Elementary Teacher Perceptions of Professional Development on the Neuroscience of Learning

Wendy Bana
Laguna Beach, CA

Jeff Cranmore
Grand Canyon University

The purpose of this qualitative case study was to explore how knowledge on the neuroscience of learning may inform the practice of teaching and classroom instruction. Twelve purposively selected elementary teachers from a private school in California were asked about their perceptions of the nature of a professional development (PD) course on the neuroscience of learning and also their perceptions of the influence such training had on their practice. The conceptual framework for this study was Desimone and Garet's (2015) model of effective professional development. Themes from semi structured interviews, focus groups, and observations of the teacher participants were identified using thematic analysis. The themes identified were: (a) the structure of PD is critical to its success, (b) follow up to PD is critical to implementation of training, (c) neuroscience of learning PD is beneficial for elementary teachers, and (d) effective PD on the neuroscience of learning needs certain components. This study elucidates considerations for stakeholders in creating effective PD neuroscience courses.

Introduction

Research on brain development and its role in the learning process has expanded considerably in the last decades. The findings from this research are potentially guiding education research and practice (Anderson, 2014; Degen, 2014; Dubinsky, Roehrig, & Varma, 2013; Nouri, 2016), and forging greater connections between the fields of education and cognitive neuroscience (Ansari, Coch, & De Smedt, 2011). Consequently, great hopes for the application of findings from human brain empirical research on educational problems have been raised (Ansari et al., 2011; Flogie & Aberšek, 2015; Knowland & Thomas, 2014; Nouri, 2016). Analyzing how the brain works during processes of thinking and understanding can provide insight for the learning process itself for teachers (Kennedy, 2006) and facilitate the creation of optimal educational environments (Aberšek, 2015; Schrag, 2013; Stein & Fischer, 2011).

From a historical perspective, the growth of knowledge from the field of neuroscience has exploded in the last several decades (Conyers, 2017; De Vos, 2015). Now, more is understood about the neurological underpinnings to how humans learn (Conyers, 2017; Stiles & Jernigan, 2010). Additionally, the collective knowledge base on how people solve problems, develop beliefs about their learning, and think metacognitively provides valuable insights into what makes efficacious learning environments (Cromley, 2000).

If the brain is the organ of learning, logic suggests that understanding how it works could then inform the field of education and ultimately transform classrooms (Ansari et al., 2011). Hohnen

and Murphy (2016) contended that teachers with knowledge of brain development could work with students more efficiently, develop more informed lessons and assessments, and consequently, increase student learning and achievement. As Sneyers, Jacobs, and Struyf (2016) contended, neuroscience knowledge can help detail the brain's processes during learning, and with the advancements in neuroimaging over the past several decades, this knowledge can foster a deeper understanding of a number of conditions students may endure (Shyman, 2017).

An example of one aspect of learning that neuroscience has helped educators better understand is attention. Research has shown that capturing student attention is foremost in the instructional process. Piquing students' interests, for example by showing an entertaining video as students enter the classroom, helps them be more likely motivated to pay attention to what happens next. Another example is the use of rubrics for assignments that students can reference while working. Rubrics are consistent with neuroscience research and can increase successful learning by motivating sustained effort towards goals and providing formative feedback (Willis, 2010). Furthermore, information is stored in the brain in complex networks and not just as a single fact (Cromley, 2000). With the knowledge, teachers can purposefully develop opportunities to make multiple connections among information for deeper learning. The two big concepts underlying the neuroscience of learning important to teachers is that the brain functions to promote survival and in accomplishing this, the brain has evolved to seek patterns and pleasure (Willis, 2010).

Incorporating neuroscience into teacher preparation could facilitate teachers' understanding of child development, the progression of learning, and the biological constraints for the learning processes (Ansari et al., 2011; Degen, 2014; Smith, 2015). While the link between student achievement and teacher preparedness is recognized, also recognized is that teachers often enter the profession unprepared (Bayar, 2014). For the profession overall, there exists a discrepancy between what teachers know about the neuroscience of learning and what the field of neuroscience understands.

One potential means of infusing knowledge on the neuroscience of learning into the practice of current teachers is through teacher professional development (PD). PD is a common means for filling such voids (Bayar, 2014) and is supported by research as the catalyst for the professionalization of teaching (Ankrum, 2016), as well as facilitating teacher knowledge of the most current instructional practices and advances (Barlow, Frick, Barker, & Phelps, 2014). PD programs vary in their form and function; however, their importance is accepted universally (Pecore, Kirchgessner, & Carruth, 2013). Therefore, it is important to understand how teachers perceive PD on the neuroscience of learning (Ansari et al., 2011; Degen, 2014; Smith, 2015) and their perceptions of its influence.

It is within this context that this research was undertaken, illuminating the intersection of neuroscience and PD. Through a qualitative methodology and case study design, this research addresses gaps and extends prior knowledge through the following two research questions:

> *How do elementary teachers perceived the nature of a professional development course on the neuroscience of learning? and*
>
> *How do teachers perceived the influence such training had, if any, on their practice?*

Framework

The conceptual framework for this qualitative case study was based on the five components of Desimone and Garet's (2015) model for effective professional development and served to direct the research problem. The theoretical foundation for this framework is based on research from the last 30 years, during which time the quest for a standards-based reform within education has drawn attention to teacher practice with the belief that by raising teacher practice, the elevation of student achievement is possible (Desimone & Pak, 2017). More specifically, over the past decade, teacher learning has experienced a restructuring movement (Stewart, 2014). The theoretical foundation stipulates that appropriate conditions and characteristics are necessary if PD is to foster a depth of understanding that ultimately informs teacher practice (Desimone & Garet, 2015). Essentially, this reform is a shift from a passive and intermittent PD model to one that is active, constant, founded in the teaching environment, and supported by colleagues (Stewart, 2014).

Furthermore, considerable evidence exists that effective PD, which improves teaching practice and student learning, is possible (Desimone & Pak, 2017). According to Desimone and Garet (2015), effective professional development needs five key features: content focus, active learning, coherence, sustained duration, and collective participation. *Content focus* denotes activities focused on subject matter content and how students learn that content. *Active learning* is the participation and engagement of students as opposed to learners being passive. *Coherence* is needed with content, goals, and activities of teachers, school, district, and state reforms and policies. *Sustained duration* means PD for more than 20 hours of contact time and ongoing throughout the school year. Lastly, *collective participation* is needed amongst the teachers to foster an interactive learning community (Desimone & Garet, 2015). Utilizing aspects from this model, we explored elementary teachers' perceptions on the nature of a PD course on neuroscience and learning. We also explored how the teachers perceived the influence the training had, if any, on their practice.

Methods

A qualitative methodology was chosen for this research specifically for its inductive nature and to build a conceptual understanding around the phenomenon under study (Merriam & Tisdell, 2016). The purpose of qualitative research methods is exploring phenomena from a subjective context as seen through the participants' perspective and to capture the subjective and varied factors involved (Yin, 2014). Gleaning the narrative perceptions of teachers on a PD course on the neuroscience of learning illuminated the participants' experiences, how they constructed their teaching worlds, and central to this particular study, what meaning they attributed to their implementation of this knowledge into their experiences (Merriam & Tisdell, 2016).

The PD course the participants experienced was conducted by a board-certified neurologist and middle school teacher, Dr. Willis, who specializes in brain research regarding learning. Her background as both a neurologist and classroom teacher contributes to the robustness and applicability of the PD she delivers to teachers. The specific topic of Willis' course was constructing durable, transferable memory, and the application of neuroscience research to teaching practice. It offered insights into the brain's most powerful information processing

networks to increase memory construction, accuracy, durability, and retrieval. This PD covered both the theoretical aspects of learning and the practical applications for teachers in the classroom.

Research Design

The research design for this study was a single-case study. This design affords researchers the opportunity to use several descriptive means for an in-depth exploration of a contemporary phenomenon. Using interviews, a focus group, and observations (Yin, 2014), this research was able to offer more details and a better understanding of how teachers perceive and use PD on the neuroscience of learning. The unit of analysis was a specific group of teachers within a bounded system limited to those who participated in the PD course. The unit of observation for this study was the teachers' perceptions of the nature of their PD experience.

Population and Sample Selection

The site of this study was a single private elementary school in southern California. Twelve elementary school teachers ranging from kindergarten through 6th grade participated. All participants had received PD on the neuroscience of learning by Dr. Willis over the past 12-18 months prior to the collection of data. Although the sample size is small and limited to the participants in one specific course on the neuroscience of learning, it was deemed sufficient for the purpose of this study.

Sources of Data

Multiple sources of data were used including observations, interviews, and a focus group. The semi-structured interviews pertained primarily to the first research question of how elementary school teachers perceived the nature of the PD course on the neuroscience of learning. The focus group pertained primarily to the second research question of, how teachers perceived the influence such training had, if any, on their practice.

The semi-structured interview and focus group questions were compiled from existing validated instruments and modified to specifically inquire about a neuroscience course (LaCursia, 2011; Meister, 2010; Morewood, Ankrum, & Bean, 2010). The interview questions specifically addressed the five key features Desimone and Garet (2015) posited are necessary for effective professional development: content focus, active learning, sustained duration, collective participation, and coherence.

Participants were designated to focus groups based on their years of teaching experience. One group was comprised of teachers with more than 10 years of experience and a second group was comprised of teachers with less than ten years of experience. The focus groups provided an opportunity for corroborating certain findings and potentially generating new ideas.

Observations of the participants in their classrooms provided the researcher an opportunity to witness the phenomenon of study. The frequency of the observed behavior over several hours of teaching was noted for each participant utilizing a checklist of suggestions given by Dr. Willis

(2010) for constructing durable, transferable memory and the application of neuroscience research to teaching practice.

Data Analysis

The results of this study are based on qualitative thematic coding using a codebook and analysis through the use of coding, pattern matching, and descriptive narratives. Themes were ultimately derived from finding the patterns, trends, or concepts illuminated by the codes elucidated from the interview and focus group data sets. Frequency data from the observation checklists were tallied. The totality of collected data was analyzed to answer the research questions.

Results and Discussion by Theme

Ultimately, four themes were produced from the codes and categories of data. The first two themes were on the structure of PD and the follow-up to it and are similar to the components of the model for effective PD by Desimone and Garet (2015) that conceptually framed this study. Those components were content focus, active learning, coherence, sustained duration, and collective participation. The second two themes related specifically to PD on the topic of the neuroscience of learning. Themes one through three address the first research question on teacher perceptions of the nature of a PD course on the neuroscience of learning while the fourth theme is a response to the second research question on teacher perceptions of the influence the PD had on their practice.

Theme 1 The structure of PD is critical to its success.

Theme 2 Follow up to PD is critical to the implementation of training.

Theme 3 Effective PD on the neuroscience of learning needs certain components.

Theme 4 Neuroscience of learning PD is beneficial for elementary teachers.

The themes were consistent between the data sources: individual interviews, focus group discussions, and observations. Two participants were absent for the focus group and observations, and while important to note, may not have a significant effect on the emergent themes and findings. Both of the participants' interview data were consistent with the other participants. These missing data create limitations to the study findings as participant perspectives and possible codes and subsequent themes could be lacking from the overall results. Table 1 provides samples of the codes relative to the four themes.

Theme 1: The structure of PD is critical to success

The first theme illuminated by the data concentrates on the actual structures within the PD course that are necessary for creating a successful one. These correlated to the components in the model of effective PD by Desimone and Garet (2015). One of those components is *sustained duration*. Participants in this study confirmed that from their perception, PD needs to be conducted at regular intervals throughout the school year and not only in the beginning of the year. Participants commented that, "We are bombarded by PD at the beginning of the year. We should be cycling back to content," and "It was too much, so I felt like I was bombarded." As the

conceptual framework and study results stipulate, effective PD needs certain components such as spacing and adequate duration.

Table 1
Theme 1 Example Codes Organized by Desimone & Garet's (2015) Components of Effective PD

Theme 1-The structure of PD is critical to success.
Sustained Duration
Bombarded by PD at the beginning of the year
Spiral the topics at regular intervals
Content Focused
PD more often in smaller chunks
Too much new content is not helpful
Active Learning
Teach PD using best practices and based on neuroscience
Coherence
Teachers want something tangible, less theoretical
PD must give teachers an application
Explore topics and then connect to the classroom

Related to the component *content focus*, the participants indicated topics must connect and apply to the classroom and not cover too much new content during one school year. As one participant shared, "I am trying to implement too many things, and then it got confusing. I had to come back to, okay, what do I know?" This data also corroborates the findings by Desimone and Garet (2015) for effective PD structures. Too many topics, too much at one time, and lack of cohesiveness do not amount to effective PD for teachers.

Participants expressed the need for PD presentations to occur systematically over time rather than the "one and done" experience. Ideally, a topic is decided upon by administration and the teachers based on current needs, and a long-range lesson plan for the PD of the teachers is created. This lesson plan includes multiple exposures to a topic with experiential learning opportunities so that teachers could practice in real-time. The plan also includes a post-hoc analysis of the effectiveness and compatibility of the topic with the school philosophy for teaching, thus creating a feedback loop for teachers to the administration.

Participants asserted the PD needs to be taught in a manner consistent with best practices and what the neuroscience evidence corroborates: active learning, not just sitting and listening to a speaker. This relates to the *active learning* component (Desimone & Garet, 2015). When asked about an example of an effective active learning PD experience, one participant stated, "I think our teachers like that type of implementation themselves because it agrees with our philosophical beliefs about learning." Another stated, "The more hands-on and interactive they are, the better." Teachers stated that having an opportunity to work with the new information assists their own learning, thus increasing the PD effectiveness.

The participant responses indicated teachers want experiential learning in their PD. In this way, new information is connected to multiple senses and not just auditorily processed. Participants asserted that just as best practices dictate that students have occasions to learn utilizing multiple modes, teachers participating in PD want these same opportunities.

Relative to Desimone and Garet's (2015) PD characteristic of *coherence*, participants specified PD topics should be decided collectively between teachers and administration based on the needs of the students and the latest information on learning available. Teachers noted, "When we walk away from PD, I want something tangible, I want to be given something today that I can go try tomorrow in my classroom and see what happens with it." Participants asserted that while theory is interesting, ultimately is the application of theory that is most helpful.

Relatedly, goal buy-in is an important element to creating lasting and transferable memories (Willis, 2010). Participants expressed this concept with their responses that PD needs to have a real-world application to their practice. For this, communication between the entities deciding on PD topics and the teachers themselves is important. Less important to participants was the theory behind learning principles. It is the application of theory that is perceived as most valuable. For the teachers to buy-in to the goal of the PD, the teachers want to leave the PD with an application for the information to their own teaching practice.

Lastly, the participants shared that incorporating the PD information into professional learning communities (PLC) within the school is important, and this relates to Desimone and Garet (2015) *collective participation* component. "Having a point person for that as a PLC come and really strategize with us on what more can we do in these next steps, and then giving us specific things that we can apply, or work towards," as stated by a participant on the importance of collective participation. This data aligns with the need to revisit topics both for deeper learning and for ascertaining the topic effectiveness. The collective participation component provides the impetus for PD topics incorporation into the ongoing curriculum for the PLC. Thus, the topic is integrated, and teachers have the opportunity to revisit together the value of the new information and its significance to their particular teaching.

Theme 2: Follow up to PD is critical to implementation of training

This second theme illuminated by the data indicates teacher participants perceived the necessity of an explicit follow up to the PD. Teachers communicated there is confusion about implementing new topics and when the new strategies don't work, they just stopped using it. Participants shared that the lack of a follow-up to the PD on the neuroscience of learning caused confusion about the implementation of new information gleaned from the course, "Are we adopting this or not?" was stated by several participants.

A diminishing of the excitement around a newly learned topic, if the topic is not revisited periodically by administration or as part of a PLC, was also noted. One participant stated, "Maybe use some of the strategies for a little bit, and then since there's no follow through or there's not a follow-up professional development where we talk about it a lot, it kind of sizzles out sometimes." Other teachers also noted a sense of excitement at first that eventually putters

out. Also described by participants was the need for a formal assessment on the practicality and sustainability for a topic is necessary in case it is inaccurate or unhelpful. One participant stated:

> And that's kind of what I feel is also another important point, to have these professional developments, and then try them out, and then really have the very concrete focus group or focus meeting back to actually take in what worked or what didn't work, and how did we each apply it? To have a practical approach.

Table 2
Theme 2 Example Codes

Theme 2-Follow up to PD is critical to implementation of training.
There is no follow up
Confusion implementing new topics
When it doesn't work, just stop using it
Initial excitement putters out
PD needs accountability

Participants expressed a dissatisfaction with the lack of follow up to PDs in general. Specific to the PD course on the neuroscience on learning, participants expressed that while there was some follow up, more was needed to fully incorporate all that was presented. Participants felt there was room for improvement on evaluating PD in general.

Without follow-up to the PD by the administration or the PLC, teachers were left to interpret the significance of the training content individually. This left many of the participants feeling unsure if their experience with utilizing the content of the PD was typical or justified. Furthermore, the lack of follow-up by administration or the PLC created a reaction by participants that if they felt it was not working well or easily, then why bother trying to use the new information. Participants asserted follow-up to the PD would alleviate these feelings and assure the teachers that the topic was important to administration and, therefore, worthy of the effort. Conversely, if the PD topic was not helpful to the teachers or caused concerns, then a follow-up would provide an opportunity to alleviate the issues.

Also, an important consideration to follow-up was the idea of cycling back to a topic to encode deeper learning. Just as with students, participants understood the importance of repeating material and cycling back to it over time with new perspectives and insights. Activating schema for teachers around their PD experiences provides not only deeper learning opportunities but could also thwart waning enthusiasm, another consequence to a lack of follow-up.

Theme 3: Effective PD on the neuroscience of learning needs certain components

The third theme correlates to the conceptual framework by Desimone and Garet (2015) used in this study but also illuminates components that are pertinent to the specific PD neuroscience course on learning. The components participants perceived as most necessary was that the PD be taught at the teachers' level and not at the level of a neuroscientist who would already understand

the topic. Participants often described that a presenter is not there to impress, rather is there to teach the participants.

Table 3
Theme 3 Example Codes

Theme 3-Effective PD on the neuroscience of learning needs certain components.
Present information at the appropriate level
Use a credible and vetted source
Keep it relevant to teachers

Participants expressed a desire to have new information presented in a manner that is relatable and relevant to their practice as opposed to listening to experts extoll their vast knowledge around a topic. When a topic is unrelatable, learning is thwarted. Given the high interest of the participants on the topic of neuroscience of learning, having this information presented in a manner comprehensible to the participants is therefore crucial for learning.

Relatedly, teachers noted that credible and fully vetted sources for the PD must be used since the trend towards brain-based teaching is so popular currently. This popularity could lead to the perpetuation of neuromyths rather than reliable science. As one participant asserted, knowing who is providing the PD and that the presenter has teaching experience is important for participants. In this case, their PD presenter had both a neuroscience background and taught in a classroom; the information was therefore perceived as particularly relevant by the participants. This idea relates to the idea that new information presented must be relatable and applicable to the participants with the additional caveat that the presenters must be truly qualified to teach the material. More important than just knowing the science of learning is the ability to actually present it in a way that teachers can learn and apply the information. Teachers perceived information from an expert who also had experience in a classroom as particularly valuable. This information was perceived as more practical and helpful to teachers in the day to day functioning of a classroom.

Participants in this study commonly expressed their perceived value of the PD on the neuroscience of learning; however, for this specific PD to be effective, certain components were necessary. Consistent with the information taught in the course on the neuroscience of learning, information must be relatable and relevant, and participants need an opportunity to respond to the learning in real-time. Participants also posited presenters with both neuroscience knowledge of learning and classroom experience embodied the most efficacious characteristics and were perceived as better poised to deliver content by forming relationships to prior knowledge, relate the learning through personal relevance, and allow participants time to respond to the learning as it is being acquired. In this way, the presenters are speaking to teachers, not neuroscientists and are fostering learning for the teacher participants.

Theme 4: Neuroscience of learning PD is beneficial for elementary teachers

The fourth theme is the overarching theme of this study. Without exception, each participant perceived the PD course on the neuroscience of learning as beneficial and influential to their

teaching practice. For example, one participant stated that because neuroscience oversees so many things, understanding the underpinnings to learning illuminates red flags around student behavior or academic concerns more quickly. Another expressed that because brains are evolving, teachers need to understand how and what to do about it. Many teachers stated that their teacher prep programs did not include any neuroscience of learning topics.

Table 4
Theme 4 Example Codes

Theme 4- Neuroscience of learning PD is beneficial for elementary teachers.
Understand progression of brain growth
Often not included in teacher prep programs
Understanding how humans learn can improve student learning
PD is a viable means of bridging the gap between neuroscience and education
Can help understand negative behavior and feedback from students
PD helps teachers understand different ways to work, promotes differentiation, improves effectiveness, and helps teachers appreciated the differences amongst students

An important caveat to this theme that several participants stated is that it is not just understanding the science behind learning so much as understanding what the science meant for students and how best to teach them. As one participant said:

> Without going into all the dendrites and the synapses and the little pockets of dopamine. I need to know just like, yeah in the brain there's this reward system and it's gonna happen and this is what it looks like in the classroom, without having to get into all the details.

Essentially, this knowledge increases the tools in the tool box for teachers by demonstrating the importance of hooking students emotionally, keeping them engaged, and having appropriate expectations of them. This is why differentiation is so critical to student success. On participate stated, “From what I've seen in my experience, the more I understand, the more education and understanding of how the brain works totally helps me to be a better teacher.” Neuroscience knowledge of learning thus serves as the umbrella for all teaching according to many participants.

The researcher’s classroom observations of the teachers also substantiated this influence of the PD course on the teacher participants’ practice, although some more than others. Behaviors, such as presenting novel stimuli, asking for predictions, creating personal relevance, giving frequent feedback, linking new input to similar patterns, having prior knowledge activation, using graphic organizers and highlighting, reducing cognitive load, using multi-sensory movement, and asking higher order questions, were observed by the researcher and support the perception that the training had an influence on the teachers’ practice.

Throughout the interviews, focus groups, and evidence from the observations, participants asserted their perceptions that the PD neuroscience course was of benefit to them professionally

and influenced their practice. For example, when asked about the efficacy of the PD course, one answered, "Absolutely. I think as many courses as possible before a teacher is even in the classroom is good." Another participant stated, "You need to know how the brain functions; you need to know how this tool works. Otherwise, we won't know how to use it properly." Several participants also made the point that this knowledge helps explain accommodations needed for different students.

Participants expressed that knowledge of the neuroscience of learning afforded them the opportunity to depersonalize student outcomes. Instead of taking personally a student's disinterest or inability to complete a lesson, teachers could analyze the situation and begin to remove the barriers and ascertain the root of the issue. Whether the issue is that the student is dyslexic or too hungry to concentrate, the teacher has an expanded repertoire of knowledge from which to draw and conceptualize ideas. This increase in options was perceived as a positive outcome for attaining neuroscience knowledge on learning.

Relatedly, several participants posited that this neuroscience knowledge elicited more compassion for their students because their behavior in the classroom was not taken as personally by the teacher; instead, teachers perceived a potential biological explanation for the behavior. All agreed more knowledge equates to more teaching strategies, or tools in the toolbox. Positive perceptions were that these help foster an understanding of what is happening with students in the moment and also in the larger context of the school year. As one participate stated, "You have to understand the child and the brain before you teach the child."

Summary

The goal of this study was to explore teachers' perceptions of a PD course on the neuroscience of learning and to explore their perceptions on the influence this training had, if any, on their teaching practice. Research from previous studies elucidated that many believe neuroscience is the new partner to the field of education and thus, neuroeducation has emerged as an evolving and viable extension for education researchers (De Vos, 2015; Nouri, 2016). The question remains, however, if this knowledge will inform the practice of teaching and classroom instruction (Bianco & Lecce, 2016; De Vos, 2015; Schrag, 2013). One perspective contends there is benefit to teachers knowing the science behind their students' learning as this will inform their practice (Degen, 2014; Smith, 2015), while others were skeptical of the applicability of this knowledge (Bowers, 2016; De Vos, 2015; Smeyers, 2016).

The conclusions made based on the findings of this study were aligned with the research that purports that there is indeed a benefit to teachers knowing the science behind learning. Regarding impressions of PD, the findings reinforce that certain structures and components are needed to be effective. All participants perceived that a PD course on the neuroscience of learning was of benefit and had an influence on their teaching practice. Participants desired follow-up to PD and that the PD be presented in a way consistent with what they learned about the neuroscience of learning. This study showed that teachers want an understanding of how external and internal stimulation changes the brain and that they can use this information in their practice. Additionally, this study indicated PD is a viable catalyst for the professionalization of

teaching and for facilitating teacher knowledge of the most current instructional practices and advances.

Recommendations for Future Research

This study is limited in that it only explored the perceptions of elementary school teachers in a single course on the neuroscience of learning. Replication is needed with other teachers receiving training on the neuroscience of learning in other settings and with teachers from different grade levels. Similar results would improve the generalization of the findings from this study. Exploring the perceptions of preschool, middle school, high school, and higher education educators, with their unique student populations, could produce distinctive results and thus promote diverse future research ideas.

This study asked teachers about the influence of the PD and gathered observational data but did not explore any measure of effect on student achievement. The positive effect of teacher professional development on student achievement is well documented (Pecore et al., 2013; Smith, 2015); however, synthesizing neuroscientific research into usable and applicable design guides for optimal learning experiences is not as yet well-documented (Anderson, 2014; Smeyers, 2016). Future research in this area, using different methodologies and research designs is necessary. Particularly interesting would be a phenomenological analysis as a means to study how teachers who are striving to apply neuroscientific based learning principles are subjectively experiencing the phenomenon. In other words, how teachers are making sense of their teaching experience.

Additional research on PD is also needed. Considerable evidence exists that effective PD, which improves teaching practice and student learning, is possible (Desimone & Pak, 2017). According to Desimone and Garet (2015), effective professional development needs five key features: content focus, active learning, coherence, sustained duration, and collective participation. Therefore, a study in which the five features deemed necessary for effective PD are fully considered in the initial design of a PD course on the neuroscience of learning might illuminate if such structure improves the teachers' perceptions of the PD and the impact of their learning to their practice. As Desimone and Garet asserted, there is a multiplicity of PD, which makes it difficult to learn from studies on PD or to draw conclusions about which factors contribute to the success or failure of PD efforts.

Author Notes

Wendy Bana is a director of curriculum and instruction for a private school in Laguna Beach, CA.

Jeff Cranmore is a Dissertation Chair at Grand Canyon University.

Corresondence regarding this article should be addressed to Wendy Bana at wendybana@gmail.com.

References

Aberšek, B. (2015). Changing educational theory and practice. *Problems of Education In the 21st Century*, *66*,4-6.

Anderson, O. (2014). Progress in application of the neurosciences to an understanding of human learning: The challenge of finding a middle-ground neuroeducational theory. *International Journal of Science & Mathematics Education*, *12*(3), 475-492.

Ankrum, R. J. (2016). Utilizing teacher leadership as a catalyst for change in schools. *Journal of Educational Issues*, *2*(1), 151-165.

Ansari, D., Coch, D., & De Smedt, B. (2011). Connecting education and cognitive neuroscience: Where will the journey take us? *Educational Philosophy and Theory*, *43*(1), 37. doi:10.111/j.1469-5812.2010.00705.x

Barlow, A. T., Frick, T. M., Barker, H. L., & Phelps, A. J. (2014). Modeling instruction: The impact of professional development on instructional practices. *Science Educator*, *23*(1), 14-26.

Bayar, A. (2014). The components of effective professional development activities in terms of teachers' perspective. *International Online Journal of Educational Sciences*, *6*(2), 319-327. doi:10.15345/iojes.2014.02.006

Bianco, F., & Lecce, S. (2016). Translating child development research into practice: Can teachers foster children's theory of mind in primary school? *British Journal of Educational Psychology*, *86*(4), 592-605. doi:10.1111/bjep.12125

Bowers, J. S. (2016). The practical and principled problems with educational neuroscience. *Psychological Review*, *123*(5), 600-612. doi:10.1037/rev0000025

Conyers, M. (2017). *Improving teaching practice through education, mind, and selected brain research* (Doctoral dissertation, University of Westminster).

Cromley, C. (2000). Learning to think, learning to learn: What the science of thinking and learning has to offer adult education. *NIFL Literacy Leadership Fellowship Program Reports*, *4*(1).

Degen, R. J. (2014). Brain based learning: The neurological findings about the human brain that every teacher should know to be effective. *Amity Global Business Review*, *9, 15-23.*

Desimone, L. M., & Garet, M. S. (2015). Best practices in teachers' professional development in the United States. *Psychology, Society and Education, 7*(3), 252-263.

Desimone, L. M., & Pak, K. (2017). Instructional coaching as high-quality professional development. *Theory into Practice, 56*(1), 3-12.

De Vos, J. (2015). Deneurologizing education? From psychologisation to neurologisation and back. *Studies in Philosophy & Education, 34*(3), *279-295.*

Dubinsky, J. M., Roehrig, G., & Varma, S. (2013). Infusing neuroscience into teacher professional development. *Educational Researcher, 42*(6), 317. doi:10.3102/0013189X13499403

Flogie, A., & Aberšek, B. (2015). Transdisciplinary approach of science, technology, engineering and mathematics education. *Journal of Baltic Science Education*, *14*(6), 779-790.

Hohnen, B., & Murphy, T. (2016). The optimum context for learning; drawing on neuroscience to inform best practice in the classroom. *Educational & Child Psychology, 33*(1), 75.

Kennedy, T. J. (2006). Language learning and its impact on the brain: Connecting language learning with the mind through content-based instruction. *Foreign Language Annals*, *39*(3), 471.

Knowland, V., & Thomas, M. (2014). Educating the adult brain: How the neuroscience of learning can inform educational policy. *International Review of Education / Internationale Zeitschrift Für Erziehungswissenschaft, 60*(1), 99. doi:10.1007/s11159-014-9412-6

LaCursia, N. (2011). Perceptions of professional development from northern Illinois secondary public-school health teachers and school administrators. *Health Educator, 43*(2), 27-36.

Meister, D. G. (2010). Experienced secondary teachers' perceptions of engagement and effectiveness: A guide for professional development. *The Qualitative Report, 15*(4), 880-898.

Merriam, S. B., & Tisdell, E. J. (2016). *Qualitative research: A guide to design and implementation.* John Wiley & Sons.

Morewood, A. L., Ankrum, J. W., & Bean, R. M. (2010). Teachers' perceptions of the influence of professional development on their knowledge of content, pedagogy, and curriculum. *College Reading Association Yearbook, 31*, 201-219.

Nouri, A. (2016). The basic principles of research in neuroeducation studies. *International Journal of Cognitive Research in Science, Engineering & Education, 4*(1), 59-66. doi:10.5937/IJCRSEE1601059N

Pecore, J. L., Kirchgessner, M. L., & Carruth, L. L. (2013). Changes in science content knowledge and attitudes toward science teaching of educators attending a zoo-based neuroscience professional development. *The Clearing House: A Journal of Educational Strategies, Issues, and Ideas, 86*(6), 238-245. doi:10.1080/0009865 5.2013.826527

Schrag, F. (2013). Can this marriage be saved? The future of 'neuro-education'. *Journal of Philosophy of Education, 47*(1), 20–30.

Shyman, E. (2017). Please wait, processing: A selective literature review of the neurological understanding of emotional processing in ASD and its potential contribution to neuroeducation. *Brain Sciences, 7*(11), 153.

Smeyers, P. (2016). Neurophilia: Guiding educational research and the educational field? *Journal of Philosophy of Education, 50*(1), 62-75. doi:10.1111/1467-9752.12173

Smith, G. (2015). The impact of a professional development program on primary teachers' classroom practice and pupils' attitudes to science. *Research in Science Education, 45*(2), 215-239.

Sneyers, E., Jacobs, K., & Struyf, E. (2016). Impact of an in-service training in neurocognitive insights on teacher stress, teacher professionalism and teacher student relationships. *European Journal of Teacher Education, 39*(2), 253-266.

Stein, Z., & Fischer, K. W. (2011). Directions for mind, brain, and education: Methods, models, and morality. *Educational Philosophy and Theory*, *43*(1), 56-66

Stewart, C. (2014). Transforming professional development to professional learning. *Journal of Adult Education, 43*(1), 28.

Stiles, J., & Jernigan, T. L. (2010). The basics of brain development. *Neuropsychology Review, 20*(4), 327-48. doi:10.1007/s11065-010-9148-4

Willis, J. (2010). Using my neuroscience to treat the sickness in our classrooms. *Catalyst for Change, 36*(2), 46-55.

Yin, R. K. (2014). *Case study research: Design and methods.* Los Angeles, CA: Sage Publications.