion. There was also a marginal relationship of feeling of comprehension with curiosity in the moderately difficult scenario. This finding requires further investigation to establish the possible relation between feeling of comprehension and

curiosity. It seems that feeling of comprehension can play the role of confidence as a reflection of what one knows and gaps in one's knowledge.

Contribution and Limitations of the study – Implications for future research

This study was a first approximation to understanding the functioning of epistemic emotions in learning. It provided evidence supporting the role of cognitive states such as discrepancy between one's prior knowledge schemas and feedback in the triggering of epistemic emotions. Furthermore, it showed that epistemic emotions change during cognitive processing as more information is gained that allows the resolution of cognitive impasses. However, more sophisticated design is needed to differentiate the impact of cognitive states such as interruption of processing from discrepancy or conflict on the specific epistemic emotions.

Another contribution of this study was the exploration of the relationships between metacognitive feelings and epistemic emotions. The evidence is encouraging but other feelings such as feeling of difficulty and awareness of effort exertion might be implicated in the formation of epistemic emotions. The possible mediating and/or moderating role of metacognitive experiences in the development of epistemic emotions during cognitive processing needs also to be investigated.

Finally, this is the first empirical study to our knowledge that introduced wonder as an epistemic emotion. The relations with surprise and confusion are high, and this requires further research to examine the conditions that give rise to wonder rather than confusion. Moreover, the relations of wonder with curiosity and interest need further investigation, because it might be that wonder leads to curiosity and exploratory behavior without the presence of confusion. However, considering the close relationship of wonder with confusion it is important to clarify the conceptualization of the two emotions before any firm conclusions can be drawn. The transformation of wonder to a positive emotion such as admiration is another challenge for future research (see Izard & Ackerman, 2000).

Finally, experimental evidence as the one provided in this study might offer insights for interventions that can take advantage of epistemic emotions to enhance learning (Muis, Psaradellis et al., 2015).

REFERENCES

Berlyne, D. E. (1960). *Conflict, arousal, and curiosity.* New York, NY: McGraw-Hill.

Brun, G., Doguoglu, U., & Kuenzle, D. (2008). *Epistemology and emotions.* Aldershot, UK: Ashgate.

Collins, R. P., Litman, J. A., & Spielberger, C. D. (2004). *The measurement of perceptual curiosity. Personality and Individual Differences, 36,* 1127-1141.

Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal experience.* New York, NY: Harper & Row.

Craik, F. I. M., & Tulving, E. (1975). Depth of processing and the retention of words in episodic memory. *Journal of Experimental Psychology: General, 104,* 268-294.

Day, H. I. (1982). Curiosity and the interested explorer. *Performance and Instruction, 21*, 19-22.

D'Mello, S. K., & Graesser, A. C. (2010). Multimodal semi-automated affect detection from conversational cues, gross body language, and facial features. *User Modeling and User-adapted Interaction, 20*(2), 147-187.

D'Mello, S. K., & Graesser, A. C. (2012). Autotutor and affective autotutor: Learning by talking with cognitively and emotionally intelligent computers that talk back. *ACM Transactions on Interactive Intelligent Systems, 2*(4), 2-39.

D'Mello, S. K., Lehman, B., Pekrun, R., & Graesser, A. C. (2014). Confusion can be beneficial for learning. *Learning and Instruction, 29*, 153-170.

Efklides, A. (2006). Metacognition and affect: What can metacognitive experiences tell us about the learning process? *Educational Research Review, 1*, 3-14.

Efklides, A. (2008). Metacognition: Defining its facets and levels of functioning in relation to self-and co-regulation. *European Psychologist, 13,* 277-287.

Efklides, A. (2017). Affect, epistemic emotions, metacognition, and self-regulated learning. *Teachers College Record, 119*(13).

Ekman, P. (1992). An argument for basic emotions. *Cognition and Emotion, 6*, 169-200.

Elgin, C. Z. (2008). Emotion and understanding. In G. Brun, U. Dogluoglu, & D. Kuenzle (Eds.), *Epistemology and emotion* (pp. 33- 50). Hampshire, England: Ashgate.

Fredrickson, B. L. (1998). What good are positive emotions? *Review of General Psychology, 2,* 300-319.

Fuller, R. C. (2006). *Wonder: From emotion to spirituality.* Chapel Hill, NC: The University of North Carolina Press.

Graesser, A. C., Ozuru, Y., & Sullins, J. (2010). What is a good question? In M. McKeown & L. Kucan (Eds.), *Bringing reading research to life* (pp. 112-141). New York, NY: Guilford.

Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist, 41,* 111-127.

Izard, C. E. (1977). *Human emotions.* New York, NY: Plenum.

Izard, C. E., & Ackerman, B. P. (2000). Motivational, organizational, and regulatory functions of discrete emotions. In M. Lewis & J. M. Haviland-Jones (Eds.), *Handbook of emotions* (pp. 253-264). New York, NY: Guilford.

Kagan, J. (2002). *Surprise, uncertainty and mental structures.* Cambridge, MA: Harvard University Press.

Kang, M. J., Hsu, M., Krajbich, I. M., Loewenstein, G., McClure, S. M., Wang, J. T., & Camerer, C. F. (2009). The wick in the candle of learning: Epistemic curiosity activates reward circuitry and enhances memory. *Psychological Science, 20,* 963-973.

Kashdan, T. B. (2004). Curiosity. In C. Peterson & M.E.P. Seligman (Eds.), *Character strengths and virtues* (pp. 125-141). New York, NY: Oxford University Press.

Kashdan, T. B., Rose, P., & Fincham, F. D. (2004). Curiosity and exploration: Facilitating positive subjective experiences and personal growth opportunities. *Journal of Personality Assessment, 82,* 291-305.

Krapp, A. (2005). Basic needs and the development of interest and intrinsic motivational orientations. *Learning and Instruction, 15,* 381-395.

Lewis, W. D., Canby, H. S., & Brown, T. K. (Eds.). (1946). *The Winston dictionary: College edition.* New York, NY: Collier.

Litman, J. A. (2008). Interest and deprivation factors of epistemic curiosity. *Personality and Individual Differences, 44,* 1585-1595.

Litman, J. A., & Jimerson, T. L. (2004). The measurement of curiosity as a feeling of deprivation. *Journal of Personality Assessment, 82,* 147-157.

Loewestein, G. (1994). The psychology of curiosity: A review and reinterpretation. *Psychological Bulletin, 116*, 75-98.

Mandler, G. (1975). *Mind and emotion.* New York, NY: Wiley.

McCabe, J. (2011). Metacognitive awareness of learning strategies in undergraduates. *Memory & Cognition, 39,* 462-476.

Μανδαλά, Μ. (2007). *Μείζον ελληνικό λεξικό* [Major Greek Dictionary] (6η έκδοση). Αθήνα: Τεγόπουλος- Φυτράκης.

Meyer, W. U., Reisenzein, R., & Schützwohl, A. (1997). Towards a process analysis of emotions: The case of surprise. *Motivation and Emotion, 21*(3), 251-274.

Morton, A. (2010). Epistemic emotions. In P. Goldie (Ed.), *The Oxford handbook of philosophy of emotion* (pp. 385-399). Oxford, UK: Oxford University Press.

Muis, K. R., Pekrun, R., Sinatra, G. M., Azevedo, R., Trevors, G., Meier, E., & Heddy, B. C. (2015). The curious case of climate change: Testing a theoretical model of epistemic beliefs, epistemic emotions, and complex learning. *Learning and Instruction, 39,* 168-183.

Muis, K. R., Psaradellis, C., Lajoie, S. P., Leo, I. D., & Chevrier, M. (2015). The role of epistemic emotions in mathematics problem solving. *Contemporary Educational Psychology, 42*, 172-185.

Pekrun, R., & Linnenbink-Garcia, L. (2012). Academic emotions and student engagement. In S. L. Christenson, A. L. Reschly, & C. Wylie (Eds.), *Handbook of research on student engagement* (pp. 259-282). New York, NY: Springer.

Pekrun, R., & Stephens, E. J. (2012). Academic emotions. In K. R. Harris, S. Graham, T. Urdan, S. Graham, J. M. Royer, & M. Zeidner (Eds.). *APA educational psychology handbook* (Vol. 2, pp. 3-31). Washington, DC: American Psychological Association.

Reisenzein, R. (2000). Exploring the strength of association between the components of emotion syndromes: The case of surprise. *Cognition and Emotion 14*(1), 1-38.

Reninnger, K. A., & Hidi, S. (2002). Student interest and achievement: Developmental issues raised by a case study. In A. Wigfield & J. S. Eccles (Eds.), *Development of achievement motivation* (pp. 173-195). New York, NY: Academic.

Rohrer, D., & Pashler, H. (2007). Increasing retention without increasing study time. *Current Directions in Psychological Science, 16,* 183-186.

Sansone, C., & Smith, J. L. (2000). Interest and self-regulation: The relation between having to and wanting to. In C. Sansone & J. M. Harackiewicz (Eds.), *Intrinsic and extrinsic motivation* (pp. 341-372). San Diego, CA: Academic.

Schmitt, F., & Lahroodi, R. (2008). The epistemic value of curiosity. *Educational Theory, 58*(2), 125-148.

Σιδηροπούλου, Ε. Γ. (2015). *Η περιέργεια ως χαρακτηριστικό προσωπικότητας και πρόθεση εξερεύνησης: Επίδραση του έργου και αλληλεπίδραση με τις μεταγνωστικές εμπειρίες και το θυμικό* [Curiosity as trait and intention for exploration: The effect of task and interactions with metacognitive experiences and affect]. Unpublished MA thesis, School of Psychology, Aristotle University of Thessaloniki, Greece.

Stein, N. L., & Levine, L. J. (1991). Making sense out of emotion. In W. Kessen, A. Ortony, & F. Craik (Eds.), *Memories, thoughts, and emotions: Essays in honor of George Mandler* (pp. 295-322). Hillsdale, NJ: Erlbaum.

Sternberg, R. J. (1994). Answering questions and questioning answers. *Phi Delta Kappa, 76,* 136-139.

Topolinski, S., & Strack, F. (2015, February). Corrugator activity confirms immediate negative affect in surprise. *Frontiers in Psychology, 6* (Article 134), 1-8.

Touroutoglou, A., & Efklides, A. (2010). Cognitive interruption as an object of metacognitive monitoring: Feeling of difficulty and surprise. In A. Efklides & P. Misailidi (Eds.), *Trends and prospects in metacognition research* (pp. 171-208). New York, NY: Springer.