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Impact of Educational Neuroscience Teacher Professional Development: Perceptions of School Personnel

*Maryam Hachem, Katarina Daignault and Gabrielle Wilcox**

Werklund School of Education, University of Calgary, Calgary, AB, Canada

There has been an increased focus on the importance of educational cognitive neuroscience for teachers, yet the research on the outcomes of teacher training in this area are minimal. We created and implemented an Educational Neuroscience professional development (PD) delivered throughout the 2020–2021 school year. This study was co-designed between researchers and school district partners. Participants were school personnel from a high school in Western Canada consisting of approximately 1,400 students and 75 teachers. All participants in the PD, including teachers and school staff, were invited to participate in interviews about their experiences during the PD. Seven in-depth structured interviews were performed to understand participants' experiences, their perceptions of the value of educational neuroscience, and how the PD impacted their teaching practice. Through inductive coding and thematic analysis, we found that the PD had a positive impact on participants and their students. The sessions primarily increased participants' knowledge of neuroscience concepts and provided them with practical and useful applications that they were able to employ in their classrooms in areas related to lesson planning, assessment, and student engagement. Participants described the remarkable impact that increased neuroscience knowledge had on their relationships with students and on students' own understandings of neuroscience concepts. Overall, these findings provide further evidence on the significance of infusing educational neuroscience in teacher PD and highlight the importance of collaborative programs between researchers and educators to bridge the research to practice gap.

Keywords: educational neuroscience, professional development, thematic analysis, student engagement, teacher-student relationship

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Brian Rivera,
University of Alabama, United States

***Correspondence:**
Gabrielle Wilcox
gwilcox@ucalgary.ca

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INTRODUCTION

Educational Neuroscience is an interdisciplinary field of research that draws on neuroscience in the aim of translating their findings to educational practice and policy (Campbell, 2011; Thomas et al., 2019). Due to the high relevance of neuroscience to teaching practice, teachers have been seeking access to information about brain development and functioning that they can use to inform their practice and better support their increasingly diverse students (Goswami, 2006; Howard-Jones et al., 2016). The term cognitive educational neuroscience acknowledges the role of cognitive and educational psychology in understanding and applying neuroscience in classrooms

(Mason, 2009; Wilcox et al., 2021). However, teachers have limited access to reputable information, which results in neuromyths infiltrating education systems (Fischer et al., 2010). Training teachers is more efficient in supporting student success than providing interventions directly to students as teachers can use knowledge and skills gained to support students in their classrooms in an ongoing basis.

Previous efforts have been made to test the effectiveness of integrating neuroscience into teacher professional development (PD), and the results have been promising. Including neuroscience in teacher education programs may improve the quality of learning and promote equity among learners (Coch, 2018). Presenting teachers with new perspectives and providing them with access to accurate scientific knowledge along with practical applications of that knowledge has the power to reshape educational practices by facilitating the use of research-informed strategies and preventing the spread of neuromyths (Fischer et al., 2010; Wilcox et al., 2021). The idea of neuroplasticity, which highlights the complexity of the brain and the connections that rewire on a daily basis as a result of learning, is a key concept that can significantly enhance teaching and learning. Neuroplasticity has been the main theme in previous teacher neuroscience PD efforts. For example, Dubinsky et al. (2013) implemented a series of workshops with a neuroscience course tailored for teachers called BrainU (MacNabb et al., 2000). The workshops aimed to get a better view of how neuroscience can be meaningfully integrated into pre-service teacher preparation to improve their pedagogy. In this study, participating teachers engaged in inquiry-based experiences focused on the concept of neuroplasticity. Assessments showed that teachers were actively engaged and demonstrated increased competency and confidence as well as improved pedagogical practices in the classroom. Participating teachers were more self-aware of the impact of their teaching behaviors on students' brains as students constructed their own knowledge (Dubinsky et al., 2013). Overall, the researchers suggested that neuroplasticity, along with other neuroscience concepts, can potentially motivate teachers and their students to actively participate in the learning process and that infusing neuroscience content into teacher training is promising, but it will require communication between experts of both fields of neuroscience and education for it to be effective (Dubinsky et al., 2013).

Furthermore, Dekker and Jolles (2015) evaluated a model that integrated neuroscience into the biology curriculum. Their study aimed to evaluate a teaching module: "Brain and Learning" in terms of its effect on the knowledge of high school biology teachers and students on brain functions and brain development. The module included lessons about brain processes underlying learning, neuropsychological development during adolescence, and lifestyle factors that influence learning performance (Dekker and Jolles, 2015). Results showed that teachers answered significantly more questions correctly after the module than before it. With respect to students, the model helped them become aware of the concept of neuroplasticity and how experience shapes the brain. Results of this study showed that both teachers' and students' knowledge of brain functions and development significantly improved and that the teaching module promoted a strong incremental theory of intelligence in students. Both of these studies demonstrate that when teachers gain an understanding of brain development and the role of neuroplasticity in learning, it positively impacts their knowledge and pedagogy.

Overall, neuroscience courses for teachers can improve pedagogy and knowledge of the brain which, in turn, empowers teachers to meet diverse learner needs (Walker et al., 2019) and equips teachers with tools to help to increase student motivation and engagement (Dubinsky et al., 2019). While there has been an increased focus on the importance of educational cognitive neuroscience, the research on the outcomes of teacher training in this area is minimal. The purpose of this study is to examine the impact of a novel educational neuroscience professional development program on teachers' understanding of neuroscience knowledge and on their teaching practice.

In the current study, we created and implemented an Educational Neuroscience professional development throughout the 2020–2021 school year. Participants were high school teachers from a high school in a large city in Western Canada. The school has approximately 1,400 students and 75 teachers. The aims of the larger study were to assess the impact of educational cognitive neuroscience professional development on teacher endorsement of neuromyths, on teacher and student reports of school climate and mental health, teacher self-efficacy and teacher perceptions of the professional development, and student executive functioning and academic motivation and engagement. The part of the study presented here includes teachers and other school personnel who participated in interviews that followed the professional development. Through the interviews teachers reflected on the impacts of the professional development on themselves and the observed impacts on their students.

This study was initiated by school district personnel and collaboratively designed by academics in neuroscience, school psychology, and school district partners, laying a foundation for continued collaboration. School personnel identified areas of they wanted more information on, and the research team designed the PD to cover those topics This is an innovative approach that addresses a major criticism in educational neuroscience research—the research to practice gap, as the research addressed concerns from school practitioners rather than only researcher interest. While this is one of the main premises of educational neuroscience, there is little evidence that this collaboration between experts of the different fields occurs. This collaboration will help reduce the isolation of the fields (i.e., neuroscience, psychology, and education) and promote collaborative efforts to better understand teachers' perceptions of the impact of training in the area of educational cognitive neuroscience on high school

teachers' knowledge, changes to their pedagogy, and impacts on their students.

AIM

In recent years, there has been an increased focus on the importance of educational cognitive neuroscience; however, there has been little research on the outcomes of in-service teacher training in the area. The purpose of this study is to examine the perceptions of teachers and school personnel who participated in the Educational Neuroscience PD program relating to the PD and how it may have shaped their views around educational neuroscience and impacted their teaching practice. This will help provide future directions for similar PD programs and will highlight key areas in which educational neuroscience PD has the highest impact and/or areas that could be further developed. With a focus on teachers' experiences, this research study will address the following question:

> How did teachers' experiences of the educational neuroscience professional development and their associated perceptions of the value of educational neuroscience impact their teaching practice?

MATERIALS AND METHODS

This was part of a larger research study examining the impact of educational neuroscience PD on both teachers and students, with quantitative data comparing students and teachers from the school that received PD and a control school in the same district with a similar demographic makeup. Both schools were in a large, urban school district in Western Canada. There were 490 students and 115 teachers involved in the larger study. All teachers from the school receiving PD (N = 75) were invited to participate in the interviews at the end of the PD provided which coincided with the end of the school year.

The research team created the professional development for the high school delivered over the course of the school year with input from school staff on important topics to cover, as well as areas to measure in the larger study (e.g., mental health, school climate, and teacher self-efficacy). There were two reasons that we worked with high schools for this project. First, the principal of a high school initiated the research because he saw understanding of educational neuroscience to be important for teachers. Second, adolescents experience significant changes that affect their learning and behavior, making it an important age group for teachers to understand the underlying reasons for those behaviors in order to support students effectively. This research on the developing brain also informed PD content in conjunction with teacher input.

School administrators were the intermediary asking teachers for topics they were interested in and passing that on to the research team. In this sense, the design and structure of the PD was meant to be empowering for teachers. Additionally, school administrators were collaborators on the grant funding the larger study. There were a total of nine sessions that were between one and one-and-a-half hours long covering topics relevant for high school: (a) introduction to educational neuroscience, (b) introduction to the brain, (c) learning and memory, (d) assessment and homework, (e) technology, (f) executive functioning and mental health, (g) risk-taking, (h) relationships, and (i) sleep. As part of each session, teachers were provided with a list of additional resources to dig deeper into the topic including books, videos, and websites. The PD sessions spanned the school year, but each one was time limited, which could lead to shallow information. We attempted to combat this by providing the additional resources, providing examples of application in school settings, pointing out common neuromyths, and revisiting previous concepts in other sessions as relevant.

These professional development sessions were designed in line with literature on what constitutes effective teacher professional development including application to practice through examples and opportunities to apply in their own classrooms, incorporation of collaboration with peers, support from the research team, opportunities for reflection, and sustained duration throughout the school year (Darling-Hammond et al., 2017). However, due to COVID-19 restrictions, most sessions were moved to an online platform, Zoom, which reduced the quality of the peer collaboration during the sessions. Additionally, the demands on teachers during this time were high, and, as a result, teachers did not take the opportunity of additional support the research team offered (e.g., problem-solving meetings).

At the end of the school year, after all sessions were completed, all teachers were invited to participate in interviews about their experiences during the year of educational neuroscience professional development. In-depth individual interviews were performed with seven participating teachers in the educational neuroscience PD sessions. Interviews were structured and took place virtually over Zoom and lasted approximately an hour each. Zoom-recorded interview sessions were transcribed by two research assistants. Interview transcripts were then imported into NVivo for the coding process. Through inductive coding and the constant comparative method, the list of codes was generated from the transcripts. Thematic analysis (Braun and Clarke, 2012, 2021; Clarke and Braun, 2017) was performed to identify the main themes that have emerged. The coding and analysis process was performed over two rounds to ensure validity and reliability of the process.

Our goal was to analyze for meaning across the entire data set and to identify meaningful patterns of shared experiences across participants. As generating codes is an essential step prior to identifying themes, inductive coding and the constant comparative method were used for the coding process. Inductive coding aims to explore the data

and identify emerging themes, ideas or concepts from the data (Thomas, 2006). It does not start with a predetermined set of codes but rather the codes are derived from the dataset, as opposed to deductive coding which starts off with a predetermined structure and a defined set of codes. The constant comparative method (Glaser and Strauss, 1967; Taylor and Bogdan, 1998) was performed by constantly coding the collected data while comparing it with other data and categorizing the codes into categories of description. The categories were then analyzed to identify any patterns among the categories and the data overall. Following the coding process, themes were actively searched for and identified through reorganizing or clustering codes that seem to share common features such that they reflect and describe coherent and meaningful patterns in the data (Braun and Clarke, 2012, 2021; Clarke and Braun, 2017).

RESULTS

Participants were asked about their school experiences in general, what they found beneficial in the Educational Neuroscience PD sessions, how the sessions have impacted their knowledge and views of educational neuroscience, how they applied what they have learned in their teaching practice, how the sessions have impacted their students, and their thoughts about the relationship between researchers and educators. Participants' current roles included teaching, leadership, and/or administration. For participants who are currently teaching or who have taught in the past, teaching experiences ranged from 9 to 20+ years. Subjects that have been taught by participating teachers include language arts, film and media arts, math, science, and physics.

Through coding the interview transcripts based on the topics discussed in the interviews, the coding resulted in many categories of description. When reorganizing and reanalyzing these categories into more specific themes, we found that the following primary themes as best captured the essence of our data: Deeper Neuroscience Knowledge, Enhanced Teaching Practice, Stronger Teacher-Student Relationships, Increased Student Engagement and Meaningful Learning, and Teacher-Researcher Collaboration (**Table 1**). Additionally, since participants were asked about their experiences during this school year, and given the PD sessions occurred during the pandemic, a COVID-19-related theme emerged across the interviews.

Deeper Neuroscience Knowledge

A prominent theme across the cases was deeper neuroscience knowledge. Some participants indicated having prior knowledge about the brain, while others were new neuroscience perspectives. In either case, participants agreed that the PD refined prior neuroscience knowledge, reinforced ideas and strategies that they have already known and applied in their classrooms (e.g., about retrieval practice, assessment, and lesson plan design) and provided them with an opportunity to learn and explore a variety of new ideas. They expressed that the PD helped normalize the use of neuroscientific terms among teachers and staff. More specifically, teachers indicated deeper neuroscience knowledge in areas related to lifestyle, instruction, assessment, lesson planning, and relationships with students. For example, teachers highlighted the importance of concepts like neuroplasticity and effort, retrieval practice, attention and retention and the implications of that for their lesson plan design. Examples on neuroscience concepts that participants were influenced by are represented in the interview quotes below:

> "It was something to do with, like, kids are only gonna remember the first, like, you know, 5–10 min of class really well. Like, that's the easiest for them to, um, like, internalize, and then the last few minutes as well" (Participant 2).

> "Understanding that it is – it is okay to challenge them – themselves and if they try hard and they make these new connections, and they'll get better and they're – they'll be more resilient and they will face things differently and everything" (Participant 5).

> "... like, the idea of understanding learning and memory certainly can drive how a lesson plan is structured in terms of what you cover first knowing how student engagement varies" (Participant 7).

Additionally, teachers communicated that the neuroscience knowledge they gained helped them feel better equipped

TABLE 1 | Resulting themes of thematic analysis.

Theme	Description
1. Deeper Neuroscience Knowledge	This theme reflects participants' descriptions of new knowledge they have gained through the educational neuroscience PD training as well as previous knowledge that was reinforced or modified
2. Enhanced Teaching Practice	This theme consists of evidence on teachers' enhanced teaching practices and how the training has impacted their views on teaching and/or has practically helped improve their teaching strategies
3. Stronger Teacher-Student Relationships	This theme encompasses participants' discussions on the impact that the PD had on their relationships with their students. It specifically captures the positive changes that teachers have witnessed with this relationship
4. Increased Student Engagement and Meaningful Learning	This theme reflects evidence on increased student engagement that participants' have linked to their educational neuroscience training through the PD sessions. It also consists of evidence on more meaningful learning that teachers witnessed in their classrooms
5. Teacher-Researcher Collaboration	This theme captures participants' views on the teacher-researcher collaboration and how that may benefit their teaching practice

to deal with students who experienced trauma and anxiety and to connect with students in general. Having a stronger rationale for their practices informed by neuroscience and communicating that to students helped enhance their perceptions of the effectiveness of those practices. Teachers also indicated increased student receptivity to those practices. Teachers also felt more confident in their teaching. Teachers explained that more knowledge about educational neuroscience and experience greatly contributes to their self-efficacy beliefs. They described having stronger self-efficacy beliefs and confidence in their teaching, which, in turn, made them feel more effective and reduced their stress. Therefore, having stronger educational neuroscience knowledge and awareness of research-informed teaching and learning practices is an important way of boosting teachers' self-efficacy beliefs.

Enhanced Teaching Practice

The second theme was related more directly to teacher practice. Teachers discussed multiple benefits that the PD sessions had on their teaching practice including reinforcing their existing knowledge and practices, refining prior inaccurate knowledge, providing practical and concrete knowledge which is easily applicable to the classroom, providing new tools to implement, and equipping them with research-informed ways to teach and deal with students. Participants highlighted some changes that they have made to their teaching based on the neuroscience knowledge that they have gained. This included focusing on effort and meaningful learning rather than grades, using assessment practices that are more representative of student's learning (e.g., using more formative assessments, modifying assessments based on factors like language, culture, emotional regulation abilities, experiences, moving away from homework as an assessment, and adding elements of challenge), encouraging students to make healthy lifestyle choices (e.g., related to sleep, diet, and technology), and being more intentional in applying with neuroscientific findings related to attention and focus (e.g., starting with the new information and ending with a recap) during lesson planning process.

Furthermore, the communication aspect between teachers and students was a main point that was highlighted throughout this theme. Communicating accurate information to students and to peers or staff was one of the main impacts that participants emphasized. Participants voiced that this aspect empowered them as they felt confident enough to explain neuroscientific terms and concepts accurately. Finally, teachers reflected on the potential for evolving as a professional through the PD sessions, not only as teachers but also as learners. They shared that the PD had an impact on self-monitoring their own learning and self-evaluating their learning outcomes. Specifically, they indicated that the sessions prompted them to focus on specific areas of interest within the large spectrum of new knowledge, to keep track of their goal progress and achievement, and to constantly think of ways to improve their teaching practices while keeping in mind the "bigger picture," that is, students as a whole (their academics, emotions, lifestyle, and experiences). For example, here's how participants 1 and 2 described this:

> It goes back to the different childhood experiences and along the way and do these kids have supports in place that can still help them get through if they've gone through a lot of adversity and things like that. I think kids – yeah, if you have a knowledge about a lot of this then it could be a way of how you interact with some of these kids, or, well, all of them, right? They're not just all the same (Participant 1).

> "It probably made them [teachers] more cognizant of what they have to pay attention to, how they ha – how they have to maybe worry about the bigger piece of the kid rather than just the, like, academic side" (Participant 2).

Stronger Teacher-Student Relationships

Participants collectively agreed that gaining a deeper understanding of neuroscience concepts supported their application of the new approaches they learned through the PD sessions and in strengthening their relationships with their students. Teachers communicated having a better understanding of students and what they are going through during adolescence including that every student is different and has unique needs and experiences which can be enhanced by effective relationship development. Participants reflected on the challenges of dealing with this particular age group, that is, adolescence, and how relationships are particularly important in this phase:

> "I think it's extremely important to, you know, how can I take things from, um, you know, from this research and – and information and how can I make my relationships better with the people that come my way, you know? How do I not get triggered and just reminding myself [laughs] this is part of the journey for a lot of these kids, right?" (Participant 1).

> "It gives you a better understanding of what they're actually, uh, thinking, feeling, how hormones are playing into it, what's – what's going on" (Participant 2).

> "Whether it's a comfort level or even a discomfort about who they are, or what they're learning, or how they learn, that so long as you can mine deeper into that with the students then it's better for the working relationship between the two" (Participant 3).

Teachers noted that they shared their learning with students, encouraging students to be more mindful of the neuroscience information they learned, like how the brain functions, the importance of organizing and planning and their ability to improve their executive functioning skills, the difference between multitasking and task-switching, how to make use of retrieval practice, and how to be in control of their own learning. Teachers established efficient and transparent communication, thus, a stronger connection with their students. Teachers also noted that students gained a better understanding of themselves, and as a result, teachers noticed shifts in students' behaviors. Overall, this supported fostering a positive and relaxed environment in the classroom supporting strong relationships between teachers and students. Participant 4 described fostering this type of environment in his classroom:

"Just to keep everybody, I want to say calmer and more relaxed, even though it's a subject that's new or it's not comfortable. There's something brand new and scaring them a bit, just keep everybody calm and then we can go through – we can get through it" (Participant 4).

Increased Student Engagement and Meaningful Learning

Teachers were asked if they noticed any impacts or changes in students after applying knowledge from the Educational Neuroscience PD sessions. Teachers reported that, according to their observation and assessment, students were more engaged in learning and demonstrated increased independence in their learning. Sharing neuroscience knowledge with their students prompted reflective discussions about the learning process, about themselves as learners, and about their life in general. Discussions related to cognitive neuroscience (e.g., executive functioning, multitasking vs. task-switching, and retrieval practice) and the impacts of technology on their functioning and learning particularly impacted students. For example, after becoming aware of the impacts of technology on their brain, a group of students shared with their teacher some of their daily life changes with regards to technology and how they now try harder to overcome the temptation of using their devices constantly. Another participant described her students as becoming more aware of neuroscience concepts in their daily lives and demonstrating their understanding of them through their explanations. She also described her students as becoming more aware of their own struggles:

". . . and they say, "oh, this is this, and this is when you're able to bounce back and go and try again and do this." And I – I feel so happy when I hear them that they can explain the others and – and they have – they caught it and – so, no it – it – definitely, I – I can see them, not all of them, of course, but many of them being more aware – more aware, eh, of the – of their struggles" (Participant 5).

Teachers also reported that their students were meeting different challenges and growing on a personal level, showing stronger executive functioning skills, stronger reasoning skills, and more meaningful learning overall with more emphasis on deep understanding rather than solely on grades. Examples from participant transcripts are presented below:

"... to help them to organize and – and to better, eh – eh, manage themselves in the use of all this, eh, structured, em, charts and – and checklists and all this, eh, will actually teach them how to better function, that it helped their executive function" (Participant 5).

"Getting them to recognize the value of doing it, not because it's an item in a grade book, but because it in fact actually helps them understand what they're doing and be able to be successful" (Participant 7).

"I think just by observation you can see how they're – they're um growing as a person, um, how they're meeting the different challenges, um, how they're responding, and some of them may be even just talking about it more, the communication piece could just be a big part of it" (Participant 1).

Teacher-Researcher Collaboration

When asked about the importance of a dialogue between neuroscientists and educators, participants stressed that having an active dialogue and maintaining a teacher-researcher collaborative relationship is essential. Particularly, participants explained that such a collaboration is important to maintain a connection between theory and practice and is an essential feedback loop between teachers and neuroscientists. It also helps fill in the neuroscience gap in teacher training and research evidence for instructional strategies. Through this part of the interviews, teachers expressed the importance of access to relevant research and resources and obtaining research-informed answers to their questions:

"You guys are the ones that are doing the background research, the educators are basically the on the frontline people. . . I think this collaboration is always really powerful" (Participant 1).

"They [the neuroscientific terms] could be complicated and they could be hard to understand. So, the more simple and accessible it's made, then we will be able to apply it better" (Participant 5).

This opens up that, like, opportunity for that communication with a neuroscientist who has more of that knowledge. Like, I'm sure, like, if I really could be like, "hey guys, like, I want to learn more about the relationship piece than what I felt like I got out of it and, you know, that's something I'm really interested in." So, like, "how – where should I look?": Or, you know, it's like, you know, "how could I get started?" Or, "could you send me some articles or something?"... Until we know how that's going to look, like, this is something you can actually do in your classroom, or, these are things that other people have done – without that it's – all it is research, it's not in practice (Participant 7).

COVID-19 Impact

Aside from the themes related to the educational neuroscience content of the PD sessions, a theme on the impact of COVID-19 was evident across all interviews. The COVID-19 pandemic had significant impact on participants during the time of these PD sessions. The majority of participants indicated experiencing stress due to the COVID-19 pandemic, specifically feelings of fear and worry, overwhelm, uncertainty, and exhaustion, especially due to the lack of normalcy and the stress of applying changing health restrictions. These were challenges experienced by both teachers and students, as reflected upon by participants 1 and 4:

"I think I feel, like, more tired than anything. Sometimes it's just being the overwhelmed– how do you keep up with things? Lots of kids. . . they were struggling. Then there's some things on the home front that you are dealing with" (Participant 1).

"Living everyday as if you are not coming back for the next 2 weeks. . . Uncertainty for me, uncertainty for the kids. Who is going to be there tomorrow?... just the lack of stability" (Participant 4).

Having the sessions moved to an online format posed further challenges for the participants, reducing connection and collaboration with their colleagues. Additionally, moving the PD online impeded their ability to work in groups with teachers of similar backgrounds, interests, and readiness to learn

neuroscientific content. Teachers indicated preferring in-person meetings which provide more social interactions as that would have increased their motivation and engagement. Furthermore, the fact that these sessions happened during the pandemic reduced teachers' motivation and engagement as they were already in the challenging phase of adjusting to online teaching and to all the daily life changes that came with the pandemic.

DISCUSSION

Participant responses indicated that Educational Neuroscience PD sessions had a positive impact on them. The sessions primarily increased participants' knowledge of neuroscience concepts and, more importantly, provided them with practical and useful applications that they were able to employ in their classrooms. Participants also reported positive changes in their students. Supporting teachers to better meet the needs of students was a main area that this study aimed to address. It was evident through participants' discourse the impact increased neuroscience knowledge had on their relationships with students and on students' own understandings of neuroscience concepts and how to control their own learning. Teachers reported noticing changes in their students' engagement and academic performance. Specifically, teachers reported noticing increased student engagement in learning, more meaningful learning experiences, and academic and personal growth. This is an important outcome of this PD which further supports infusing educational neuroscience in teacher PD programs.

Participants' reflections, although anecdotal, are powerful in revealing the importance of enhancing teaching practices, providing meaningful learning experiences, and strengthening teacher-student relationships. Participants voiced the importance of learning about cognitive neuroscience for teachers and their students and the positive impacts that has on lesson planning, lesson delivery, assessment, student engagement, and the teacher-student relationship. Teachers indicated their knowledge of the brain increased their ability to be understanding and empathetic toward students' diverse needs and behaviors. They understood better the variety of influences in the students' environments that may impact their learning (including stress, diet, sleep…. etc.). Furthermore, being able to provide a rationale and scientific explanation for why certain practices were useful for their learning seemed to make teachers feel empowered and increased their self-efficacy. Strong teacher self-efficacy has demonstrated positive relationships to wellbeing, learning, achievement, and more, for both teachers and students alike (Zee and Kooman, 2016). This further reinforces the value of educational neuroscience PD for teachers, our study indicated that the PD filled existing gaps in teacher knowledge, reinforced existing practices, and taught new skills and approaches to teachers, all of which benefited their self-efficacy. As teachers continue to seek stronger understandings of neuroscience, it is essential that they have access to reputable information to inform their practices, rather than misinformation that could be misleading at best, or damaging to their self-efficacy at worst (Dekker and Jolles, 2015; Coch, 2018).

Further investigations into the level of the impact and benefit that the PD had on teachers and students will be required. Completing these sessions during normal circumstances, that is, not during a pandemic, would allow PD that more closely follows strong PD guidelines. For example, ongoing reflection and monitoring of the impact of the PD on teachers' practice would be possible rather than solely retrospectively addressing it. Furthermore, teachers would be able to apply the practices informed by neuroscience more directly in their classrooms, rather than virtually, and witnessing their students' responses and interactions in real time.

CONCLUSION

This study helps to begin to address concerns about the disparity between neuroscience and education. Being a co-designed study between researchers in neuroscience and school psychology and school district partners, this study will help move educational neuroscience forward, by providing school personnel identified as useful in informing their practice in order to begin bridging the research to practice gap. It begins to address gaps in the current educational neuroscience literature by collaboratively designing training content and delivery for high school teachers and measuring the impact of the training on both teachers and students. There is increasing diversity in schools and continued calls to better meet both the academic and mental health needs of students. By addressing teachers, who have a broad reaching impact on students, our aim was to contribute to understanding how training teachers to understand adolescent brain and cognitive development can positively impact both teachers and students. Findings of this study show that the PD sessions impacted teachers' perceptions of their knowledge and understanding of the brain and as a result had a noticeable impact on their perceptions of their teaching practice. Teachers reported modifying their instruction and practiced applying new strategies informed by neuroscience and were able to witness changes in their students' engagement and overall performance in different academic subjects.

On the other hand, some limitations of this study include switching to a fully online platform after the first two sessions, due to the pandemic, which may have negatively impacted social interactions and teachers' engagement in the PD sessions. Teachers reported going through a stressful year which may have impacted their ability to apply the knowledge they learned during the PD sessions in their teaching practice and likely negatively impacted the number of teachers who chose to participate in the study. Collectively, these factors, in addition

to the interviews occurring at the end of the school year when many teachers are exhausted, may have contributed to the low number of participants in the interviews, contrary to our original expectations when designing the study. Another limitation of this study, common in qualitative studies, is that we were not able to ensure that there no other experience or previous knowledge of topics affected their experiences. Finally, it is possible that teachers who chose to participate in the study represent those who were more interested in the topic or who found it valuable. Consequently, those who did not value the PD or who did not find it valuable may have chosen not to participate and were not represented. Relatedly, this was an area of special interest to the principal of the school, who initiated the research project, so it may not have represented the interests of all participants.

There is support for the role of cognitive educational neuroscience; however, it requires continued research to continue to refine our understanding on specific areas that are transferable and to understand which information and strategies are actually effective in classrooms (Perry et al., 2021). Without this nuanced understanding, educators may apply strategies that are ineffective in real classrooms, even if they have demonstrated efficacy in research settings. Future collaborative programs which provide a means of collaboration between scientists and teacher educators will help translate and disseminate neuroscience and neuropsychological findings to broader audiences of educators, who have the capacity to support large numbers of students by applying this knowledge in their classrooms. Future research can increase the directness of researcher-teacher collaboration by directly engaging with teachers rather than using administrators as intermediaries. Interdisciplinary work can also support the translation of this knowledge to improve outcomes for students, while decreasing misinformation and increasing judiciously applied knowledge in school settings.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because they include potentially identifiable interview data. Requests to access the datasets should be directed to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the University of Calgary Conjoint Faculties Research Ethics Board. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MH completed the first round of coding, analyzed the data, extracted the main themes, and prepared the drafts of the manuscript. KD and GW completed the second round of coding. GW designed and implemented the study, supervised the work, verified the methods and findings, and revised the first and final draft of the manuscript. KD contributed to the revisions of the manuscript. All authors discussed the results, contributed to the final manuscript before the submission, and read and agreed to the published version of the manuscript.

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