Proceedings of the 4th International Conference on Software Engineering and Machine Learning
DOI: 10.54254/2755-2721/2026.32661

Normative Cognitive Structures in Learning Processes: A Hybrid Behavioral and EEG Experimental Investigation

Yuwei Li

University College London, London, United Kingdom
rara481846778@gmail.com

Abstract. The discussion of normative issues in educational philosophy has always been one of the central issues of interest within academic circles, particularly concerning the role of normative cognitive structures in the cognitive development of an individual and learning efficiency within the learning and cognitive process. Experimental psychology has greatly helped to uncover the learning mechanisms through the real-time monitoring of brain cognitive activities through the use of electroencephalography (EEG). The study combines educational philosophy and experimental psychology to investigate the role of normative cognitive structures within the learning process. The experimental design involves behavioral tasks and the collection of EEG data, where the experimental group showed improved cognitive integration capacity and efficiency of task execution by adhering to normative tasks. The EEG results showed the impact of normative compliance on cognitive brain processing. The findings of this study show that not only was the performance of the learners improved by adhering to the norms, but it also showed brain activity in certain areas. The study lends support to the theoretical aspects of normative issues in educational theory and serves as a theoretical base for the design of curriculum and cognitive interventions.

Keywords: Educational Philosophy, Normativity, Cognitive Development, Learning Process, EEG

1. Introduction

Educational philosophy, as a discipline that studies the principles and practices of education, has long focused on the normative issues related to education, including values, standards, and norms in the educational process [1]. With the development of educational research, scholars have increasingly recognized the significant role of normative cognitive structures in learning, especially in terms of cognitive development and learning efficiency. Experimental psychology provides ample empirical support for exploring the mechanisms of learning and cognition, particularly in understanding how individuals follow and internalize norms [2]. In recent years, with the development of technologies such as EEG, researchers have started to explore the formation and evolution of cognitive structures in learning from a biological perspective. Normative cognitive structures, as an internalized knowledge system, play a crucial role in the learning process and task performance [3]. However, existing research has mainly focused on either behavioral observations

© 2026 The Authors. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

DOI: 10.54254/2755-2721/2026.32661

or EEG data analysis separately, with fewer studies systematically revealing the formation mechanism of normative cognitive structures and their role in cognitive development through a combined perspective of educational philosophy and experimental psychology. Therefore, this study uses behavioral experiments and EEG technology to investigate the formation and development of normative cognitive structures in learning processes, aiming to reveal the impact of normative adherence on cognition and understanding mechanisms.

2. Literature review

2.1. Normative issues in educational philosophy

Educational philosophy, as a field, has traditionally dealt with normative issues, which are defined as the principles, standards, and values that should be followed in the process of education. Normative education focuses on the development of student values, especially in the development of moral education, critical thinking, and social responsibility [4]. According to various research works, it has been identified that normative concepts not only affect the choice of curriculum content, but also affect the relationship between teachers and students in the process of education. The heart of normative issues in education lies in whether or not education enables students to apply socially acceptable knowledge and behavior in real life [5]. However, literature on the topic mostly focuses on theoretical aspects, with very little in-depth research on the analysis of empirical data.

2.2. Applications of experimental psychology in education

Psychology experiments have found extensive usage when conducting research on the area of learning and cognition. This means that cognitive psychology experiments were predominantly based on information processing theory. In this case, the experimenters focused on identifying the information processing systems that learners use in order to get information about the world they live in [6]. This way, the basis of the cognitive structures was developed through learning. Nevertheless, due to the emergence of cognitive neuroscience, scientists have used various methods, such as electroencephalography and functional magnetic resonance imaging, to analyze the cognitive reaction within the process of learning [7]. It is evident from the findings of the studies that normal information processing during the learning task uses brain components such as the frontal and parietal lobes. Besides the information processing mechanisms, the technique can be applied to understand the cognitive reaction of the learner following the norm.

2.3. Normative adherence and cognitive development

Normative adherence is equally significant to cognitive development. The cognitive theory of learning and development asserts that learning involves constant optimization and adaptation of human cognitive abilities in order to meet both internal and external demands. It is reported that normative adherence not only facilitates the internalization of learning processes but also helps humans enhance their cognitive ability in complex tasks [8]. Normative adherence is advantageous to an individual because it helps him create a stable framework of cognitive development, through which he can effectively integrate learning into his cognition [9]. In the process of acquiring mathematics knowledge, for instance, one is required to follow certain sets of rules when attempting to solve mathematically challenging equations. The set of rules are not only extrinsic but intrinsic in nature to the individual's cognition. In addition, research studies indicate that human cognition plays

DOI: 10.54254/2755-2721/2026.32661

an integral role in the emergence of normative cognition. Furthermore, the concept of normative cognition is very important in understanding what concepts mean.

3. Experimental methods

3.1. Participants and experimental design

The population sample of this study consisted of 60 students between 18 to 25 years arranged randomly as experimental group and control group consisting of 30 students each. The experimental group was trained on normative tasks, whereas the control group underwent doing ordinary learning tasks. The experimental design was based on the 2x2 mixed design, in which the independent variables had the type of the task (normative task and regular task) and the group (experimental and control group). The baseline tests were conducted first with the participants, which included conventional ability cognitive tests, and time-taken to complete them in the experiment. Next, the experimental condition performed normative activities, in which they had to complete a set of cognitive exercises, such as solving math problems and logical reasoning exercises, according to certain norms. The control group has done tasks without explicit norms. Subsequently, the reaction time, the error rate and following of the task norms of each participant were noted.

3.2. Data collection and analysis methods

The collection of data was divided into two stages behavioral and neural activity data. The behavioral data consisted of the time of finishing the task, the error rate, and the reaction time (RT). EEG recordings were made with a 32 channels cap at a frequency of 1000Hz. ICA was employed in removing artifacts in the data and event-related potentials (ERP) extracted at important moments of the task execution (e.g., decision-making moments and task completion moments) [10]. Data analysis involved application of multiple regression models to determine the effect of normative adherence on cognitive tasks, where task performance (reaction time and error rate) was the dependent variable and normative adherence and cognitive ability of the participants were their independent variables. Data analysis was performed with the SPSS 26.0 that involved repeated-measure ANOVA to compare the groups in relation to differences and correlation analysis to evaluate the association between EEG data and behavioral data.

3.3. Experimental process

During this experiment, two key mathematical formulas were used to analyze the relationship between behavioral data and neural activity [11]. First, for calculating task reaction time, the following formula as shown in Equation (1):

$$RT=\frac{\sum_{i=1}^{N}(T_{end}^{(i)}-T_{start}^{(i)})}{N} \quad (1)$$

Where $T_{start}^{(i)}$ is the start time of task i, $T_{end}^{(i)}$ is the end time of task i, and N is the total number of tasks. This formula calculates the average reaction time for each participant during the task, reflecting their response speed to the task.

Second, to analyze EEG data related to normative adherence, the following event-related potential (ERP) model as shown in Equation (2):

DOI: 10.54254/2755-2721/2026.32661

$$ERP(t)=\frac{1}{N}\sum_{n=1}^{N}X_n(t) \quad (2)$$

Where $X_n(t)$ is the EEG signal of participant nnn at time t, and N is the total number of participants. These two formulas allow the quantification of the relationship between behavioral data and neural activity, supporting the subsequent analysis.

4. Results

4.1. Formation of normative cognitive structures

The experiment findings indicated that experimental group worked significantly better in normative tasks compared to the control group. The experimental group also took a shorter time to complete the task (M = 18.3s, SD = 3.2s vs. M = 23.4s, SD = 4.1s, $p < 0.05$) and had a smaller error rate (experimental group 5.4 vs. control group 8.1, $p < 0.01$). It means that the application of normative tasks increased the cognitive integration capacity and effectiveness of the experiment member in performing tasks. The transfer of EEG showed further that the application of the task required the use of the frontal and parietal areas of the brain and the electrophysiological responses of the brain were significantly higher in the experimental group, particularly in the moments of decision-making when the ERP waveforms revealed a serious positive depolarization (Figure 1). This effect implies that experimental group participants gave more attention to the processing of normative-related information, which leads to an increase in cognitive load. The results of the EEG responses by the experimental and the control groups on critical decision points is presented in Figure 1 and indicated that the brain activity of the experimental group was more focused and enhancing, as compared to that of the control group, supporting the promoting influence of normative adherence on the cognitive processing.

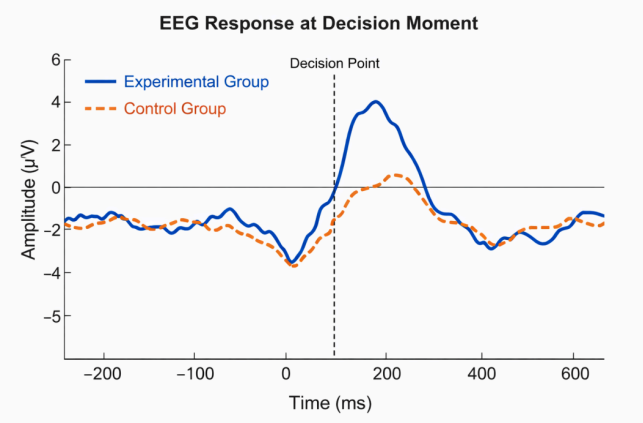

Figure 1. EEG waveform differences between the experimental and control groups at decision-making moments

4.2. EEG results

When considering EEG data analysis, analysis showed that the experimental and control groups differed considerably in terms of the activity of their brains in the frontal and parietal regions. ERP analysis indicated that experimental group demonstrated higher capabilities of cognitive integration ability when performing the normative tasks particularly when they had to make a decision. The

DOI: 10.54254/2755-2721/2026.32661

motivation of the brain activity of the study of Table 1 shows the intensity of the brain activity of the different groups at various stages of the task. At the decision-making period, frontal brain activity of the experimental group was quite high compared to the control group (experimental: $M = 0.76$ μV, $SD = 0.12$ μV and control: $M = 0.58$ μV, $SD = 0.09$ μV, $p < 0.05$). Also, in the parietal area, the experimental group was more synchronized in the brain activity, which demonstrates the strong effect of normative adherence, which affects cognitive processing. The information presented in Table 1 also substantiates the presence of normative cognitive structures as a guiding force in the learning process as the data indicated that the frontal and parietal areas of the brain are very important in the processing of normative information.

Table 1. Brain activity intensity at different task stages in the experimental and control groups

Group	Task Stage	Frontal Activity (μV)	Parietal Activity (μV)
Experimental Group	Decision-Making Moment	0.76 ± 0.12	0.65 ± 0.10
Control Group	Decision-Making Moment	0.58 ± 0.09	0.52 ± 0.08
Experimental Group	Task Completion Moment	0.73 ± 0.11	0.62 ± 0.09
Control Group	Task Completion Moment	0.60 ± 0.10	0.55 ± 0.07

5. Discussion

Based on the results of this study, it can be concluded that normative cognitive structures play an important role in the learning process by enhancing the cognitive integration capabilities of the learner and the efficiency of task execution. The experimental group surpassed the control group in normative tasks, and EEG signals were recorded for brain response to normative information processing. This study is the first to explore the impact of normative adherence from the perspectives of both educational philosophy and experimental psychology by combining the normative issues in the field of educational philosophy with the empirical analysis of experimental psychology. Nevertheless, this study has certain limitations. Firstly, the sample size and the singularity of the experimental task may influence the results. Secondly, the study only observed the effects of normative adherence by means of short-term task completion; the long-term effects can be further verified through long-term intervention experiments.

6. Conclusion

This study focuses on the role and formation mechanisms of normative cognitive structures in the process of learning. This study, based on the theories of educational philosophy and experimental psychology, uses experimental methods and EEG technology to explore the impact of normative behavior on cognitive development. The experimental results suggest that, in the process of learning, adhering to norms can significantly improve the performance of learners, with certain brain regions showing higher levels of activity in the EEG, which proves the significance of normative cognitive structures in cognitive development. Although there are some limitations in this study, it presents a new perspective on the design of normative teaching in practice and offers a basis for further research in the field of education in the future, which could focus on the differences in normative cognitive structures in different cultures and education systems and their long-term impact on learning outcomes.

DOI: 10.54254/2755-2721/2026.32661

References

[1] Williamson, Ben, Jessica Pykett, and Dimitra Kotouza. "Learning brains: educational neuroscience, neurotechnology and neuropedagogy." Pedagogy, Culture & Society (2025): 1-21.
[2] Li, Yue, et al. "Exploring dynamics in learners' cognitive engagement associated with learning activities using EEG microstate approach." Thinking Skills and Creativity (2025): 101911.
[3] Wu, Shu-Fen, et al. "A Method Detecting Student's Flow Construct during School Tests through Electroencephalograms (EEGs): Factors of Cognitive Load, Self-Efficacy, Difficulty, and Performance." Applied Sciences 12.23 (2022): 12248.
[4] Syed, Madiha Khalid, et al. "EEG-Based Attention Classification for Enhanced Learning Experience." Applied Sciences 15.15 (2025): 8668.
[5] Shih, Chuan-Cheng, et al. "Electroencephalography (EEG) Predicts the Success of Scientific Conceptual Changes Involving Weak and Radical Restructuring." Journal of Science Education and Technology (2025): 1-15.
[6] Hong, Yi-Kyung, and Ji Young Cho. "Characteristics of physical environments that enhance learning: A systematic review of EEG-Based empirical studies." Journal of Environmental Psychology 102 (2025): 102525.
[7] Gkintoni, Evgenia, et al. "Challenging cognitive load theory: The role of educational neuroscience and artificial intelligence in redefining learning efficacy." Brain Sciences 15.2 (2025): 203.
[8] Pradeep, K., et al. "Neuroeducation: Understanding neural dynamics in learning and teaching." Frontiers in Education. Vol. 9. Frontiers Media SA, 2024.
[9] Khan, Rozemun, et al. "Assessing cognitive load using EEG and eye-tracking in 3-D learning environments: A systematic review." Multimodal Technologies and Interaction 9.9 (2025): 99.
[10] Sun, Yuzhi, and David A. Nembhard. "Knowledge representation learning with EEG-based engagement and cognitive load as mediators of performance." Behaviour & information technology 44.13 (2025): 3180-3193.
[11] Mohamed, Norliza, and Salmiza Saleh. "Brainwaves and higher-order thinking: An EEG study of cognitive engagement in mathematics tasks." International Electronic Journal of Mathematics Education 20.4 (2025): em0852.