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“Epic-Genetics”: An Exploration of Preservice Helping Professionals’ (Mis)Understanding of Epigenetic Influences on Human Development

ABSTRACT

Mental health researchers emphasize the importance of practitioner understanding of biology-environment interplay. Accordingly, our goal of the study described in this article was to understand students’ preconceptions and misconceptions about biological and environmental influences on development through investigating their conceptions of epigenetics. Using a short-term longitudinal design, we explored preservice helping professionals’ conceptions and misconceptions pertaining to epigenetics within the framework of a graduate level human development course. Baseline knowledge about epigenetics was low. Students developed multiple misconceptions about epigenetics and how the phenomenon relates to biological and environmental influences on human development. Students reported feeling highly efficacious for detecting and resolving misconceptions related to biology-environment interactions but varied in their perceptions of interest for learning about the content. Findings support the use of open-ended questions to detect misconceptions about epigenetics and are discussed in light of how to teach students about this phenomenon. Overall, this research speaks to the importance of understanding the misconceptions students believe and instructional strategies that may assist in correcting them.

KEYWORDS

epigenetics, misconceptions, motivation, human development, educational psychology

INTRODUCTION

Educational psychologists have long stressed the importance of understanding individuals’ existing knowledge of a topic prior to instruction, as current knowledge shapes how new information is learned (Chinn & Samarapungavan, 2009). This prior knowledge can facilitate new learning by giving structure to new information (*conceptual growth*) or interfere with new learning if the existing knowledge is incorrect. In the latter scenario, students’ *misconceptions* about a given phenomenon alter how they learn new information (Hughes, Lyddy, & Lambe, 2013). Misconceptions are even observed through the undergraduate years and beyond (Badenhorst, Mamede, Hartman, & Schmidt, 2015; Balkissoon,

Blossfield, Salud, Ford, & Pugh, 2009; Lilienfeld, Lynn, Ruscio, & Beyerstein, 2010). Instructors themselves often unknowingly hold misconceptions that endure despite instruction to counter them; for example, several preservice teachers regressed to incorrect beliefs regarding the nature of science five months after instruction on the topic (Akerson, Morrison, & McDuffie, 2006). Overall, this research speaks to the importance of understanding what misconceptions students believe and instructional strategies that assist in correcting them.

Much of the research on misconceptions has focused on topics within both science (Gilbert & Watts, 1983; Thompson & Logue, 2006) and psychology (Furnham & Hughes, 2014; Kowalski & Taylor, 2009; Thompson & Zamboanga, 2004). Given the highly interdisciplinary nature of psychology (Cacioppo, 2013) and recent empirical advancements at the intersection of psychology and biological sciences, it is especially important for researchers and practitioners to understand students' misconceptions of interdisciplinary concepts. One particularly salient interdisciplinary phenomenon is the dynamic interaction of biological and environmental factors. Given the rapid progress of scientific knowledge in this area, it is critical for instructors of human development courses to understand students' prior knowledge related to "nature and nurture." However, because this topic crosses both psychology and biology, instructors teaching this content in psychology courses may find themselves daunted by tackling misconceptions about phenomena so deeply rooted in biological science.

Theoretical background

Broadly, research on misconceptions can be situated within a constructivist view of learning (as illustrated by the contributions in Rogoff & Wertsch, 1984), such that individuals build or *construct* their understanding of the world through active exploration and personal experiences. Students arrive in classrooms with prior knowledge that either supports or hinders new learning. When prior knowledge is incorrect (misconceptions), this shapes how students interpret factually correct new information.

Research on individuals' reporting of psychological misconceptions has uncovered a number of frequently occurring incorrect beliefs. For example, many undergraduate psychology majors incorrectly believe that people only use a small portion of their brains or think that learning styles-based instruction is effective (Bensley & Lilienfeld, 2017). Students who enter psychology courses with a greater number of misconceptions typically perform worse on exams (Kuhle, Barber, & Bristol, 2009), underscoring the importance of instructors' ability to detect and properly refute these misconceptions through conceptual change. Because the process of conceptual change involves removing these misconceptions and replacing them or modifying them with correct conceptions (Chi & Roscoe, 2002), it is critical for educators to understand students' misconceptions prior to instruction (diSessa, 2006).

Researchers have moved from a "cold" (cognitive factors) to a "hot" (motivational factors) approach to studying conceptual change, referring to the shift in focusing primarily on cognitive factors to seeking to understand the role that motivation plays in facilitating knowledge change (Pintrich, Marx, & Boyle, 1993; Sinatra, 2005). As prior knowledge can either facilitate or impede learning new information, so motivational beliefs (interest, feelings of competence and efficacy) can support or hinder conceptual change. Students' belief in their ability to alter their misconceptions, along with their interest in the subject matter, have combined associations with their likelihood to engage in conceptual change (Cordova, Sinatra, Jones, Taasoobshirazi, & Lombardi, 2014). Interest and perceived competence may be especially salient to consider in understanding students' revision of misconceptions on

interdisciplinary topics; interest facilitated by learning about cutting-edge science may facilitate conceptual change. At the same time, students may feel less confident in their ability to understand such topics.

Interdisciplinary phenomena and misconceptions

Despite the substantial body of literature on misconceptions in both psychology (Furnham & Hughes, 2014; Lilienfeld, 2012; Lyddy & Hughes, 2012) and biology (Brumby, 1984; Bahar, 2003), little is known about misconceptions that intersect both fields. Specifically, little is known concerning students' understanding (and misunderstanding) of biological and environmental influence on human development and, critically, about their understanding and misunderstanding of how these factors interact. For example, mental health researchers have emphasized the importance of practitioner understanding of the complex nature of environmental and genetic interplay in the development of mental illness (Sonuga-Barke, 2010).

Scholars in the social sciences have urged for a paradigm shift in the approach to studying biological and environmental influences on human development with some arguing they be conceptualized as closely interrelated or even inseparable rather than viewed as separate and competing factors (e.g., Champagne & Mashoodh, 2009; Dodge, 2004; Lerner, 2006; Meaney, 2001; Spencer et al., 2009). Moving beyond the "versus" paradigm when considering biology ("nature") and environment ("nurture") has been similarly echoed by those speaking to the importance of practitioner understanding of disease etiology (Sonuga-Barke, 2010).

One topic that crosses biological and psychological sciences, and therefore is of importance to preservice helping professionals, is epigenetics. The definition and use of "epigenetics" can be somewhat controversial and complicated (Henikoff & Greally, 2016). Here, we use epigenetics to refer to the study of "heritable" molecular or chemical alterations made to DNA, that do not directly result in changes to the nucleotide sequence itself, but do associate with later outcomes (Bonasio, Tu, & Reinberg, 2010); for example, gene expression regulation and/or behavior and disease. In other words, epigenetics examines a change in gene expression rather than a change in the genes themselves. Akin to the way DNA mutations are traditionally viewed, epigenetic alterations can persist through "generations" at both the cellular (i.e., mitosis) and organismal levels (i.e., meiosis).

Epigenetics resides at the interface between the environment and the genome, with many known examples of epigenetic changes occurring in response to environmental factors (e.g., toxins, stress, infection, and malnutrition; Feil & Fraga, 2012). This point, considered alongside the fact that epigenetic modifications can have "heritable" components (i.e., changes in genetic expression may be transmitted from parent to offspring), sets a precedent for exploring how life experiences can lead to changes in observable outcomes including disease. Such a point has implications for how students are taught about biological and environmental influences on development. One of the most often cited classic demonstrations of epigenetics is that of the Dutch Famine cohort, a longitudinal study of individuals who were exposed to prolonged periods of severe malnutrition in early development. Studies with this cohort have consistently shown that exposed individuals exhibited higher propensities to a broad spectrum of adult-onset diseases, including heart disease, diabetes, and mental health disorders (Roseboom, De Rooij, & Painter, 2006; Roseboom, Painter, Van Abeelen, Veenendaal, & De Rooij,

2011), including clear epigenetic links to genetic material (Heijmans et al., 2008; Tobi et al., 2014). Similar impacts of malnutrition have been noted elsewhere (Peter et al., 2016).

The roles of epigenetics in observable (phenotypic) variation have now been explored in a broad array of contexts. Many other examples pertinent to students' understanding of this content come from psychiatry and the behavioral sciences. For example, epigenetics has been used to explain environmentally induced changes in brain circuitry and reward pathways, with later influences on a host of conditions, such as depression, anxiety, and addiction (Robison & Nestler, 2011; Nestler, Peña, Kundakovic, Mitchell, & Akbarian, 2016). These again include demonstrations that early life exposures to factors such as stress and substance abuse can have lasting effects into adolescence and adulthood (Meaney & Szyf, 2005; Feder, Nestler, & Charney, 2009; Morris, DiNieri, Szutorisz, & Hurd, 2011; Tomasiewicz, Jacobs, Wilkinson, Wilson, Nestler, & Hurd, 2012; Barbier et al. 2017).

Current study

The goal of our study was to understand preservice helping professionals' preconceptions and misconceptions about biological and environmental influences on development through investigating their conceptions of epigenetics. Using a short-term longitudinal design, we explored students' conceptions and misconceptions of epigenetics both before and after learning about the topic. Guided by the "hot conceptual change" paradigm (Sinatra, 2005) we also examined key student motivation beliefs (self-efficacy for conceptual change, situational interest for epigenetics). Content on epigenetics was delivered by a guest speaker. The context for the study was a master's level course on human development taken by preprofessional students in helping professions (e.g., counseling psychology, school counseling).

We address the following three research questions:

1. ***What conceptions and misconceptions do students hold about epigenetics?***
2. ***How does students' baseline understanding of the interactions between biological and environmental influences relate to their later ability to explain epigenetic influences on development within this nature-nurture framework?***
3. ***What are students' motivational beliefs (self-confidence or efficacy for conceptual change, situational interest for the guest speaker) pertaining to learning about epigenetics, and do they relate to exam understanding?***

To address the first question we used an open-ended assessment at baseline (week 1) and on the second exam (week 11), which followed the guest lecture on epigenetics (given week 7), we asked students to explicitly conceptualize epigenetics within the framework of biological and environmental influences on development. To address the second and third questions we collected data on key motivation perceptions with a goal of understanding both mean-level perceptions and variability.

Method

Participants in the study included 29 master's-level students (preservice helping professionals from art therapy ($n = 2$), counseling psychology ($n = 16$), clinical mental health ($n = 7$), and school counseling ($n = 4$)) enrolled in a human development course during spring 2017 (24 female, 5 male). Due to changes in enrollment at the start of the semester and absences during the semester on data-

collection dates, sample size varied slightly across the various time points (noted below in the measures section).

Open-ended responses were examined for content by all authors. These authors included the instructor of the course, two doctoral students in educational psychology and counseling psychology (who had both taken this course and later served as a teaching assistant for the course), and the epigenetics researcher who provided the guest lecturer. Throughout the open-ended responses we interpreted correct definitions for epigenetics as needing to note *heritable changes* and *no modification to DNA sequence*. The coding process is described below for key indicators.

Measures

As outlined in the procedures section below, we assessed student understanding of key ideas in epigenetics at baseline (week 1 prior to instruction, $n = 26$) and at week 11 during the second exam ($n = 26$). At week 1, students responded to the open-ended question (“What is epigenetics?”)¹ At week 11 on the second exam we measured understanding of epigenetics through an open-ended question (“Explain how epigenetics relates to our major theme of ‘nature and nurture.’ In your response be sure to (1) Define epigenetics and (2) Provide an example of an epigenetic influence. Give an example to explain your answer.”). As a supplement to this open-ended question on exam 2, we also examined student responses to a true/false item tapping a central idea behind epigenetics (“Epigenetics entails changes in DNA sequence”).

Items measuring self-efficacy for conceptual change (administered at the start of week 7, prior to the guest lecture) were modified from an instrument developed by Saçkes, Trundle, Tuckman, and Krişsek (2012) in order to reflect self-efficacy for conceptual change related to the theme of nature-nurture interactions. The scale items assess efficacy for *detecting contradictions* (four items, e.g., “I can recognize whether the new concepts about nature and nurture that I have learned conflict with my previous understanding”) and efficacy for *revising understanding* (three items, e.g., “I can revise what I already know about nature and nurture based on the new concepts I have been learning in this class”). Items were measured on a seven-point Likert-type scale (1 = *strongly disagree* to 7 = *strongly agree*) and averaged to form a composite measure of efficacy for conceptual change pertaining to nature and nurture, with higher scores reflective of greater efficacy ($n = 22$). Overall internal consistency reliability was good ($\alpha = .87$).

Eight items from Linnenbrink-Garcia, Pugh, Koskey, and Stewart’s (2012) scale were adapted to measure situational interest for the guest lecture on epigenetics, administered at the end of the class at week 7 after the guest lecture. Four items assess “catch” (triggered situational interest; e.g., “Class was so exciting that it was easy to pay attention”) and four items measure “hold” (maintained situational interest-feeling; e.g., “I like what we learned about epigenetics”). Participants responded to the items on a five-point Likert scale (1 = *strongly disagree* to 5 = *strongly agree*). Items were averaged to form a composite score for situational interest ($\alpha = .93$), with higher scores reflective of greater situational interest ($n = 24$).

Participants also responded to items developed by the researchers to gauge students’ perceptions of the guest speaker, administered at the end of class on week 7. These questions were preceded by the phrase, “What we learned about epigenetics today . . .” and assessed various components of student perceptions about their learning and motivation: (1) helps me understand the

core theme of nature and nurture better, (2) makes me more interested in nature and nurture, (3) helps me understand epigenetics better, (4) makes me more interested in epigenetics, and (5) helps me realize that I may have had some misconceptions about epigenetics. All items were assessed on a five-point Likert scale (1 = *strongly disagree*; 5 = *strongly agree*) and were maintained as distinct indicators of perceptions rather than averaged to form a composite score ($n = 24$).

Understanding of epigenetics

At week 1, students responded to the open-ended question: “What is epigenetics?” Responses were coded for the presence (1 = *correct*) and absence (0 = *incorrect* or *absent*) of correct explanations. The correct definition for epigenetics needed to describe heritable changes and no modification to DNA sequence to be coded as correct. Understanding of epigenetics at week 11 was assessed with both a true/false item (“Epigenetics entails changes in DNA sequence”) and an open-ended question (“Explain how epigenetics relates to our major theme of ‘nature and nurture.’ In your response, be sure to 1. define epigenetics and 2. provide an example of an epigenetic influence.”).

The open-ended exam question, administered at week 11, was coded for the presence of a basic understanding of epigenetics (1 = *correct*, 0 = *incorrect*), for the presence or absence of a correct example of an epigenetic influence (1 = *correct*, 0 = *incorrect*), and for the presence or absence of a correct explanation of how epigenetics pertained to the course’s major theme of nature-nurture interactions (1 = *correct*, 0 = *incorrect*). This allowed for a summed score of understanding epigenetic influence for the exam that ranged from 0 to 3, with higher scores reflective of greater understanding of epigenetics in the context of biological and environmental influences on development.

Understanding of biology and environment (nature-nurture)

Understanding of nature and nurture was assessed at three¹ time points with open-ended questions: (1) at week 1 prior to any instruction (“What roles do nature and nurture play in development, if at all? Give an example to explain your answer.”) and at week 11 on the second exam (exam question described above). Responses at the first two time points were coded for a correct understanding of the concept of “nature” if the response mentioned genes, inheritance, predisposition, or biology, for a correct understanding of nurture if the response mentioned the environment, socialization, parenting, or early experiences, and for the presence of and correct understanding of the interaction between both constructs. Correct responses were coded as “1” and incorrect responses were coded as “0”.

Procedure

At week 1, we administered an open-ended question to assess baseline conceptions of epigenetics. Throughout the six weeks following the start of the semester, students discussed the dynamic interaction of biological and environmental influences on human development (core theme of “nature *and* nurture, not nature *versus* nurture”) during every class meeting. For example, students read an article explaining linkages between children’s sleep behavior, executive functioning, and caregiving behavior, in which active biology-environment interactions were highlighted (Bernier, Matte-Gagné, & Bouvette-Turcot, 2014). This overarching concept was highlighted as one of the four major themes of

the course along with the role that context plays in development, multiple pathways in development, and the interaction between physical, cognitive, and social development.

During week 7, students engaged in a guest lecture on epigenetics in the context of understanding risk taking in adolescence. At the start of class, students completed brief survey measures asking about self-efficacy for conceptual change with respect to understanding the interaction of biology and environment (nature and nurture). At the end of class, students responded to questions asking about situational interest in epigenetics ($n = 22$). The second exam for the course occurred on week 11 and contained two questions assessing knowledge of epigenetics in the context of biological and environmental interaction.

The guest lecturer was an assistant professor in the department of biochemistry and molecular genetics. His background and training are in genomics, with firsthand experience in the epigenetics field investigating the effects of DNA methylation (a commonly studied “epigenetic mark”) in disease, using both human and animal model systems. In his guest lecture, he outlined the basic principles of epigenetics, providing a short history of epigenetic concepts and drawing on classic examples from the field. These examples included a discussion of twin studies and early life environmental exposures and their long-term effects on conditions ranging from birth defects to adult-onset diseases, maternal care, and drug addiction. Evidence for multigenerational epigenetic inheritance was also presented and discussed. For the remaining portion of the class, students worked in small groups on concept maps broadly centered on risk-taking in adolescence (e.g., epigenetics, adolescent brain sensitivity to social feedback); the guest lecturer, course instructor, and course teaching assistant circulated among groups to discuss their concept maps.

Analysis

Rather than limit the sample to students with complete data at all time points ($n = 19$), we opted to use all available data. Descriptive statistics, measures of internal consistency reliability, and zero-order correlations for all quantitative variables are provided in Table 1.

Table 1. Descriptive statistics, internal consistency reliability, and zero-order correlations for all variables

CONSTRUCT/ITEM	M (SD)	α	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Self-efficacy for conceptual change	5.61 (0.85)	0.87	-						
(2) Situational interest	3.05 (0.80)	0.93	.01	-					
(3) Helps me understand the core theme of nature and nurture better.	3.17 (1.17)		.22	.70**	-				
(4) Makes me more interested in nature and nurture.	3.21 (0.88)		-.05	.79**	.68**	-			
(5) Helps me understand epigenetics better.	3.29 (1.33)		-.15	.73**	.64**	.61**	-		
(6) Makes me more interested in epigenetics.	2.96 (1.20)		-.11	.84**	.69**	.79**	.69**	-	
(7) Helps me realize that I may have had some misconceptions about nature and nurture.	2.63 (1.10)		-.20	.48*	.32	.53*	.27	.42	-

Note. Items for self-efficacy for conceptual change were measured on a 1-7 Likert scale. Items for situational interest and perceptions of the epigenetics guest speaker were measured on a 1-5 Likert scale. Scores for exam understanding of epigenetics could range from 0 to 3. * $p < .05$, ** $p < .01$, *** $p < .001$.

Results: What conceptions and misconceptions do students hold about epigenetics?

Baseline familiarity with epigenetics was low. Only two students provided a relatively correct definition for epigenetics at week 1, with one student referencing a classic epigenetic study in the response: “epigenetics is the study of how learning is passed down through the genes, such as the study done with mice and the smell of cherry blossoms-fear associated with the smell was passed down through several generations.” The remaining students either specifically stated that they did not know what it was ($n = 13$) or posed a guess ($n = 4$). Guesses included hypothesizing that epigenetics was related to genetics in some way (“altering genes” and “our overall gene pool including ancestors”), that it was a field combining epidemiology and genetics, that it dealt with episodic events, that perhaps it dealt with pregnancy, or that it was the study of “epic genetics.”

Understanding of epigenetics improved by the second exam at week 11; the following examples are all from week 11. Almost all students correctly responded to the true/false question asking if epigenetics entailed an alteration to DNA sequence ($n = 17$, 89.5 percent). Importantly, understanding of epigenetics as measured by the open-ended question proved more fruitful in revealing facets of student understanding and misconceptions. An examination of two out of the eight correct exam responses provides insight into how students accurately understood epigenetics through the lens of biological and environmental influences on human development:

Epigenetics: heritable trait [sic] influences by marks on DNA sequence. Marks are not changes in the sequence, only influences the DNA. Epigenetics is related to nature and nurture because although DNA is marked by various chemicals, environmental factors influence the traits that are displayed. Ex. If your parents were addicted to cocaine, this trait is passed on to you if you are exposed to drugs as an adult you have a chance of [sic] onsetting the addictive trait.

Epigenetics is a heritable trait that is the results of the environment but does not change the DNA sequence. It is “markers” on DNA that are passed down. An example would be one that [speaker] gave us. Two rats were exposed to THC [tetrahydrocannabinol] in adolescence with recreational doses every 3 days for 3 weeks. As adults, they mated and their children were raised by a drug naive mom. When the baby rats grew up, they worked harder for heroin than rats whose parents were not exposed. Also, the Dutch famine. During the Dutch famine pregnant women had a diet of 1000 calories. Their kids were followed and compared to other kids who were not exposed to famine in utero. When the Dutch famine babies grew up they had higher rates of schizophrenia, diabetes, heart disease, anti-social personality disorder.

An exploration of these exam responses with a focus on misconceptions provides insight into the ways in which students appear to have misunderstood the principles of epigenetics through describing an example. Six students demonstrated incorrect extrapolations of epigenetic influence. For example, two students extended the idea to behavioral traits not discussed by the guest speaker. The first of these appears to have misinterpreted the speaker’s example of Lamarckian genetics: “an example would be a father passing along his trait of strength, which was made possible because of his strenuous job (blacksmith hitting metal).” The other student noted:

an example of epigenetics is that a grandfather robs a bank when he was young and then several generations later his great grandson robs a bank too. That trait of robbing banks was passed down but it did not change the DNA.

The bank robbing example also suggests that the student believes that epigenetics is when something emerges later, especially generations later, through seemingly mysterious means. Two other students shared similar ideas in their responses. One noted, “an example of epigenetics is if someone is naturally artistic, but their children hate art. However, generations down the line, this person’s descendent spontaneously becomes artistic.” Another provided a similar explanation related to suicide: “if a great (x3) grandfather commits suicide, then later his great (x3) grandchild is adopted by another family with no history of suicide, however the great grandchild commits suicide.” The examples suggest that without a clear understanding of the mechanisms underlying epigenetics, students conclude that the process is somewhat mysterious and unexplained.

Because students’ interpretations of epigenetics can provide insight into their ideas underlying biological and environmental influences on human development, we noted instances in which students demonstrated misconceptions for this area on their exam responses. Notably, students described epigenetics as an “extension of nature and nurture”; “influences on the genome . . . the gray area of the concept of nature and nurture”, “middle ground between biology (DNA) and the environment . . . it attempts to offer an explanation when neither nature and nurture can”, and “essentially an extension of nature and nurture.” Together, these responses suggest that some students may not have completely understood epigenetics as representing the interactive relation between biology and environment. Some students more closely grasped this interaction, with one describing, “how the environment can have an impact on genetics. So how nature can affect nurture” and another describing the opposite influence, “the environment we are raised in (nurture) is affecting the way our genes are expressed (nature).”

Connecting baseline understanding of nature-nurture interaction to later understanding of epigenetics

Building on our exploration of the misconceptions that we observed in students’ exam responses, we sought to investigate potential connections between students’ baseline understanding of the interactions between biological and environmental influences and their later ability to explain epigenetic influences on development within this nature-nurture framework. For this, we turned to our coding of students’ baseline responses to how nature and nurture function in human development and our coding of students’ exam responses. A Spearman’s rho correlation between these two codes reveals a moderately strong relation of $\rho = .541$, suggesting that students’ baseline understanding of the interactive relation between biology and environment is related to their later ability to explain epigenetics within this context.

Motivation beliefs and perceptions

Motivation beliefs assessed included self-efficacy for conceptual change pertaining to nature and nurture (perceived confidence to both detect contradictions between current knowledge and new information as well as revise current knowledge based on new information), situational interest for the

guest speaker and content on epigenetics, and perceptions of the lesson on epigenetics. Overall, students perceived themselves to be highly efficacious for their ability to engage in conceptual change for the “dynamics of nature and nurture” theme of the course ($M = 5.61$, $SD = 0.85$; range: 4.29 to 7.0). Multiple students rated themselves at a perfect 7.0, suggesting strong perceived confidence to detect misconceptions and revise their understanding based on new information.

In contrast to self-efficacy for conceptual change, situational interest for the guest speaker and content on epigenetics varied substantially ($M = 2.94$, $SD = 0.85$), with composite scores spanning the full range of the scale. In examining mean-level perceptions, students felt generally in agreement that the guest lecture helped them understand epigenetics ($M = 3.29$, $SD = 1.33$) and the core class theme of nature and nurture ($M = 3.17$, $SD = 1.17$) but less in agreement that the guest lecture helped them uncover their misconceptions around nature and nurture ($M = 2.63$, $SD = 1.10$).

Correlating the coding of students’ open-ended exam responses (ability to explain epigenetic influences on human development within the framework of biology-environment interactions) with self-efficacy for conceptual change and situational interest for the guest speaker reveals two interesting findings. Self-efficacy for conceptual change in nature-nurture was not correlated with code for correct understanding on the open-ended exam question ($\rho = .081$). Conversely, situational interest for the guest speaker was related to the code for correct understanding on the open-ended exam item ($\rho = .561$), such that higher situational interest was associated with greater understanding.

Discussion

Given the accelerating rate of research advancements in understanding biological and environmental interactions in human development, it is critical to ensure that information about intergenerational transmission of genetic information is effectively shared with preservice practitioners in helping professions. One salient topic in this realm is epigenetics, a subject which has not only resulted in conceptual debate in the research realm (Henikoff & Greally, 2016), but has also received media attention. Because effective refutation of misconceptions requires instructors to not only possess a strong knowledge base about the topic itself but become familiar with the types of misconceptions held by students, our primary goal of the current study was to explore preservice helping professionals’ preconceptions and misconceptions about epigenetics within the context of learning about biological and environmental influences on human development.

Despite coverage of epigenetics research in the media (e.g., Park, 2015), students in this course were almost completely unaware of epigenetics at the start of the semester. Using an open-ended question to assess understanding of epigenetics proved fruitful in uncovering misconceptions about how epigenetics relates to human development. Notable examples included misconceptions about epigenetics being a function of spontaneous changes that randomly emerge after several generations or extrapolating to make inferences that all behaviors (such as “robbing banks”) could be heritable through epigenetics.

It is possible that students’ misconceptions about epigenetics develop jointly from both preexisting knowledge about biology and environmental influences on human development along with the content of the guest lecture on epigenetics. In moving forward with empirical inquiry into the effectiveness of conceptual change teaching methods for epigenetics, it may be helpful to draw upon students’ prior knowledge on these related factors (e.g., Cordova et al., 2014) beyond just prior

knowledge on epigenetics alone. For example, our review of exam responses suggested that asking students to explain epigenetics within the frame of biological and environmental influences on development was effective in uncovering both correct conceptions (as interrelated) and misconceptions (that epigenetics was an “extension” of this theme, a “middle ground” between the constructs, and more).

Just as existing conceptual knowledge shapes future learning, students’ motivational beliefs also shape learning and engagement (Schunk & Usher, 2012), likely in an interactive manner such that prior knowledge about nature and nurture informs students’ motivational beliefs for learning related topics, and these motivational beliefs may shape how students engage with the new material. Students often overestimate knowledge when engaging in metacognitive judgements of competence (Dunlosky & Lipko, 2007), consistent with how students in our sample rated themselves very highly in confidence to detect their own misconceptions but simultaneously expressed misconceptions on the exam. Accordingly, self-efficacy can serve both a supportive and hindering role in learning new content (e.g., Saçkes et al., 2012). The variability around students’ interest for the guest lecture is also informative in considering the role that interest may have played in students’ willingness to engage with the content at a deep level. Together, these findings add to the existing literature that has examined the varying combinations of motivation beliefs and their relative associations with student understanding and conceptual change (Dole & Sinatra, 1998; Linnenbrink-Garcia et al., 2012; Pintrich et al., 1993).

Limitations and future directions

A few limitations should be noted with the goal of continuing research in this realm. We primarily focused on beginning an inquiry into misconceptions pertaining to epigenetics and perceptions (including motivation) regarding the experience of learning about epigenetics; therefore, our goal was not to fully characterize how these factors interacted or to draw causal conclusions. Future research may build on these initial findings through a quasi-experimental design across multiple classrooms in order to understand how these factors interact (e.g., how different methods of teaching about epigenetics shape motivational beliefs and misconceptions). Additionally, we had intended the true/false question on exam 2 to serve as an indicator of a basic idea behind epigenetics (that it does not entail change to DNA sequence) rather than a tool to uncover in-depth understanding or even misconceptions. The high rate of correct responses suggests that this item may be subject to ceiling effects; researchers should consider the development and validation of items that can be used to quantify understanding of epigenetics.

Educational implications

Synthesizing the findings from the study (while being mindful of the aforementioned limitations), we offer the following recommendations. First, asking open-ended questions in the study about epigenetics allowed us to capture more nuances in and better identify the nature of students’ misconceptions, particularly when compared to information that would be gained from a close-ended questioning. This is consistent with previous recommendations that instructors interested in understanding biomedical misconceptions carefully probe students’ understanding through open-ended questions (Badenhorst et al., 2015).

Second, instructors should be mindful of the way in which students' motivational beliefs may relate to conceptual understanding and conceptual change. Because self-efficacy for conceptual change was quite high, it may be fruitful to engage students in activities that break down these illusions of knowing (i.e., the incorrect belief that understanding has been achieved) by highlighting discrepancies between baseline responses and empirical research; many of the suggested activities by Sheldon (2018) could potentially serve well in prompting students to actively reflect on their implicit assumptions about biological and environmental influences on human development.

Instructors should remain mindful of the importance of both catching and sustaining students' interest in new content. The interdisciplinary nature of psychology (Cacioppo, 2013) may naturally assist in sparking students' interest. It is also possible that highlighting the implications of epigenetics research for clinical practice (such as suggested in the variety of activities proposed by Sheldon, 2018) may also serve to promote students' deeper interest. As preservice practitioners learn how this research can be used to inform client conceptualization and treatment (Sonuga-Barke, 2010), long-term motivation beliefs for continued education in this area may be supported.

One additional point to consider is the connection between prior background knowledge and situational interest: moderate levels of knowledge are related to situational interest (Schraw, Flowerday, & Lehman, 2001) and situational interest can help further more long-term, individual interest through the acquisition and strengthening of subject-matter knowledge (Alexander, Kulikowich, & Schulze, 1994). Specifically, situational interest has been found to drive knowledge acquisition, as well (Rotgans & Schmidt, 2014), suggesting that promoting students' situational interest in epigenetics may help to facilitate further learning and longer individual interest in the topic.

CONCLUSION

Despite the challenges associated with understanding misconceptions in a highly interdisciplinary topic such as epigenetics, findings from the current study highlight the importance of continuing to educate students (particularly preservice helping professionals) in this area. Further, this more nuanced insight into the types of misconceptions that students develop about epigenetics can be used to tailor future teaching efforts for this critically important topic.

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NOTES

1. Students were also asked to respond to the same open-ended prompt administered at week 1 after the guest speaker at week 7; however, due to time constraints during the class period, students completed this question after class and returned responses the following week. Upon examining student responses, it appeared that the majority of students used content directly from their notes in responding, and therefore, we opted not to analyze these responses as it was not a truly

equivalent assessment to week 1, in which students were not allowed to access material during responding.

REFERENCES

- Akerson, V. L., Morrison, J. A., & McDuffie, A. R. (2006). One course is not enough: Preservice elementary teachers' retention of improved views of nature of science. *Journal of Research in Science Teaching*, 43(2), 194-213. <https://doi.org/10.1002/tea.20099>
- Alexander, P. A., Kulikowich, J. M., & Schulze, S. K. (1994). How subject-matter knowledge affects recall and interest. *American Educational Research Journal*, 31(2), 313-337. <https://doi.org/10.3102/00028312031002313>
- Badenhorst, E., Mamede, S., Hartman, N., & Schmidt, H. G. (2015). Exploring lecturers' views of first-year health science students' misconceptions in biomedical domains. *Advances in Health Sciences Education*, 20(2), 403-420. <https://doi.org/10.1007/s10459-014-9535-3>
- Bahar, M. (2003). Misconceptions in biology education and conceptual change strategies. *Educational Sciences: Theory & Practice*, 3, 55-64. <https://doi.org/10.1080/00219266.2018.1490798>
- Balkissoon, R., Blossfield, K., Salud, L., Ford, D., & Pugh, C. (2009). Lost in translation: unfolding medical students' misconceptions of how to perform a clinical digital rectal examination. *The American Journal of Surgery*, 197(4), 525-532 <https://doi.org/10.1016/j.amjsurg.2008.11.025>
- Barbier, E., Johnstone, A. L., Khomtchouk, B. B., Tapocik, J. D., Pitcairn, C., Rehman, F., . . . Heilig, M. (2017). Dependence-induced increase of alcohol self-administration and compulsive drinking mediated by the histone methyltransferase PRDM2. *Molecular Psychiatry*, 22(12), 1746-1758. <https://doi.org/10.1038/mp.2016.131>
- Bensley, D. A., & Lilienfeld, S. O. (2017). Psychological misconceptions: Recent scientific advances and unresolved issues. *Current Directions in Psychological Science*, 26(4), 377-382. <https://doi.org/10.1177/0963721417699026>
- Bernier, A., Matte-Gagné, C., & Bouvette-Turcot, A. A. (2014). Examining the interface of children's sleep, executive functioning, and caregiving relationships: A plea against silos in the study of biology, cognition, and relationships. *Current Directions in Psychological Science*, 23(4), 284-289. <https://doi.org/10.1177/0963721414534852>
- Bonasio, R., Tu, S., & Reinberg, D. (2010). Molecular signals of epigenetic states. *Science*, 330(6004), 612-616. <https://doi.org/10.1126/science.1191078>
- Brumby, M. N. (1984). Misconceptions about the concept of natural selection by medical biology students. *Science Education*, 68(4), 493-503. <https://doi.org/10.1002/sce.3730680412>
- Cacioppo, J. T. (2013). Psychological science in the 21st century. *Teaching of Psychology*, 40(4), 304-309. <http://dx.doi.org/10.1177/0098628313501041>
- Champagne, F. A., & Mashoodh, R. (2009). Genes in context: Gene-environment interplay and the origins of individual differences in behavior. *Current Directions in Psychological Science*, 18(3), 127-131. <https://doi.org/10.1111/j.1467-8721.2009.01622.x>
- Chi, M. T. H., & Roscoe, R. D. (2002). The processes and challenges of conceptual change. In M. Limón & L. Mason (Eds.), *Reconsidering conceptual change: Issues in theory and practice* (pp. 3-27). Dordrecht: Kluwer Academic Publishers.
- Chinn, C. A., & Samarapungavan, A. (2009). Conceptual change—Multiple routes, multiple mechanisms: A commentary on Ohlsson (2009). *Educational Psychologist*, 44(1), 48-57. <http://dx.doi.org/10.1080/00461520802616291>
- Cordova, J. R., Sinatra, G. M., Jones, S. H., Taasooobshirazi, G., & Lombardi, D. (2014). Confidence in prior knowledge, self-efficacy, interest and prior knowledge: Influences on conceptual change. *Contemporary Educational Psychology*, 39(2), 164-174. <http://dx.doi.org/10.1016/j.cedpsych.2014.03.006>
- diSessa, A. A. (2006). A history of conceptual change research: Threads and fault lines. In R. K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (pp. 265-281). Cambridge: Cambridge University Press.
- Dodge, K. A. (2004). The nature-nurture debate and public policy. *Merrill-Palmer Quarterly*, 50(4), 418-427. <https://www.jstor.org/stable/23096214>

- Dole, J. A., & Sinatra, G. M. (1998). Reconceptualizing change in the cognitive construction of knowledge. *Educational Psychologist*, 33(2/3), 109-128. http://dx.doi.org/10.1207/s15326985ep3302&3_5
- Dunlosky, J., & Lipko, A. R. (2007). Metacomprehension: A brief history and how to improve its accuracy. *Current Directions in Psychological Science*, 16(4), 228-232. <https://doi.org/10.1111/j.1467-8721.2007.00509.x>
- Feder, A., Nestler, E. J., & Charney, D. S. (2009). Psychobiology and molecular genetics of resilience. *Nature Reviews Neuroscience*, 10(6), 446-457. <http://dx.doi.org/10.1038/nrn2649>
- Feil, R., & Fraga, M. F. (2012). Epigenetics and the environment: Emerging patterns and implications. *Nature Reviews Genetics*, 13, 97-109. <https://doi.org/10.1038/nrg3142>
- Furnham, A., & Hughes, D. J. (2014). Myths and misconceptions in popular psychology: Comparing psychology students and the general public. *Teaching of Psychology*, 41(3), 256-261. <http://dx.doi.org/10.1177/0098628314537984>
- Gilbert, J. K., & Watts, D. M. (1983). Concepts, misconceptions and alternative conceptions: Changing perspectives in science education. *Studies in Science Education*, 10(1), 61-98. <https://doi.org/10.1080/03057268308559905>
- Heijmans, B. T., Tobi, E. W., Stein, A. D., Putter, H., Blauw, G. J., Susser, E. S., . . . Lumey, L. H. (2008). Persistent epigenetic differences associated with prenatal exposure to famine in humans. *Proceedings of the National Academy of Sciences*, 105(44), 17046-17049. <https://doi.org/10.1073/pnas.0806560105>
- Henikoff, S., & Grealia, J. M. (2016). Epigenetics, cellular memory and gene regulation. *Current Biology*, 26, R644-R648. Retrieved from [https://www.cell.com/current-biology/pdf/S0960-9822\(16\)30623-6.pdf](https://www.cell.com/current-biology/pdf/S0960-9822(16)30623-6.pdf)
- Hughes, S., Lyddy, F., & Lambe, S. (2013). Misconceptions about psychological science: A review. *Psychology Learning & Teaching*, 12(1), 20-31. <http://dx.doi.org/10.2304/plat.2013.12.1.20>
- Kowalski, P., & Taylor, A. K. (2009). The effect of refuting misconceptions in the introductory psychology class. *Teaching of Psychology*, 36(3), 153-159. <https://doi.org/10.1080/00986280902959986>
- Kuhle, B. X., Barber, J. M., & Bristol, A. S. (2009). Predicting students' performance in introductory psychology from their psychology misconceptions. *Journal of Instructional Psychology*, 36(2), 119-124.
- Lerner, R. M. (2006). Developmental science, developmental systems, and contemporary theories of human development. In R. M. Lerner, W. Damon (Eds.), *Handbook of child psychology* (6th ed.): Vol. 1. *Theoretical models of human development* (pp. 1-17). Hoboken, NJ: Wiley.
- Lilienfeld, S. O. (2012). Public skepticism of psychology: Why many people perceive the study of human behavior as unscientific. *American Psychologist*, 67(2), 111-129. <http://dx.doi.org/10.1037/a0023963>
- Lilienfeld, S. O., Lynn, S. J., Ruscio, J., & Beyerstein, B. L. (2010). Mythbusting in introductory psychology courses: The whys and the hows. In S. A. Meyers, J. R. Stowell, S. A. Meyers, J. R. Stowell (Eds.), *Essays from "Excellence in Teaching"* (Vol. 9, pp. 55-61.) Retrieved from <http://teachpsych.org/Resources/Documents/ebooks/eit2009.pdf>
- Linnenbrink-Garcia, L., Pugh, K. J., Koskey, K. L. K., & Stewart, V. C. (2012). Developing conceptual understanding of natural selection: The role of interest, efficacy, and basic prior knowledge. *Journal of Experimental Education*, 80(1), 45-68. <https://doi.org/10.1080/00220973.2011.559491>
- Lyddy, F., & Hughes, S. (2012). Attitudes toward psychology as a science and the persistence of psychological misconceptions in psychology undergraduates. In S. McCarthy, K. L. Dickson, J. Cranny, A. Trapp, & V. Karandashev (Eds.), *Teaching Psychology around the World* (Vol. 3, pp. 330-349). Newcastle upon Tyne: Cambridge Scholars Publishing.
- Meaney, M. J. (2001). Nature, nurture, and the disunity of knowledge. *Annals of the New York Academy of Sciences*, 935(1), 50-61. <https://doi.org/10.1111/j.1749-6632.2001.tb03470.x>
- Meaney, M. J., & Szyf, M. (2005). Environmental programming of stress responses through DNA methylation: Life at the interface between a dynamic environment and a fixed genome. *Dialogues in Clinical Neuroscience*, 7(2), 103-123. Retrieved from <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3181727/>
- Morris, C. V., DiNieri, J. A., Szutorisz, H., & Hurd, Y. L. (2011). Molecular mechanisms of maternal cannabis and cigarette use on human neurodevelopment. *European Journal of Neuroscience*, 34(10), 1574-1583. <https://doi.org/10.1111/j.1460-9568.2011.07884.x>
- Nestler, E. J., Peña, C. J., Kundakovic, M., Mitchell, A., & Akbarian, S. (2016). Epigenetic basis of mental illness. *Neuroscientist*, 22(5), 447-463. <https://doi.org/10.1177/1073858415608147>

- Park, A. (2015, June 8). *Explaining “epigenetics”: The health buzzword you need to know*. *Time*. Retrieved from <http://time.com/3911161/explaining-epigenetics-the-health-buzzword-you-need-to-know/>
- Peter, C. J., Fischer, L. K., Kundakovic, M., Garg, P., Jakovcevski, M., Dincer, A., . . . Akbarian, S. (2016). DNA methylation signatures of early childhood malnutrition associated with impairments in attention and cognition. *Biological Psychiatry, 80*(10), 765-774. <https://doi.org/10.1016/j.biopsych.2016.03.2100>
- Pintrich, P. R., Marx, R. W., & Boyle, R. A. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research, 63*(2), 167-199. <http://dx.doi.org/10.2307/1170472>
- Robison, A. J., & Nestler, E. J. (2011). Transcriptional and epigenetic mechanisms of addiction. *Nature Reviews Neuroscience, 12*, 623-637. <https://doi.org/10.1038/nrn3111>
- Rogoff, B., & Wertsch, J.W. (Eds.). (1984). *Children’s learning in the “zone of proximal development.”* San Francisco: Jossey-Bass.
- Roseboom, T. J., De Rooij, S., & Painter, R. (2006). The Dutch famine and its long-term consequences for adult health. *Early Human Development, 82*(8), 485-491. <https://doi.org/10.1016/j.earlhumdev.2006.07.001>
- Roseboom, T. J., Painter, R. C., Van Abeelen, A. F., Veenendaal, M. V., & De Rooij, S. R. (2011). Hungry in the womb: What are the consequences? Lessons from the Dutch famine. *Maturitas, 70*, 141-145. <https://doi.org/10.1016/j.maturitas.2011.06.017>
- Rotgans, J. I., & Schmidt, H. G. (2014). Situational interest and learning: Thirst for knowledge. *Learning and Instruction, 32*, 37-50. <http://dx.doi.org/10.1016/j.learninstruc.2014.01.002>
- Saçkes, M., Trundle, K. C., Tuckman, B. Q., & Krissek, L. A. (2012). Development of the efficacy beliefs for conceptual change learning questionnaire. *Journal of Experimental Education, 80*(4), 338-351. <https://doi.org/10.1080/00220973.2011.600355>
- Schunk, D. H., & Usher, E. L. (2012). Social cognitive theory and motivation. In R. M. Ryan (Ed.), *The Oxford handbook of human motivation* (pp. 13-27). New York, NY: Oxford University Press.
- Schraw, G., Flowerday, T., & Lehman, S. (2001). Increasing situational interest in the classroom. *Educational Psychology Review, 13*(3), 211-224. <https://doi.org/10.1023/A:1016619705184>
- Sheldon, J. P. (2018). Incorporating a discussion of genetic attributions into psychology courses. *Teaching of Psychology, 45*(1), 91-101. <https://doi.org/10.1177/0098628317745463>
- Sinatra, G. M. (2005). The “warming trend” in conceptual change research: The legacy of Paul R. Pintrich. *Educational Psychologist, 40*(2), 107-115. http://dx.doi.org/10.1207/s15326985ep4002_5
- Sonuga-Barke, E. J. (2010). ‘It’s the environment stupid!’ On epigenetics, programming and plasticity in child mental health. *Journal of Child Psychology and Psychiatry, 51*(2), 113-115. <https://doi.org/10.1111/j.1469-7610.2009.02213.x>
- Spencer, J. P., Blumberg, M. S., McMurray, B., Robinson, S. R., Samuelson, L. K., & Tomblin, J. B. (2009). Short arms and talking eggs: Why we should no longer abide the nativist–empiricist debate. *Child Development Perspectives, 3*(2), 79-87. <http://dx.doi.org/10.1111/j.1750-8606.2009.00081.x>
- Thompson, F., & Logue, S. (2006). An exploration of common student misconceptions in science. *International Education Journal, 7*(4), 553-559. Retrieved from <http://ehlt.flinders.edu.au/education/iej/articles/mainframe.htm>
- Thompson, R. A., & Zamboanga, B. L. (2004). Academic aptitude and prior knowledge as predictors of student achievement in introduction to psychology. *Journal of Educational Psychology, 96*(4), 778-784. <http://dx.doi.org/10.1037/0022-0663.96.4.778>
- Tobi, E. W., Goeman, J. J., Monajemi, R., Gu, H., Putter, H., Zhang, Y., . . . Heijmans, B. T. (2014). DNA methylation signatures link prenatal famine exposure to growth and metabolism. *Nature Communications, 5*, 5592-5605. <https://doi.org/10.1038/ncomms6592>
- Tomasiewicz, H. C., Jacobs, M. M., Wilkinson, M. B., Wilson, S. P., Nestler, E. J., & Hurd, Y. L. (2012). Proenkephalin mediates the enduring effects of adolescent cannabis exposure associated with adult opiate vulnerability. *Biological Psychiatry, 72*(10), 803-810. <https://doi.org/10.1016/j.biopsych.2012.04.026>



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