

THE EFFECT of USING PID INTERACTIVE MEDIA on CRITICAL THINKING SKILLS of GRADE V STUDENTS at SD NEGERI 4 SUKAJAWA

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Article Info

Keywords:

critical thinking, elementary school, interactive PID media, quasi experiment, science learning

Informasi Artikel

Kata Kunci:

Berpikir kritis, kuasi eksperimen, media interaktif PID, pembelajaran ipas, sekolah dasar.

Article History

ABSTRACT

This study examines the effectiveness of Digital Interactive Boards (DIB) in fostering critical thinking skills among fifth-grade elementary school students. The central premise of this investigation stems from the persistent gap between the availability of technological infrastructure in educational settings and its suboptimal utilization for advancing higher-order thinking competencies. A quantitative approach employing a quasi-experimental nonequivalent control group design was applied to 40 students of SD Negeri 4 Sukajawa, Bandar Lampung, divided equally into two groups. The experimental group received DIB-assisted instruction, while the control group underwent conventional teaching methods. Data were collected through a 10-item essay instrument constructed upon Facione's six critical thinking indicators, demonstrating satisfactory validity (CVI=0.92) and reliability (Cronbach's Alpha=0.865). Hypothesis testing was conducted using an Independent Sample t-test, N-Gain analysis, and Cohen's d effect size measurement. Findings revealed a statistically significant difference in post-test scores between both groups (85.35 vs. 68.42), corroborated by $t=8.735$ ($p<0.001$). The magnitude of effect was classified as very large (Cohen's $d=2.33$), with the experimental group demonstrating a moderate-to-high improvement (N-Gain=0.69) compared to the control group's moderate gain (N-Gain=0.34). These results affirm that DIB integration substantially advances students' critical thinking development. It is recommended that future instruction be structured around problem-based learning frameworks, accompanied by systematic reinforcement of teachers' TPACK competencies.

ABSTRAK

Penelitian ini bertujuan menganalisis efektivitas penggunaan Papan Interaktif Digital (PID) dalam meningkatkan keterampilan berpikir kritis siswa kelas V sekolah dasar. Kesenjangan antara ketersediaan infrastruktur teknologi dan pemanfaatannya secara optimal untuk pembelajaran tingkat tinggi menjadi landasan utama kajian ini. Pendekatan kuantitatif dengan rancangan kuasi-eksperimen tipe *nonequivalent control group* diterapkan pada 40 siswa SD Negeri 4 Sukajawa, Bandar Lampung, yang terbagi merata menjadi dua kelompok. Kelompok eksperimen menerima pembelajaran berbantuan PID, sedangkan kelompok kontrol mengikuti pembelajaran konvensional. Pengumpulan data dilakukan menggunakan instrumen esai sebanyak 10 butir yang dikembangkan berdasarkan enam indikator berpikir kritis Facione, dengan tingkat validitas CVI=0,92 dan reliabilitas Cronbach's Alpha=0,865. Pengujian hipotesis menggunakan Independent Sample *t*-test, N-Gain, serta Cohen's *d*. Temuan penelitian memperlihatkan perbedaan capaian postes yang signifikan antara kedua kelompok (85,35 vs. 68,42), dikonfirmasi oleh nilai $t=8,735$ ($p<0,001$). Besaran pengaruh yang diperoleh tergolong sangat tinggi (Cohen's $d=2,33$), dengan peningkatan kelompok eksperimen berkategori sedang-tinggi (N-Gain=0,69) dibandingkan kelompok kontrol yang berkategori sedang (N-Gain=0,34). Hasil ini menegaskan bahwa integrasi PID secara signifikan mendorong perkembangan kemampuan berpikir kritis siswa. Sebagai tindak lanjut, disarankan agar pembelajaran dirancang berbasis masalah dengan dukungan penguatan kompetensi TPACK tenaga pengajar.

Received : 10/08/2026

Revised : 15/09/2026

Accepted : 21/10/2026

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1. Introduction

Basic education serves as a strategic foundation for enhancing students' cognitive, affective, and psychomotor capacities before they advance to the next level. In the era of the Fourth Industrial Revolution and Society 5.0, there has been a fundamental shift in the educational paradigm—from a traditional, teacher-centered learning model to an interactive learning system that places greater emphasis on students[1]. Mastery of higher-order thinking skills is essential for this shift, particularly critical thinking skills, which are a prerequisite for the development of other skills. The Merdeka Curriculum policy, which is part of the national education policy, identifies critical thinking as a key element of the Pancasila Student Profile. This underscores the need to cultivate these skills starting in elementary school. The digitization of education has spurred the introduction of a variety of advanced technological devices into classrooms across Indonesia. Through initiatives to accelerate digital transformation, the government has allocated funds to provide devices such as Digital Interactive Whiteboards (DIWs) to thousands of elementary schools[2]. Real-time object manipulation software, a high-resolution touch panel, and built-in internet connectivity enable this device to transform learning from passive to interactive. According to an analysis of educational media development needs, students greatly prefer interactive media with engaging instant feedback mechanisms.[3]. However, the availability of advanced hardware does not automatically correlate positively with an improvement in the quality of students' thinking processes. This is the case if the hardware is not used properly.[4]. Empirical studies show that the use of PIDs in various elementary schools often reduces the function of interactive tools to that of a mere one-way display medium. [5]. To ensure that students' critical thinking skills are truly enhanced, the development of interactive digital media must be thoroughly planned and employ a learning approach that focuses primarily on solving real-world problems. In addition, problem-based learning has been shown to significantly improve students' critical thinking skills and their independence in learning at school[4]. These findings confirm that without instructional design focused on improving thinking skills, the presence of digital devices in the classroom will not immediately enhance students' cognitive abilities. Therefore, interactive media must be developed with equal consideration of both pedagogical and technical aspects.[6].

The research site was SD Negeri 4 Sukajawa in Bandar Lampung, which accurately reflects these conditions. Although this school received a grant for PID devices, initial observations indicate that their use is still limited to linear, one-way presentation of material. Technology-based interactive books have been found to enhance critical thinking skills when used in conjunction with the appropriate learning approach[7]. The fifth-grade students at this school, who are between ten and eleven years old, are theoretically in a period of cognitive transition that bridges the concrete operational phase and the early operational stage[8]. At this point, students are beginning to master abstract reasoning, but they are still heavily influenced by hands-on, empirical experiences and visual representations[9]. At this stage, the development of critical thinking skills among elementary school students requires concrete visual scaffolding. The "Question-Have Student"

method uses scrapbooks to assess students' critical thinking skills[10].

A person with critical thinking skills is able to take wise actions and form sound opinions through cognitive analysis and reflection[11]. A systematic literature review found that elementary school students' critical thinking skills can be improved through the use of learning tools, especially when used in conjunction with interactive and contextual content[12]. The use of Articulate Storyline interactive multimedia has been shown to contribute significantly to the improvement of elementary school students' critical, analytical, and evaluative thinking skills[13]. Theoretically, interactive multimedia with touchscreens and immediate feedback can serve as a visual scaffold to connect abstract concepts with real-world objects.

Over the past five years, a comprehensive literature review of scientific publications indexed in Scopus and Sinta has shown that there has been little research on the application of PID to critical thinking. Studies indicate that, more than the technology itself, the success of information technology in enhancing critical thinking skills depends on the strength of active learning design.[14]. According to the research, only about one-third of the studies reviewed assessed important cognitive metrics such as problem-solving, analysis, and evaluation, even though interactive media and Android-based media generally increase student participation[15]. In addition, it was found that PID has been shown to increase student motivation and engagement. However, there is still little empirical evidence regarding its impact on specific indicators of critical thinking[16].

Three factors account for the novelty of this study. First, no previous study has evaluated all six of Facione's indicators of critical thinking—interpretation, analysis, evaluation, inference, explanation, and self-regulation—simultaneously in relation to the use of PID in elementary schools. Previous studies have typically assessed critical thinking only in general terms or, at most, three of these indicators [13], [15]. Second, because this study employed a quasi-experimental design with strict controls (the same teachers, the same time allocation, and the same instructional materials), the treatment effects could be better isolated than in previous studies, which often used different teachers[2],[16]. Third, although IPAS requires integration between science and social studies, the contextualization of IPAS subjects within the Merdeka Curriculum has rarely been studied.

Given this background, the purpose of this study is to evaluate and measure the impact of Digital Interactive Whiteboards (DIWs) as an interactive medium on the critical thinking skills of fifth-grade students at SD Negeri 4 Sukajawa. Specifically, this study tests the hypothesis that there is no significant difference in average critical thinking skills between the group of students learning through conventional methods (H0) and the group of students learning with DITs (H1). This study is expected to make a theoretical contribution toward enhancing digital pedagogical resources in Indonesia and to support constructivist theory in the context of technology-based learning. On a practical level, the findings of this study can serve as evidence-based guidelines for teachers and school principals to optimize digital pedagogical tools so that they become more

than just presentation tools; they must become strategic tools that actively foster students' critical thinking.

2. Method

This study employed a quantitative approach and utilized a quasi-experimental design. More specifically, a non-equivalent control group design was used. In this type of design, two groups of subjects were assigned without randomization: one experimental group received a PID media-assisted learning intervention, while the control group participated in conventional learning. Prior to the intervention, both groups took a pre-test. The final test was administered after the treatment was completed[17]. Students received scores on the critical thinking skills test, which formed part of the quantitative data collected in this study. Data were collected through a pretest (before the intervention) and a posttest (after the intervention). Students used six key thinking standards to assign scores: interpretation, analysis, evaluation, inference, explanation, and self-regulation. Each test item was scored on a scale of 0 to 4, so the maximum total score was 40[11]. There were a total of 40 fifth-grade students at SD Negeri 4 Sukajawa in Bandar Lampung during the 2025–2026 school year, divided into two separate classes. Purposive sampling was used to select the sample based on several criteria. These included comparable IPAS scores from the odd-numbered semester, the availability of PID devices in one of the classrooms, and the willingness of teachers and parents. Class VA had 20 students in the experimental group, and Class VB had 20 students in the control group. Because the sample size was manageable, the entire population was used as the sample[18]. The measurement tool used was a 10-item open-ended question test designed to measure critical thinking skills. Prior to implementation, this instrument underwent a validation process conducted by three experts (a pedagogy professor, an educational technology practitioner, and a fifth-grade teacher) and achieved a content validity index (CVI) of 0.92. Test results from respondents outside the sample confirmed that all test items were valid (r-value

> 0.30) and that the instrument had high reliability with a Cronbach's Alpha coefficient of 0.865[19].

The study was conducted over five weeks with the following stages[20]:

Week I (pretest): Both groups took the initial critical thinking skills test for 70 minutes (2 × 35 minutes) simultaneously.

Weeks 2–4 (intervention): The experimental group studied using PID-based materials for 3 sessions per week (a total of 12 instructional hours). Each session followed this sequence: a PID simulation was used to frame the problem, variables were identified through direct touchscreen manipulation, hypotheses were tested using immediate feedback, conclusions were drawn, and results were presented.

The control group used lectures, question-and-answer sessions, whiteboard-assisted discussions, and static projector images that were not directly manipulated by the students.

Week V (Posttest): The critical thinking test was administered again to both groups using the same questions as the pretest, with the item order randomized and the same level of difficulty.

To ensure internal validity, the researchers ensured that the same teachers taught both groups, that the time allocation and frequency were the same, that the same instructional material (the Merdeka Curriculum) was used, and that the pre- and post-test schedules were the same[21].

Before testing the hypotheses, the Shapiro-Wilk normality test was used (since $n < 50$ per group) and Levene's test for homogeneity of variances. The data were considered to meet the requirements if the p-value was greater than 0.05[22]. To ensure that the two groups were equivalent before the treatment, the pretest scores were analyzed using an independent samples t-test at a 5% significance level ($\alpha = 0.05$)[23].

After the prerequisite tests were completed, the hypotheses were tested using a two-tailed independent-samples t-test at a 5% significance level ($\alpha = 0.05$). The hypotheses tested[24]:

H_0 : There is no difference in the mean critical thinking ability between the experimental and control groups.

H_1 : There is a difference in the mean critical thinking ability between the experimental and control groups.

Criteria: H_0 is rejected if the significance value (two-tailed) is < 0.05.

To measure the increase in critical thinking ability resulting from the treatment, the N-Gain score is calculated using Hake's formula[25]:

Categories: $g \geq 0.70$ (high); $0.30 \leq g < 0.70$ (moderate); $g < 0.30$ (low)[26].

In addition, to measure the effect size in practical terms, Cohen's d is calculated using the following formula[27]:

$$d = \frac{Mean_1 - Mean_2}{SD_{pooled}}$$
$$SD_{pooled} = \sqrt{\frac{SD_1^2 + SD_2^2}{2}}$$

where

Categories: $d \leq 0.2$ (small), $0.2 < d \leq 0.5$ (moderate), $0.5 < d \leq 0.8$ (large), $d > 0.8$ (very large).

All analyses were conducted using Jamovi software (Version 2.5)[24]. The Ethics Committee of Yogyakarta State University, the Bandar Lampung City Education Office, and the Principal of Sukajawa Public Elementary School No. 4 granted permission for this study. After the research objectives and procedures were explained, the students' parents or guardians provided written consent, also known as informed consent. Participation was voluntary, and student identities were kept confidential using respondent codes[18].

3. Results and Discussion

3.1 Data Description and Experimental Procedure

This quasi-experimental study examines how a pedagogical intervention using a Digital Interactive Whiteboard (DIW) affects the critical thinking skills of fifth-grade middle school students in the IPAS subject. Using a non-equivalent control group design, The study compared the experimental group (Class VA, $n=20$), which learned using PID, with the control group (Class VB, $n=20$), which learned using conventional methods (blackboard and static projector). Six indicators of critical thinking—interpretation, analysis, evaluation, inference, explanation, and self-regulation—were measured using an open-ended essay instrument based on empirical cases. The results showed that they were valid ($CVI = 0.92$) and reliable (Cronbach's Alpha= 0.865). The framework developed by Facione is referred to as “critical thinking”[11].

The average score for the experimental group was 52.14 (standard deviation 7.42), and for the control group it was 51.85 (standard deviation 7.65) in the pretest phase. After the intervention, both groups showed improvement, but with very different results. The experimental group achieved a posttest average of 85.35 with a standard deviation of 6.18, while the control group achieved only 68.42 with a standard deviation of 8.24. The experimental group had an N-Gain index of 0.96, indicating a moderate category; the control group had an N-Gain index of 0.34, which also indicated a moderate category. The experimental group achieved a mean pretest score of 52.14 with a standard deviation of 7.42, while the control group achieved a mean score of 51.85 with a standard deviation of 7.65. The minimum and maximum values for the experimental group were 39.66 and 66.66, and for the control group, 36.58 and 65.05. Here, there was no significant difference between the two groups before treatment, according to an independent samples t-test, with a pretest t-score of 0.124 and $p = 0.902$ ($p > 0.05$). For differences in the posttest phase to be attributed to the treatment, this initial equivalence is an important prerequisite.

There was a marked improvement following the one-month intervention, which consisted of twelve class hours. The experimental group achieved a posttest average of 85.35, with the standard deviation decreasing to 6.18, while the control group achieved an average of only 68.42, with the standard deviation increasing to 8.24. The scores obtained by the experimental group ranged from 72 to 96, while those of the control group ranged from 54 to 82. The decrease in standard deviation in the experimental group indicates that the use of PID not only accelerates learning among high-achieving students but also helps low-achieving students understand the material in a more equitable and inclusive manner. These results are consistent with previous studies on how effective PID is in increasing student engagement and motivation to learn[2].

The hypotheses of normality and homogeneity were tested prior to testing the main hypotheses. Based on the results of the Shapiro-Wilk test, the pretest and posttest data for both groups were found to be normally distributed, with significance values of 0.314 and 0.388 for the experimental group and 0.152

and 0.210 for the control group, all of which were above the 0.05 threshold. For the posttest data, Levene's test yielded a p-value of 0.240 ($p > 0.05$), indicating that the variance across groups is homogeneous. If both prerequisites are met, the use of the independent samples t-test is appropriate.

3.2 Hypothesis Testing and Treatment Effects

A statistically significant difference was demonstrated by the results of the independent samples t-test on the posttest scores. The t-test results showed an absolute calculated t-value of 8.735, with 54 degrees of freedom (df) and a significance level (p) less than 0.001. Since the p-value is much smaller than the alpha level of 0.05, the null hypothesis (H_0)—which states that there is no difference in critical thinking ability between the two groups—is rejected. Therefore, there is a significant causal difference attributable to the use of PID; the mean difference ($\Delta\mu$) is 16.92 points.

The Normalized Gain (N-Gain) calculation, as described by Hake, was performed to measure the practical significance of the intervention while controlling for the ceiling effect on January 14, 2014, at 7:24 pmg [26]. The experimental group obtained an N-Gain index of 0.69, which falls at the upper threshold of the “Moderate” category, bordering on “High” (since 0.69 is not exactly 0.70 but is very close). On the other hand, the control group had an N-Gain index of only 0.34, which falls at the lower end of the “middle” category. In addition to N-Gain, Cohen's d effect size was also calculated to measure the practical magnitude of the treatment's effect. Based on the posttest data, Based on the effect size calculation using Cohen's d formula, a value of 2.33 was obtained. According to the criteria established by Cohen[27], this figure falls into the “very large” effect category because it exceeds the threshold of 0.8. This finding supports the notion that the difference between the two groups is both practically meaningful and statistically significant. While conventional methods tend to hinder conceptual understanding, these data suggest that PID can provide effective cognitive scaffolding to help students transition from concrete to abstract thinking.

3.3 Microanalysis Based on Facione's Six Indicators of Critical Thinking

When Facione's six indicators[11] are analyzed separately, the findings show that the experimental group outperformed the control group on all indicators. Table 2 presents a comparison of N-Gain by indicator.

Table 2. Comparison of N-Gain in Critical Thinking Skills Based on Indicators

In other words, three indicators (interpretation, analysis, and explanation) succeeded in elevating the experimental class to the “High” category, while the other three indicators were also very good. Findings regarding the importance of self-reflection in learning also support better self-regulation[28]. The following is a theoretical explanation of these benefits. The 4K visual resolution and the PID digital annotation feature for interpretation serve as attention filters that help students focus on specific IPAS objects. This makes abstract material meaningful. The touchscreen functionality in the analysis enables embodied intelligence: students can test hypotheses directly and discover cause-and-effect relationships through physical experience. A meta-analysis confirms that touchscreen devices significantly enhance early childhood learning[27]. In evaluations, gamification and instant polls create real-time transparency regarding opinions, trigger cognitive conflict, and help assess peers’ arguments. In inference, multitouch capabilities transform a single study desk into a collaborative workspace, enabling students to construct logical conclusions together. In explanation, wireless screen mirroring enhances students’ academic performance and reduces affective barriers (affective filters). The self-regulation system allows students to correct misconceptions voluntarily and independently by providing corrective feedback without a judgmental tone.[29].

3.4 Comparison with Previous Research

These findings clarify and enrich the results of previous studies. [13] According to that study, the Articulate Storyline interactive multimedia program improved elementary school students’ critical thinking skills by an N-Gain of 0.61, which falls into the moderate category; however, this study found a higher N-Gain (0.69). This improvement is likely due to the PID’s touchscreen feature, which allows for direct manipulation of objects (kinesthetic interaction), whereas Articulate Storyline is click-based (interaction limited to the mouse).

[16]This study differs from previous studies, which found only an increase in learning motivation ($d = 0.45$) without a significant increase in evaluation and analysis indicators. In contrast, this study found indicators for interpretation ($d = 1.98$) and analysis ($d = 1.89$). This can be explained by the application of problem-based learning steps carried out in a sequential and structured manner in this study; each session began with an introduction to the problem through a PID simulation.

[2]A study reported that PID increases student engagement ($d = 0.76$) but does not directly measure critical thinking skills. This study fills that gap by demonstrating that the increase in engagement facilitated by PID does indeed lead to an increase in critical thinking ($d = 2.33$). [30]Furthermore, these findings are consistent with the results of a meta-analysis, which concluded that touchscreen devices have a moderate to large effect on early childhood learning (mean $d = 0.58$). However, due to the longer duration of the intervention (12 hours) and the use of the PBL model, this study showed a much larger effect ($d = 2.33$).

3.5 Theoretical Discussion: Cognitive Load Theory and Sociocultural Constructivism

Indicator	N-Gain Experiment	Category	N-Gain Control	Category
Interpretation	0.74	High	0.38	Moderate
Analysis	0.72	High	0.35	Moderate
Evaluation	0.65	Moderate	0.31	Moderate
Inference	0.68	Moderate	0.32	Moderate
Exploration	0.71	High	0.33	Moderate
Self regulation	0.63	Moderate	0.34	Moderate

Two main theoretical frameworks underpin the effectiveness of PID from a philosophical perspective. First, PID functions as a regulator of cognitive load across two channels[30]. The kinesthetic channel (touch and direct manipulation), the auditory channel (the teacher’s narration and the PID’s voice), and the visual channel (high-resolution animations and diagrams) deliver information in a balanced manner. As a result, extraneous cognitive load is significantly reduced. Consequently, the freed-up working memory can be fully utilized for higher-order thinking skills (HOTS). This effect is enhanced by the use of interactive simulations, which enable safe and flexible virtual experiments[31]. Second, it is crucial to apply the concept of the Zone of Proximal Development in sociocultural constructivism[32]. PID functions as a digital scaffold that knows more than others (MKO)—an artificial scaffold that fosters an ecosystem of intellectual dialogue and empirical dialectics. Students now rely on teachers as their sole source of knowledge; they now collaborate in front of interactive screens to learn. According to self-determination theory, the social connectedness and autonomy facilitated by PID enhance students’ intrinsic motivation[33].

3.6 Research Implications

Theoretical implications: This study shows that multimodal media—visual, audio, and kinesthetic—help reduce external cognitive load. This is evidenced by the increase in N-Gain in the experimental group[30]. It can be shown that PID can help students aged 10–11 transition from the concrete to the abstract by extending Vygotsky’s ZPD concept to the digital realm (Digital MKO). Based on these findings, teachers are advised to: (a) design hands-on activities in PID for at least 15 minutes per session, (b) use the instant polling feature to enhance cognitive conflict, (c) provide non-judgmental corrective feedback through digital annotations, and (d) systematically integrate PID with problem-based learning (PBL) rather than simply using it as a digital whiteboard.

Implications for schools and education agencies: In addition to providing hardware, school principals must provide TPACK (Technology, Pedagogy, and Content Knowledge) training to teachers. Since this study shows that the effectiveness of PIDs depends heavily on instructional design ($d = 2.33$) rather than on the sophistication of the devices themselves, education agencies must allocate funds for technical support following the procurement of PIDs

3.7 Limitations of the Study

This study acknowledges certain limitations. First, the quasi-experimental design—in which the control group was not comparable—did not fully control for external variables such as students' initial motivation or the influence of teacher-student interactions, which may vary even when the same teacher is involved. Second, the generalizability of the findings to a larger population is limited by the relatively small sample size ($n = 20$ per group). by the relatively small sample size ($n = 20$ per group). Research with a larger sample size (n greater than 50 per group) is needed to confirm these results. Third, essay tests, even when validated, can still produce subjective scores. The use of double-blind scoring and more detailed scoring rubrics can help reduce this bias. Fourth, to test the long-term sustainability of the PID's effects, a one-month intervention (12 class hours) is not sufficient. Long-term studies—such as those lasting six months or one year—are needed. Fifth, this study did not account for factors that could influence the treatment's effects, such as students' learning styles, parents' digital literacy, or support for learning at home. Sixth, studies with a longer habituation period prior to measurement can mitigate the novelty effect (related to the new technology).

These findings will be further strengthened if confirmed by follow-up studies using a randomized controlled trial (RCT) design, with a larger sample size, a longer duration, and consideration of moderator variables.

4. Conclusion

Based on all the data and discussions, the use of Digital Interactive Whiteboards (DIWs) overall had a positive, significant effect and contributed substantially to improving the critical thinking skills of fifth-grade elementary school students in the IPAS subject. The t -value is 8.735 with $p < 0.001$, Cohen's $d = 2.33$ (very large effect), and the experimental N-Gain is 0.69 (compared to 0.34 for the control group). Three indicators (interpretation, analysis, and explanation) of Facione's six metacognitive pillars achieved the "High" category. Multimodality and digital sociocultural scaffolding support PID. However, the success of this technology depends entirely on educators' TPACK competencies. Furthermore, the role of teachers has shifted from that of knowledge transmitters to facilitators of inquiry-based learning environments. Further research is recommended to examine the effectiveness of PID in the social sciences and humanities, to assess teachers' readiness for digital literacy more comprehensively, and to use an RCT design with a larger sample size. The goal of these recommendations is to develop critical thinking skills in various situations.

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