

What Do You See? Signature Pedagogy in Continuous Electroencephalography Teaching

Citation for published version (APA):

Fernandez, A., Asoodar, M., van Kranen-Mastenbroek, V., Majoie, M., & Balmer, D. (2025). What Do You See? Signature Pedagogy in Continuous Electroencephalography Teaching. *Journal of Clinical Neurophysiology*, 42(1), 81-86. <https://doi.org/10.1097/WNP.0000000000001075>

Document status and date:

Published: 01/01/2025

DOI:

[10.1097/WNP.0000000000001075](https://doi.org/10.1097/WNP.0000000000001075)

Document Version:

Publisher's PDF, also known as Version of record

Document license:

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What Do You See? Signature Pedagogy in Continuous Electroencephalography Teaching

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Purpose: Electroencephalography (EEG) is commonly used in neurology, but there is variability in how neurologists interpret EEGs, potentially from variability in EEG teaching. Little is known about how EEG teaching is done to prepare neurologists for professional practice.

Methods: We interviewed a group of EEG experts to characterize their teaching practices around continuous EEG (cEEG). We used signature pedagogy as a framework to analyze and interpret the data.

Results: We identified pervasive and characteristic forms of cEEG teaching. Teaching is based on apprenticeship, relying on “learning by doing” in the context of real-life clinical practice.

There are habitual steps that learners take to anchor teaching, which typically occurs during rounds. There is a common language and core knowledge that trainees need to master early in their training.

Conclusions: There are pervasive characteristic forms of cEEG teaching. These findings can help facilitate instructional design and implementation of complementary or enhanced cEEG teaching practices.

Key Words: Electroencephalography, EEG education, EEG teaching, Signature pedagogy.

(J Clin Neurophysiol 2024;00: 1–6)

Electroencephalography is commonly used in clinical practice because it provides critical information with significant clinical implications.¹ Despite this clinical significance, EEG teaching is inconsistent and widely variable, including EEG educational structures and dedicated EEG teaching.² The lack of EEG teaching structures could result in variability in EEG interpretation with potentially adverse consequences from EEG misinterpretation.³

Our current understanding of EEG teaching is rooted in typically quantitative EEG education studies clustered into three categories: tests of EEG knowledge and skills focused on short EEG educational interventions, usually at single centers^{4–22}; studies describing the development and evaluation of online EEG learning tools^{23–26}; and surveys exploring perceptions of EEG teaching and training competencies.^{27–29} The exception is the qualitative EEG study by Moeller and Fawns, which explored conceptually difficult but pivotal concepts (i.e., threshold concepts) in EEG education.³⁰

A common characteristic in the above studies is the lack of grounding in theoretical frameworks, an important aspect of education research.³¹ Here, too, the exception is the use of the threshold concepts framework of Moeller and Fawns, which was

first described in higher education.³² Grounding education research in theoretical frameworks helps us to better position and interpret our findings in the broader context of educational scholarship.^{31,33} The dearth of EEG education studies rooted in theoretical frameworks limits the ability to situate EEG teaching within the larger body of health professions education literature. Without the ability to contrast teaching practices within broader educational frameworks, the capacity to change and adapt EEG teaching is limited. For example, using signature pedagogy as a lens to analyze and interpret this study creates an anchor to contrast findings with other educational studies that use signature pedagogy.

In this study, we analyzed the perceived cEEG teaching practices of EEG experts through the lens of the signature pedagogies framework.³⁴ Signature pedagogies are defined as characteristic forms of teaching or taken-for-granted rituals that organize the education of trainees in various professions.^{34–36} Signature pedagogies are pervasive and point us to what is assumed to be true about knowledge transmission, i.e., “how things become known,” and assumed to be critical knowledge, i.e., “what counts as knowledge.”³⁴ Signature pedagogies have been applied in healthcare fields such as medicine, nursing, and occupational therapy.^{37–39} For example, Balmer et al. used signature pedagogy to illustrate teaching rituals in a pediatric inpatient unit setting.³⁷ Specific to neurology, uncovering assumptions about how we teach EEG is pivotal to improving EEG teaching and, ultimately, to how well we prepare trainees for professional practice.

This study uses signature pedagogy to explore commonplace and potentially ritualistic forms of teaching by analyzing experts' accounts of their cEEG teaching practices (in the inpatient and critical care setting) for epilepsy and neurophysiology fellows. This description provides a starting point for new

The authors declare no conflict of interest related to this work.

Work for this study was part of the activities for the Faculty Innovation in Education Award (Recipient: Andres Fernandez, 2018–2019) from the American Board of Psychiatry and Neurology.

Presented as a poster on January 18, 2023, at the Children's Hospital of Philadelphia Education Symposium, Philadelphia, PA, USA.

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ISSN: 0736-0258/24/0000-0001

DOI 10.1097/WNP.0000000000001075

ways of thinking about cEEG instructional design and teaching practices.

METHODS

We conducted in-depth interviews with a convenience sample of 21 neurologists with expertise in EEG interpretation (fellowship-trained in adult epilepsy and/or clinical neurophysiology). They represented 13 institutions of various sizes (including two outside the United States) and had a median of 7 years in practice. These neurologists (referred to in this study as “teachers”) were also responsible for providing workplace-based EEG teaching to trainees (referred to in this study as “learners”). The learners referred to in this study were epilepsy or neurophysiology fellows. The Institutional Review Board of the Thomas Jefferson University approved this study with exempt status.

In early 2018, the first author (A.F.) developed the interview protocol, intending to elicit information about the interpretation of cEEG in the inpatient and critical care setting and specific teaching practices. In mid-2018, A.F. conducted interviews with the teachers in person (*n* = 13) or over the phone (*n* = 8). Interviews were recorded, transcribed verbatim, and deidentified. Using a constant comparative process,⁴⁰ A.F. and D.B. created a preliminary codebook in early 2022 and applied these codes to the first set of transcripts. They created new codes because they saw evolving patterns within the data and added these codes to the codebook. When no new codes were added, the codebook was finalized. Then, A.F. and D.B. went back through all interview transcripts to ensure the consistent application of codes throughout the data set. They clustered codes into categories that characterized teaching methods and content (e.g., “teaching technique” or “teaching specific EEG concept”), and then, they created two themes that reflected the concepts of signature pedagogy. In mid-2022, A.F. and D.B. shared their preliminary findings with the research team who reviewed them and made minor modifications. NVivo 12 software (QRS International, Doncaster, Australia) was used to manage the data.

In the final stages of analysis in late 2022, A.F. conducted member checking with four teachers who represented a range of teaching experience. The purpose of member checking was to help ensure that our study findings “made sense” to participants.⁴¹ Given the gap between data collection (mid-2018) and data analysis (2022), A.F. also asked about changes in their cEEG teaching practices during the COVID pandemic.

RESULTS

We report the findings through two themes: how things become known and what counts as critical knowledge (Table 1). Quotes from participants are labeled with participant identification numbers. Quotes serve as representative examples to illustrate the themes identified across study participants’ descriptions of EEG teaching practices.

Participants had Assumptions About How Things Become Known

Teaching Occurs in an Apprenticeship Model

cEEG teaching was uniformly described as an apprenticeship: “learning by doing” in the workplace context with the facilitation of an experienced “master.” This apprenticeship method was viewed by the participants as the “standard”: “I think this is the standard way EEG has always been taught: It’s, see one and read it, interpret it and interpret it with the attending. So I think I learned my teaching style because that’s the way I was taught.” [Participant 1] None of the participants questioned whether teaching through the apprenticeship model would result in learner knowledge. Thus, these pervasive, concrete acts of teaching (i.e., apprenticeship) perpetuated the assumptions of how things become known.

Teaching Occurs in Parallel to Real-Life Clinical Practice

The context was critical to apprenticeship because the act of teaching occurred amidst real-life clinical care. Thus, acts of teaching were affected by the ebb and flow of patient volume and cEEG case characteristics: “Our lab is so busy, and we have such a variety of pathology coming through that pretty much everything is going to come through in that first few weeks.” [Participant 12] More specifically, cEEG teaching almost always occurs in the setting of rounds, where teachers and learners meet at an agreed-upon time to review cEEGs. Because cEEG teaching was an apprenticeship, inseparable from clinical practice, teachers typically moved through cEEGs by first addressing and teaching the cEEGs that were the most questionable or concerning and ending with the most “benign” studies.

Learners Have Predictable Routines to Prepare for Teaching

Nearly every teacher described a distinct three-step process of learner preparation for cEEG teaching: prereading, marking, and generating a preliminary report. This preparatory process

TABLE 1. Themes and Facets of Themes

Themes	Facets of Themes
Participants had assumptions about how things become known	Teaching occurs in an apprenticeship model Teaching occurs in parallel to real-life clinical practice Learners have predictable routines to prepare for teaching Teachers use the learner preparation to focus cEEG teaching
Participants had assumptions about what needed to be known (i.e., critical knowledge)	Learners need to distinguish between a “real” EEG signal and artifact Learners need to distinguish between seizure versus no seizure Learners “shift” their EEG calling behavior as their training progresses Teachers use a common cEEG language: the ACNS nomenclature

ACNS, American Clinical Neurophysiology Society; cEEG, continuous EEG.

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was the learner's responsibility and foundation for *how things would become known*. To prepare for teaching, learners had to pre-read the cEEG. Pre-reading was the preamble and involved an independent review of the cEEG study by the learner. As part of the pre-reading phase, learners marked the cEEG (i.e., highlighting key areas). Marking demanded pattern recognition and reflected the learners' ability to select cEEG segments of interest to review with teachers. Finally, learners generated a preliminary report based on the pre-reading and marking. The process description was intuitive and almost mechanical, as described by this teacher:

We sit down, and we go through each study in turn. Ideally, they've prepared reports already, and they've already interpreted – they've already made an interpretation of an EEG. They may be right on the money. They may be completely wrong. But either way, they've already looked at the study, they've interpreted it, and they've made a report that has their interpretation on it. [Participant 14]

Teachers Use the Learner Preparation to Focus cEEG Teaching

Through this three-step preparation process, learners committed to their impression of the cEEG that teachers would use as a focal point for their concrete acts of teaching. As one teacher shared:

Asking the person to form their impression on the first page. That allows me to diagnose the learner, and it's going to give me a sense of what to focus on. If somebody looks at that first page and just nails it, then I am going to start probing for deeper understanding. If the person gets the first page and is all over the place, then I'm going to be much more directive. [Participant 16]

In fact, a common description of how teachers opened the discussion of cEEG studies was by asking for the learners' impressions: "What do you see? Asking this question was paramount: "I'll try to, actually, use an open approach to, basically – I don't try to force them to actually try to see what I see, but it's – in some ways, you have to teach them how to look at the EEG." [Participant 13]

Although learners' commitment to an impression was critical at the start of teaching, teachers remained attuned to what the learner was saying during subsequent discussions. They adapted their teaching to meet the learners' needs. Some teachers characterized this adaptation as "good teaching": "I think good EEG teachers do this – is never letting your guard down in terms of probing for understanding. So if a learner says, this looks worse, saying, what do you mean by worse? And encouraging the learner to challenge their own assumption." [Participant 16]

In summary, cEEG teaching uniformly occurs as an apprenticeship where the learners are "learning by doing" in the real-life context of clinical practice, typically in the setting of rounds and with specific preparatory steps taken by the learner to focus cEEG teaching. No one spoke of options to apprenticeship or consensus processes for teaching. Instead, there were agreed-

upon acts of teaching as if they were passed down from generation to generation.

Participants Had Assumptions About What Needed to be Known (i.e., Critical Knowledge)

Learners Need to Distinguish Between a "Real" EEG Signal and Artifact

All teachers reported, or implied, that learners needed to distinguish between a "real signal" on the EEG (i.e., a signal generated by the brain) and artifacts. Several participants described this critical concept as foundational knowledge. That is, they made assumptions about what needed to be known:

The EEG has to be done in a very orderly fashion. Any time you see a wave – I should be able to point to a wave, they should know the first question always, is it artifact or not? The first question in an EEG, is it artifact or not? Then is it normal or abnormal? If it's abnormal, is it a specific abnormality? [Participant 12]

In other words, some things were so critical to know, that NOT knowing them was paramount to NOT being able to read a cEEG. NOT knowing has potential clinical importance:

I would say they need, probably above all, to be very familiar with artifacts on EEG, because artifacts can be very much overcalled on critical care EEG. And given the diagnostic uncertainty of all these graphoelements and findings, it's dangerous to let someone who can't tell artifact versus not out and read EEG in the ICU because everything could be a seizure. [Participant 4]

Learners Need to Distinguish Between Seizure Versus No Seizure

In addition, all teachers reported or implied that learners needed to distinguish whether a "real signal" was a seizure. That is, they needed to develop the skill of distinguishing seizures from artifacts early in their training. As one teacher pointed out, "The most important first thing for them to learn is to be able to identify electrographic seizures and being able to differentiate that from artifact." [Participant 6]

Learners "Shift" Their EEG Calling Behavior as Their Training Progresses

As learners progressed through training, their knowledge application shifted. Several teachers described a "pendulum" to illustrate how a cEEG was called, depending on the training stage. The perception was that learners tended to over-call early on in training due to the lack of knowledge and then under-call as they gained experience and confidence: "When they first start reading, they don't know very much, and they start calling, overcalling a lot. Then, they under call, the shift, and then you have to get them to swing back to the middle." [Participant 12] This was important because only when learners modulated toward the middle could teachers focus on higher-order concepts, such as making meaning of correct visual data and efficiently communicating findings:

It's our goal to teach them how to think and how to evaluate the visual data ... EEG reporting is you're trying to take complex visual data over a long period of time and put it into words that mean something ... also being able to write a cohesive clinical interpretation of what you think this all means. [Participant 2]

Teachers Use a Common cEEG Language: the ACNS Nomenclature

Language was critical to convey “what needed to be known” in a way that there was uniformity in the description of cEEG findings. Teachers predominantly used and taught a common “language,” i.e., the American Clinical Neurophysiology Society (ACNS) nomenclature, to facilitate communication of cEEG findings:

I would have to say, you just have to spend a lot of time sitting with them and distinguishing which patterns translate to the nomenclature. And once, I think, you get that principal, which requires a lot of practice and a lot of effort, I think that's sort of the pillar of then understanding the building blocks on how to interpret things that you don't really see so commonly. [Participant 13]

In summary, foundational cEEG teaching had to include distinguishing real EEG signals from artifacts and further distinguishing what constitutes a seizure. As the learners gain confidence and knowledge, there are perceived changes in how they interpret or “call” the cEEG. A common language, the ACNS nomenclature, was deemed necessary to convey what must be known.

DISCUSSION

Using signature pedagogy as our theoretical framework, we describe key characteristics of teaching by cEEG experts. We offer

two key findings that point to signature pedagogy: First, cEEG teaching was “learning by doing” in an apprenticeship model in the setting of workplace-based clinical practice, where learners routinely took concrete steps that anchored cEEG teaching (Fig. 1). Second, the learning that counted (i.e., critical knowledge) was the ability to detect what was a real signal and what was an artifact on the EEG. Early in training, learners had to recognize and differentiate artifacts from real signals and identify seizures. In addition, a common language, the ACNS nomenclature, is critical for conveying what needs to be known.

This study adds depth to our understanding of cEEG teaching given its qualitative nature and grounding in the theoretical framework of signature pedagogy. It builds on the work by Moeller and Fawns³⁰ on “threshold concepts” by providing a window into what is perceived to be foundational cEEG knowledge, “what counts as critical knowledge.” We were struck by the similarities in teachers’ accounts, wording, and examples. Although these similarities may facilitate common teaching practices, they may also make other ways to teach cEEG appear less intuitive. The pervasive and habitual nature of these teaching practices could limit the field to adopting up-to-date and potentially better teaching practices that can complement or enhance the apprenticeship model, including structured curricula (e.g., synchronous or asynchronous programs that include EEG teaching⁴²) or the use of technology in teaching (e.g., online cEEG self-directed education).

The pervasive nature of cEEG teaching is at first glance counter to the statement of the variability of EEG teaching mentioned in the introduction.² Still, the signature pedagogy for cEEG described here, with its uniformity in teaching practices, applies to the way we teach cEEG in the workplace-based setting through apprenticeship. This leaves room for potential variability in other settings, such as the formal curricular structures of EEG teaching outside of the clinical workplace.

I. Pre-Rounds

(Independent and preliminary review of the EEG by the learner)

II. Rounds

(Agreed upon time and location e.g., 10am in the EEG Reading Room)

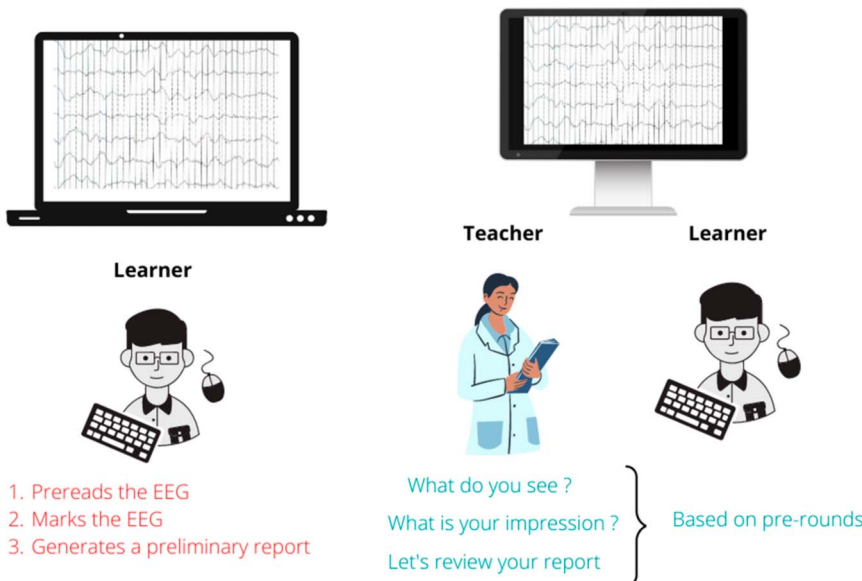


FIG. 1. Typical steps during cEEG teaching.

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We acknowledge the tension in the need for cEEG teaching in a structured educational setting while simultaneously meeting the needs of the demanding and necessary day-to-day clinical work of reading and interpreting cEEGs. Given the inpatient and critical care settings where cEEGs occur, rounds are typically structured progressing from the most difficult and abnormal to the most normal studies for triaging purposes. This strategy might counter how some would structure an educational activity when teaching in other settings, such as routine EEGs or an EEG curriculum outside the workplace, where triaging considerations would not be as critical.

This study has several limitations. We used a convenience sample of experts who interpreted cEEG for inpatient and critical care studies in the setting of teaching epilepsy and neurophysiology fellows. EEG teaching in the epilepsy monitoring units, for routine outpatient studies, in a classroom setting, or for other populations of learners may differ. We only interviewed teachers; therefore, the learners' perspectives on teaching practices were not represented. We focused this study on teaching practices; exploring how teaching facilitates EEG reading competence (and how to best define it) is an important area for future studies. Another limitation of our study was the use of data from 2018. Although member checking in 2022 revealed the introduction of online resources and video conferencing, the core teaching practices remained largely unchanged. The availability of online resources provides opportunities to complement the apprenticeship model, which is an essential area to explore in future studies.

In conclusion, we describe a signature pedagogy in cEEG teaching with pervasive assumptions about how things become known and what needs to be known. The findings of the signature pedagogy for cEEG described in this study can serve as a baseline to facilitate the development of complementary or enhanced ways of teaching cEEG.

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