Mothers’ and fathers’ cognitive and affective responses to epigenetics concepts

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Abstract

Advances in our understanding of epigenetics present new opportunities to improve children’s health through the counseling of parents about epigenetics concepts. However, it is important to first evaluate how parents respond to this type of information and determine the consequences of educating parents about epigenetics. We have taken an initial step toward this goal by assessing parental responses to an epigenetics learning module. Parents (n = 190, 126 mothers) responded to pre- and post-module survey questions. Prior to the module, parents reported that mothers’ lifestyles prior to conception were more important for children’s health than fathers’ lifestyles prior to conception (t = 4.49, df = 316.5, P < 0.0001). However, after the module, there was no difference between ratings of the importance of mothers’ and fathers’ preconception lifestyles (t = 1.18, df = 319.8, P = NS). Furthermore, after viewing the module, parents increased their ratings of the importance of both mothers’ (t = −5.65, df = 294.8, P < 0.0001) and father’s (t = −9.01, df = 287.2, P < 0.0001) preconception lifestyles for child health. After viewing the module, most parents reported feelings of guilt and negativity regarding epigenetics (78 and 55%, respectively). When compared with lean parents, parents with overweight more often reported feelings of guilt (χ² = 10.27, P = 0.001). This work represents an important first step in evaluating parental responses to epigenetics concepts.

Key words: mothers; fathers; epigenetic education; epigenetic communication; gender; obesity; parents; transgenerational epigenetics

Introduction

Epigenetics is a rapidly growing field that has significant potential to affect population health. Epigenetic changes are dynamic and can be affected by an individual’s environment and behavior throughout the life course. These changes are defined as DNA modifications which influence gene activity or expression, without changing the DNA sequence [1]. Epigenetic changes have been shown to be associated with behaviors such as foods consumed, physical activity, and tobacco use, as well as environmental exposures such as pollutants and stress, among many others [2]. Changes in epigenetics have been previously associated with many health outcomes including obesity and
Environmental Epigenetics

For parents, this potential ability to influence one’s epigenetics can have implications for their children’s health outcomes. Although children’s epigenetics can be influenced by their own environmental experiences [7, 8], parents also can pass down gene expression patterns that were established prior to conception and during pregnancy through transgenerational epigenetic mechanisms [9]. Whether parents are aware of how such epigenetic changes affect their children, and how parents respond to such information, remains an unexplored area of research that we address in this article.

Due to published recommendations and frequent prenatal care, mothers are typically aware of the general connection between their behaviors and environment during pregnancy and their children’s health, even if they are not aware of epigenetic mechanisms specifically [10–12]. Epigenetic changes have been associated with many well-established health behaviors before and during pregnancy [13–17]. The impact of fathers’ preconception lifestyle and environment on children is less clear. However, recent evidence indicates fathers’ behaviors and environmental exposures have the potential to impact their children’s health prior to conception through epigenetic mechanisms; e.g. fathers’ exposure to trauma [18] and cannabis use [19] have been associated with epigenetic changes in sperm.

In addition, mothers’ and fathers’ weight status can influence their children’s health outcomes [20]. Though the research is still limited, the role of epigenetics in the connection between mothers’ and fathers’ weight status and children’s health is becoming clearer. Obesity in fathers has been associated with changes in methylation of genes associated with growth and development in their children [21, 22]. Additionally, a few studies have reported that the weight status of fathers is associated with methylation differences in sperm, suggesting a pathway for transgenerational inheritance of obesity risk through epigenetic mechanisms [23]. Mothers’ influence on their children’s risk for obesity can occur prior to conception [24] as well as during pregnancy [25]. Specifically, mothers’ preconception weight status has been associated with epigenetic changes in newborns [26] and mothers’ diet during pregnancy has been shown to have an effect on children’s risk for obesity; researchers posit that this likely occurs through epigenetic changes [25].

As the science exploring the role of epigenetics in children’s health advances, it becomes important to understand how the general population responds to these concepts. Some parents may be starting to learn about epigenetics concepts through the media exposure, where headlines are often targeted specifically to mothers [27–29] and fathers [30–32]. If we are to use epigenetics research for clinical and public health gain, it will be necessary to develop strategies to communicate these concepts to current and future parents. Indeed, research has shown that health risks are more likely to be acted upon when individuals understand the pathway through which they act [33]. As such, it will likely not be sufficient to tell future parents that their behaviors have implications for their child’s health; rather, it will be important to explain the route through which this behavior can be influential. Understanding parent responses to epigenetics messages may aide us in creating educational materials that reduce potential fatalism and increase the likelihood of positive behavior change, especially among fathers who may be unaware of their role in shaping their child’s epigenetics and thus their child’s health. In this study, we examine epigenetics messages specifically focused on the impact of parental behavior and environment on a child’s epigenetic markers prior to conception. Through this work, we aim to inform future messaging during parents’ prenatal, as well as preconception, counseling, which is recommended and common in the USA [34].

To our knowledge, no extant studies have assessed parental responses to epigenetics concepts. However, previous literature on parental responses to genetic messages that are relevant for their children may provide some insight. Although genetic and epigenetic concepts are distinct, our study focuses on the epigenetic changes that have occurred prior to a child’s conception, which parents can no longer directly change. As parents also lack direct control over genetic contributors to their child’s risk, there may be similarities in their responses to each message type. In the context of rare diseases, previous studies have shown that parents respond to genetic risk information with worry, guilt, and self-blame [35, 36], and find genetic messages more threatening than non-genetic messages due to an inability to take action [37]. In contrast, in the context of common diseases, parents generally respond positively to the prospect of genetic testing and feel that it would be beneficial, often because they anticipate learning that their child is at a lower genetic risk [38]. However, one study found that when mothers were exposed to family history-based personalized risk information suggesting their child was at increased risk for obesity, they felt more lifestyle- and genetics-related guilt, but also chose to feed their child a healthier meal [39, 40]. Thus, in the context of common diseases such as obesity, it appears that the receipt of genetic information has the potential to lead to nuanced and interrelated behavioral and affective outcomes that may be both positive and negative.

If epigenetic messages are interpreted similarly to genetic messages, then epigenetic messages may influence parents on multiple levels including their behavior, beliefs, and affect. Thus, this study explores several dimensions of parental response to an epigenetics message. First, we investigate how parents understand their role in influencing their child’s epigenetics and downstream health risks; as this is the first study to explore this, we do not pose hypotheses regarding this aim. Second, we explore how learning about epigenetics affects parents’ feelings regarding their ability to act to improve health; because we are focused on parental lifestyle before conception, to which parents may respond similarly as they do to genetic information, we anticipate that parents may feel relatively fatalistic after learning about these epigenetic mechanisms. Finally, we survey parents’ potential feelings of guilt related to their impact on their child’s epigenetics; given emergent findings related to parental guilt in the genetics literature, we anticipate that parental guilt will play a salient role in their responses to epigenetics information.

In addition, we examined potential moderators of parental responses to epigenetics educational material. First, we anticipated gender differences because mothers are likely already aware of the influence they have on their child before and during pregnancy, whereas fathers may not be aware of the impact of their lifestyle prior to conception, as research in this area is newer and currently growing [41]. Second, research regarding the impact of parental obesity on children’s obesity risk leads us to believe that parental weight status may influence how parents respond to these messages [20]. We anticipate that there may be differences by parent weight status because of the societal use of weight as a proxy for health in the USA [42, 43], as well as the focus on weight, diet, and physical activity during preconception counseling and during pregnancy [44, 45].
Additionally, parents in our study were exposed to epigenetics information in the context of a larger behavioral trial which was centered around parental feeding behavior (described in detail below); thus, parental weight status may be particularly salient within this study. In all, this study provides an exploration of how parents respond to epigenetics when introduced as a new concept, and how this response may vary by parent characteristics.

**Results**

**Prior Knowledge of Epigenetics**

Because of our interest in understanding parental responses to initially learning about the concept of epigenetics, we excluded participants with a previous knowledge of epigenetics from analyses. Participants who correctly defined epigenetics were considered to have a prior knowledge of epigenetics. Of the 52 participants who stated they knew what epigenetics meant, 28 correctly defined the term and were thus excluded from further analysis. Significant differences between participants with and without prior knowledge of epigenetics emerged such that 100% of participants with prior knowledge were college educated, whereas 76% of those without prior knowledge were college educated (Fisher’s exact test \( P = 0.001 \)). Additionally, racial breakdown of the two groups differed such that 8% of participants with prior knowledge were African American, whereas 29% of participants without prior knowledge were African American (\( \chi^2 = 11.18, P = 0.02 \)). Outside of this difference, racial breakdown was similar across groups. Composition of the two groups did not differ by age, gender, or self-identified weight status. Analyses in the remainder of the study included a sample of 162 individuals (112 mothers and 50 fathers).

**Overall Responses to Learning about Epigenetics**

Prior to viewing the epigenetics module, parents endorsed a higher score for the impact of a mother’s lifestyle prior to birth on a child’s overall health compared with a father’s lifestyle (\( t = 4.49, df = 316.5, P < 0.0001; \) Table 1). Post-educational module, parents endorsed an equivalent impact of mothers’ and fathers’ lifestyles on children’s overall health (\( t = 1.18, df = 319.8, P = NS \)); parents no longer felt that mothers’ lifestyles prior to birth were more impactful than fathers’ lifestyles on children’s overall health. Parents endorsed a significantly higher impact of both mother’s (\( t = -5.65, df = 294.8, P < 0.0001 \)) and father’s (\( t = -9.01, df = 287.2, P < 0.0001 \)) lifestyles prior to birth on a child’s overall health after viewing the module compared with before viewing the module (Table 1).

Most parents (73%) expressed some level of guilt about the impact they may have had on their child through epigenetics. Within the free responses, negative tone was more prevalent than positive tone (\( \chi^2 = 33.68, P < 0.0001; \) Table 1). This pattern was consistent regarding behavioral and environmental influences mentioned by parents: negative influences were more prevalent within the free responses than positive influences (\( \chi^2 = 11.81, P = 0.0005 \) for behaviors; \( \chi^2 = 27.63, P < 0.0001 \) for environment; Table 1).

Overall, parents indicated that learning about epigenetics made them feel they could take action for both their own health (\( M = 3.98 \)) and their child’s health (\( M = 3.96 \), as the means are higher than the midpoint of the scale (Table 1).

| Variable name | \( n \) = 162 |
|---------------|----------------|
| Survey questions | Mean ± SD |
| Pre-module impact of mother’s lifestyle | 4.06 ± 0.87 |
| Pre-module impact of father’s lifestyle | 3.59 ± 0.99 |
| Post-module impact of mother’s lifestyle | 4.53 ± 0.63 |
| Post-module impact of father’s lifestyle | 4.44 ± 0.69 |
| Learning about epigenetics made me feel like I can act for my health | 3.98 ± 0.82 |
| Learning about epigenetics made me feel like I can act for my child’s health | 3.96 ± 0.89 |

\( \text{P} \times \text{NS} < 0.0001 \) and \( \chi^2 = 82.62, \text{df} = 82.62, P < 0.0001; \text{Fig. 1} \).

The pre- to post-module increase in endorsement of mothers’ (\( t = -0.75, df = 78.18, P = NS \)) and fathers’ (\( t = 1.68, df = 79.61, P = NS \)) lifestyle importance did not vary by gender. In other words, mothers and fathers displayed similar increases in their endorsement of both mothers’ and fathers’ lifestyle importance on children’s health. Other closed-ended responses did not vary significantly by parent gender.

In the open-ended questions, no significant differences emerged by parent gender. Although not statistically significant, we observed that some (eight) mothers expressed feelings of guilt whereas no fathers expressed this feeling. See Fig. 2 for a full summary of open-ended themes by gender.

**Differences in Responses by Parent Weight Status**

We did not observe any significant demographic differences between the two weight-based subgroups of parents. In the closed-ended questions, both parents with overweight and lean parents endorsed a significantly higher impact of mother’s (\( t = -4.39, df = 169.7, P < 0.0001 \) and \( t = -3.57, df = 123.6, P = 0.0005 \), respectively) and father’s (\( t = -6.69, df = 163.9, P < 0.0001 \) and \( t = -6.01, df = 121.4, P < 0.0001 \), respectively) lifestyle on a child’s health after viewing the epigenetics educational materials.
Here, we utilize person-first language with respect to describing people who have obesity, as recommended by the American Medical Association. The magnitude of these changes did not differ significantly by weight group (Fig. 3). Parents with overweight more often endorsed guilt about the effect their lifestyle or environment may have had on their child’s epigenetic markers ($\chi^2 = 10.27, P = 0.001$); 83% of parents with overweight endorsed guilt, compared with 55% of lean parents. Despite this more frequent endorsement of guilt, parents with overweight were equally as likely to feel that they could act to improve their child’s health because of learning about epigenetics ($t = 2.04, df = 144.12, P = \text{NS}$; Fig. 3).

Within the free response data, parents with overweight were more likely to identify exercise or healthy eating as a positive behavior that may have impacted their child, e.g. ‘I was raised to eat healthy and be active, those likely transferred to [my child].’ These positive behaviors, or lack of negative behaviors, were not cited as often among parents with overweight.

Discussion

This work is the first to explore parental responses to learning about epigenetics concepts wherein epigenetic changes caused by parent environment and behavior are passed down to their child. Overall, after learning about epigenetics, parents endorsed a higher importance of both a mother’s and father’s pre-conception lifestyle on a child’s health. Furthermore, parents felt that the impacts of mothers’ and fathers’ lifestyles prior to conception were equivalent after viewing the epigenetics module. In terms of affective response to epigenetics, most parents...
expressed some level of guilt after viewing the module and felt more negatively than positively about epigenetics concepts. Differences in response between mothers and fathers were minimal, with the exception that mothers were more likely to discuss outside factors, such as stress or environment that negatively influenced them, and therefore their child, through epigenetic processes. Interestingly, compared with parent gender, parental weight status had more influence on reception of the epigenetics content. Parents with overweight were more likely to feel guilt and less likely to discuss epigenetics using positive tone. This was despite the epigenetics learning module not mentioning the impact of parent weight on children’s epigenetics or health. The larger research context in which this study was embedded did, however, discuss healthy eating for children and contained some content about obesity in questionnaires which may have influenced these outcomes.

Prior to investigating these responses, we excluded 15% of participants because they were already familiar with the concept of epigenetics. This may be because ~30% of the sample was employed at the National Institutes of Health. It is therefore very likely that the prevalence of epigenetics knowledge within the general population is lower. Although epigenetics messages are becoming more prevalent in media and educational contexts, most of our sample had not seen these messages, recognized them as epigenetics, and/or understood the concept.

When exploring how parents understand their role in influencing their child’s epigenetics, we found that prior to viewing the epigenetics module; parents endorsed a higher impact of mothers’ preconception lifestyles on children’s health than fathers’ lifestyles. We suspected this would be the case due to the ubiquity of clinical and public health messages mothers receive which emphasize health-promoting behaviors during pregnancy, and sometimes during preconception counseling in preparation for pregnancy. Additionally, the potential for intrauterine influences on a developing fetus are generally well-known among the public [46]. Without knowledge about epigenetic influences, parents likely perceive there to be few mechanisms through which fathers’ preconception environment and behavior could influence the child, except as they relate to the mother. Following provision of epigenetics information, however, ratings of parental influence rose for both mothers and fathers with fathers’ influence ultimately equaling

Figure 3: comparison of parents with overweight and lean parents for Likert response items. For most survey questions, there was no difference between parents with overweight and lean parents. However, parents with overweight more often stated that learning about epigenetics made them feel like they could act for their child’s health ($t = 2.04, df = 144.12, P = 0.04$)

Figure 4: comparison of themes and guilt between parents with overweight and lean parents. Of 70 lean parents, 27 endorsed positive tone when answering free response questions. This was significantly higher than parents with overweight, where 11 of 92 total parents endorsed positive tone ($\chi^2 = 15.68, P < 0.0001$). Of 92 parents with overweight, 76 endorsed guilt about the effect their lifestyle may have had on their child’s epigenetics. This was significantly less than lean parents, 42 (of 70 total) of who expressed guilt ($\chi^2 = 10.27, P = 0.001$). There were no other significant differences between parents with overweight and lean parents.
mothers’. Presumably this occurred because epigenetics introduced a new mechanism through which fathers’ preconception behavior and environment could influence child health. Consistent with the heightened recognition of their role in conferring health risk to their children, most parents endorsed some level of guilt about the influence they may have had on their child’s health through epigenetic changes. These results are consistent with previous work demonstrating the significant role of parental guilt related to passing down genetic risk for health conditions [35, 36, 40]. Both conceptually and in previous work, guilt has been linked to behavior change such that individuals improve their behavior to alleviate the source of their guilt [47]. It may be the case that experiencing guilt due to epigenetic messages could reinforce parental behavior change. However, this is unlikely to happen if parents feel fatalistic, or feel unable to act to reduce the health threats caused by the epigenetic changes they passed down. It is therefore encouraging that we observed that most parents reported they ‘could’ take action to improve their own and their child’s health in the face of epigenetic mechanisms. This was particularly interesting because, while epigenetic changes also occur after birth, the module did not focus on these changes. Thus, it is possible that information about parental behavior as it relates to post-natal epigenetic changes may be additionally motivating for parents.

We anticipated that we might see differences based on parent gender because epigenetic information would introduce a new role for fathers in influencing child health prior to conception, and also because of gender differences in child care and responsibility [48–50]. We did observe some differences, though only on a few fronts. Namely, mothers more frequently discussed negative environmental factors, such as stress they had experienced, that may have impacted their child’s epigenetic markers. This could indicate that mothers are either more affected by environmental factors or more aware of how these influences are affecting them; e.g. women report being more affected by stress than men [51, 52]. Generally, the relative lack of observed differences provides preliminary evidence that future public health messages invoking epigenetics may be effective for both mothers and fathers.

Finally, we observed differences by parental weight status such that parents with overweight reported more guilt about the negative effects they may have had on their child’s epigenetic markers. Higher guilt among parents with overweight is consistent with a previous study which found that mothers who reported a higher body mass index endorsed more genetic-oriented guilt after receiving an obesity risk report for their children [40]. Weight status seems to play an important role in how parents’ process information related to genetics and health behavior [40, 53]. Importantly, although parents with overweight reported more guilt, they felt as able to take action for their child’s health after learning about epigenetics as lean parents. This suggests that these parents were not feeling fatalistic after viewing the information and may be receptive to messages prompting behavior change to improve their child’s health in the future. Interestingly, we also observed a pattern wherein lean parents felt more positively about epigenetics and the effect they may have had on their child’s epigenetics. Further research is needed to determine if this positive engagement encourages healthy behaviors (or the maintenance of them) or if parents are not focused on healthy behaviors because they feel like their children are protected from negative health outcomes due to epigenetics. These results suggest that future epigenetics messages may benefit from being tailored to parental weight status.

This study has several limitations. The first is that the epigenetics module presented to parents was simplified and general; it did not discuss all aspects of epigenetics; while this work was informative as an initial study of parent perspectives, our generalizability is limited. Additionally, while the information presented was simplified, it was likely more detailed content than parents would get from public health or clinical messages, which limits our ability to generalize these findings to other message contexts. Furthermore, this study occurred in the context of a larger study which focused on child feeding. Even though we did not observe differences by experimental group in the analyses presented herein, we cannot disentangle the priming effects that the primary study may have had on our participants. This is especially true given our lack of control group. However, health messages are likely to be delivered together in public health and clinical settings, so our participants received epigenetics information in a context that may be similar to that of the real world. Future work should establish the effect of epigenetic information when it stands on its own, as compared with a control group.

This study represents an initial step toward understanding mothers’ and fathers’ reactions to epigenetics educational material. However, follow-up research is needed to understand these responses in greater depth, including exploring factors that promote message acceptance and behavioral changes, while discouraging feelings of fatalism. Future work should further investigate the mechanisms by which epigenetics messages may successfully spur behavior change; for example, whether feelings of guilt lead to health-promoting behavior among parents. Furthermore, the positive emotions endorsed by lean parents need to be further studied to ensure that parents do not perceive positive preconception behaviors as protective against the effects of later, unhealthy behaviors as the child grows. If epigenetics messages do lead to positive behavior change, they could be leveraged to improve public health through educating current and future parents about how their behaviors and environments impact their children’s health. As concepts surrounding epigenetics continue to become more salient in educational, media, and medical contexts, it will be essential to understand whether and how we can leverage these concepts to positively affect parents’ health behaviors on behalf of their children, and the factors and mechanisms that may underlie the successful communication of such ideas.

Methods
Participants

This study included 190 parents (126 mothers) with a child between the ages of four and seven who was the participant’s biological child, lived with the participant at least part of the time, and who had no major dietary restrictions. Participants were recruited for a larger study focused on the impacts of health messaging on parental feeding behavior [54]. We excluded individuals wherein another household member or their child’s other biological parent had already participated in the study. See the primary outcome paper for full inclusion and exclusion criteria [54]. Participants were compensated $60 for their participation, and the Institutional Review Board at the National Human Genome Research Institute approved the protocol.
Table 2: description of closed response measures utilized in the study

| Measure name          | Question                                                                 | Responses                           |
|-----------------------|--------------------------------------------------------------------------|-------------------------------------|
| Perceived weight status | Which of the following best describes your weight right now?           | Underweight                        |
|                       |                                                                          | About right                         |
|                       |                                                                          | Overweight                          |
|                       |                                                                          | Very overweight                     |
| Act for my health     | To what extent did learning about epigenetics make you feel that there is action you can take to improve 'your' health? | 1–5 scale                           |
|                       |                                                                          | 1 = I feel a lot less able to take action to improve my health            |
|                       |                                                                          | 5 = I feel a lot more able to take action to improve my health.           |
| Act for my child’s health | To what extent did learning about epigenetics make you feel that there is action you can take to improve 'your child’s' health? | 1–5 scale                           |
|                       |                                                                          | 1 = I feel a lot less able to take action to improve my child’s health.   |
|                       |                                                                          | 5 = I feel a lot more able to take action to improve my child’s health.   |
| Impact of mother’s lifestyle | In your opinion, how important is a ‘mother’s’ lifestyle prior to a child’s birth in determining the overall health of the child throughout the child’s life? | 1–5 scale                           |
|                       |                                                                          | 1 = not at all                       |
|                       |                                                                          | 5 = extremely                        |
| Impact of father’s lifestyle | In your opinion, how important is a ‘father’s’ lifestyle prior to a child’s birth in determining the overall health of the child throughout the child’s life? | 1–5 scale                           |
|                       |                                                                          | 1 = not at all                       |
|                       |                                                                          | 5 = extremely                        |
| Guilt                 | To what extent did learning about epigenetics make you feel guilty about the influence your lifestyle may have had on your child’s health through epigenetic changes you passed down? | 1–5 scale                           |
|                       |                                                                          | 1 = not at all                       |
|                       |                                                                          | 5 = extremely                        |

Procedure

Participants were recruited for a study evaluating the interactive effects of emotional state and health messaging frameworks on parents’ food choice behavior [54]. As a part of this study, participants were consented online and filled out a baseline questionnaire online prior to coming into the National Institutes of Health campus for a lab visit. During the in-person lab visit, participants were re-consented and completed the first part of the study, wherein they were randomized to either a fear or anger emotion induction and to either a gain or loss-framed message focused on the importance of fruits and vegetables in a child’s diet. Participants then used a virtual reality buffet where they were instructed to create a lunch plate for their child. A final questionnaire followed. Aside from demographic items presented on the baseline questionnaire, none of the data for the current analysis were collected during these parts of the study.

The epigenetics module within this study is the focus of the current analysis. Following the tasks described earlier, participants completed a short questionnaire about their familiarity with epigenetics, viewed an educational video and slideshow about epigenetics concepts, and completed a post-educational materials questionnaire.

Epigenetics Module

The epigenetics educational materials consisted of a video created by MinuteEarth [55] and a slideshow created for this project (Supplementary Appendix SA). The video explains how the inheritance of acquired characteristics is possible through epigenetic processes which affect how genes are expressed. It utilizes the paternal inheritance of fear of the smell of acetophenones in rats [56], and the health effects of famine among human men on future generations in Overkalix, Sweden [57, 58] as illustrative examples of the effects of epigenetics on the inheritance of acquired characteristics.

Following the video, participants viewed a digital slideshow that reiterated the effect of changes in gene expression due to epigenetics, with a specific focus on the effects of maternal experiences on offspring (Supplementary Appendix SA). The slideshow reviewed the rat example from the video and discussed an example in humans where the children of mothers who experienced hardship during the 1998 Quebec ice storm had poor health outcomes later in life [59]. The end of the slideshow discussed how epigenetics has the potential to affect the participants’ children through parental exposure to factors such as smoking, chemicals, and poor nutrition.

Measures

Demographics

All demographic information was collected through self-report in the baseline questionnaire. Participants provided their gender, age, level of education completed, and census-category ethnicity and race. We also collected participants’ perceived weight status with one question (‘Which of the following best describes your weight right now?’, ‘Underweight’, ‘About right’, ‘Overweight’, ‘Very overweight’). In subsequent analyses, participants who responded Overweight or Very overweight were categorized as having overweight, and participants who responded ‘Underweight’ or ‘About right’ were categorized as lean.

Pre-Educational Measures

All questionnaire items were developed de novo for the purposes of this study as suitable measures did not exist. Prior to viewing the educational materials, participants were asked two yes-or-no questions: ‘Have you heard of the term epigenetics?’ and ‘Do you know what epigenetics means?’ If they answered ‘yes’ to the first question, participants were asked to provide context regarding where they had heard the term. If they answered ‘yes’ to the second question, participants were asked to define epigenetics in their own words. This free response item was double
Table 3: description of themes used in quantitative theme analysis*

| Theme name                        | Theme description                                                                 | Example quote                                                                 |
|-----------------------------------|-----------------------------------------------------------------------------------|-------------------------------------------------------------------------------|
| **Behavioral Influence—Positive** | Parent references his/her own behaviors which may have 'positively' impacted his/her child’s epigenetic markers | 'Improving diet and exercise during pregnancy (cut out sodas, added organic whole foods, prenatal yoga)' |
| **Behavioral Influence—Negative** | Parent references his/her own behaviors which may have 'negatively' impacted his/her child’s epigenetic markers | 'My eating habits are not good for [my child]'                               |
| **Environmental Influence—Positive** | Parent references his/her environment which may have 'positively' impacted his/her child’s epigenetic markers | 'I’m fortunate to have led a very low-stress life, so I suspect it’s benefitted him more than the average child' |
| **Environmental Influence—Negative** | Parent references his/her environment which may have 'negatively' impacted his/her child’s epigenetic markers | 'I was exposed to significant stress before pregnancy that I never thought would impact [my child] on a biological level.' |
| **Personal Fault**                | In addition to referencing his/her own behaviors which may have negatively impacted his/her child’s epigenetic markers, parents also take responsibility and express regret for these behaviors. | 'I allowed stress to impact my pregnancy. It would have been better to be in a better financial situation before having [my child] and be more focused on my overall health.' |
| **Positive Tone**                 | Parents utilized positive language and examples in their responses; Determined by examination of entire response as to whether parent felt positively about epigenetics. Tone did not require that parents discussed themselves specifically. | '[Epigenetics] means if we have good eating habits, the genes will read this information and pass through future generations, making them healthy people and with less chance to get obesity and all different kinds of diseases' |
| **Negative Tone**                 | Parents utilized negative language and examples in their responses; Determined by examination of entire response and determination as to whether parent felt negatively about epigenetics. Tone did not require that parents discussed themselves specifically. | 'Stressful periods, poor eating habits, alcohol - all seem like potentially negative impacts through epigenetic processes' |

*Each participant’s combined free response was coded for the presence of each theme. Behavioral Influences, Environmental Influences, and Personal Fault required that participants specifically referenced themselves or their child. Tone did not require the specific reference to the self or child.

coded by trained coders to determine if the participant’s definition of epigenetics was accurate ($\kappa = 0.88$). In total 52% of the free response dataset was double coded; the remainder of the data was single coded once coders had reached sufficient agreement. Participants who correctly defined the term were considered to have a prior knowledge of epigenetics. Participants also responded to questions assessing their thoughts regarding the impact of mothers’ and fathers’ preconception lifestyle on children’s health (Table 2).

**Post-Educational Measures**

Following the educational materials, participants again answered the two questions about the importance of a mother’s and a father’s lifestyle prior to a child’s birth. In later analyses, we computed the difference between the pre-education score and the post-education score for each of these questions by subtracting the pre-education score from the post-education score. Participants also answered questions regarding whether learning about epigenetics made them feel they could act for their own or their child’s health (Table 2). We also assessed guilt with one question (Table 2). In later analyses, we dichotomized participants into two groups based on this question: the first group did not report any guilt (response = 1) and the other group indicated some level of guilt (response > 1), as the scale responses were not normally distributed, displaying a skewness of 0.34 and kurtosis of -0.84. Finally, participants responded to two open-ended questions: ‘Please describe what you think epigenetics might mean for your own children and family’ and ‘What are some specific ways in which your lifestyle and/or environment could impact your child’s health through epigenetic processes?’

**Data Analysis**

The two post-educational module free-response questions were combined into one response per participant and coded for themes by two independent trained coders. Responses were coded for the following content: parent behavioral influences on child’s epigenetic markers (positive and negative), environmental influences on the parent which may have impacted the child’s epigenetic markers (positive and negative), personal fault, positive tone, and negative tone; see Table 3 for details. Each item was coded dichotomously as present (i.e., mentioned by the parent) or not present (i.e., not mentioned by the parent). In some cases, both positive and negative content were coded as present (i.e., the parent mentioned a positive behavioral influence and a negative behavioral influence). After double coding 50% of the data, each theme yielded a minimum kappa of 0.64, indicating sufficient agreement between coders. The remaining 50% of the data was single coded.

The t-tests were used to compare Likert-scale questions. Chi-squared tests or Fisher’s exact tests were used to compare themes from quantitative content analysis and guilt. To determine the need for covariates in later analyses, t- and chi-squared tests were used to compare demographics and close-ended measures across gender and weight status groups. No significant demographic differences emerged across either group type. Thus, no demographic variables were included in subsequent analyses. Additionally, when included in later analyses,
experimental condition was a non-significant covariate and did not change the nature of other relationships, and thus is not included in results below. Participant gender and perceived weight status were assessed as potential moderators of relationships. A false discovery rate of 10% was used to assess significance [60]. The P-values ≤ 0.02 were considered significant.

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Supplementary data

Supplementary data are available at EnuEpig online.

Conflict of interest statement. None declared.

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