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Article

Profile of Students' Science Process Skills on Electrolyte and Non-Electrolyte Solution Material Assisted by E-LAPD Based on Guided Inquiry in Senior High School

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A B S T R A C T

This study addresses the low mastery of science process skills (SPS) among high school students on electrolyte and non-electrolyte solution material, exacerbated by the limitations of conventional E-LAPD in the Industry 4.0 era. It aims to identify the SPS profile of grade XI students purposively sampled at SMA Muhammadiyah 4 Sidayu, Gresik, through a mixed descriptive preliminary study design. The instruments comprised a reliable essay-based SPS test measuring six key indicators — observation, classification, prediction, measurement, communication, and conclusion drawing — supplemented by questionnaires and interviews, analyzed through descriptive statistics and qualitative content analysis. The findings reveal that all students fell within the very low to low SPS categories, with no students reaching the medium or high level. Conclusion drawing emerged as the relatively strongest indicator, while communication was the weakest, reflecting students' greater proficiency in concrete observation-based skills over complex scientific reasoning. These findings confirm that conventional E-LAPD, which only contains material summaries and practice questions, fails to facilitate inquiry-based learning, necessitating the development of guided inquiry-based E-LAPD to systematically improve students' SPS.

Keywords: *E-LAPD, Guided Inquiry, Science Process Skills, Electrolyte Solution, Student Profile*

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INTRODUCTION

The Industrial Revolution 4.0 and the post-pandemic situation have shifted the educational paradigm, requiring high school students to master science process skills (SPS) such as observation, classification, measurement, communication, prediction, and conclusion drawing to address complex global challenges. SPS is a key foundation in chemistry learning, as it enables students to systematically apply scientific thinking in everyday life (Widodo, 2015; Azwar, 2020). The topic of electrolyte and non-electrolyte solutions often presents challenges due to its abstract and submicroscopic nature, requiring active exploration for in-depth understanding (Sari & Putra, 2018; Wulandari, 2023). Recent research shows that integrating SPS into high school chemistry learning can significantly improve learning outcomes through an inquiry-based approach (Rahmawati et al., 2021; Aisyara, 2020). This phenomenon is increasingly relevant in Indonesia, where students still struggle to translate observations of electrical phenomena into the concept of ionization.

Previous studies have examined SPS in chemistry learning from various angles. Aisyara (2020) documented students' basic SPS profiles on electrolyte and non-electrolyte solutions, while Aqmarina et al. (2022) explored the potential of guided inquiry-based practicum worksheets to develop KPS in the same topic. Rahmawati et al. (2021) further demonstrated that discovery learning approaches can improve students' SPS on electrolyte material, and Kusuma (2022) confirmed a significant relationship between SPS achievement and overall chemistry learning outcomes. These studies collectively establish that inquiry-oriented approaches hold promise for improving SPS; however, they predominantly focused on urban or state schools, with limited attention to the contextual challenges faced by rural Muhammadiyah schools where digital learning infrastructure remains constrained. Furthermore, no study has specifically examined the SPS profile of students who are already using conventional E-LAPD as their primary digital learning medium, leaving a critical gap in understanding how existing digital tools either support or hinder inquiry-based SPS development at the school level.

The main problem arises from students' low mastery of SPS in electrolyte and non-electrolyte solutions, which impacts conceptual understanding and overall learning outcomes. Studies show that high school students tend to be weak in integrated SPS indicators such as prediction and inference, with an average achievement below 50% on essay tests (Kusuma, 2022; Aqmarina et al., 2022). Conventional E-LAPD media at SMA Muhammadiyah 4 Sidayu only contains summaries and practice questions, so 63.2% of students feel they are not facilitated to think critically (Wahyudi & Santoso, 2023; Rosa et al., 2022). This is exacerbated by the lack of guided inquiry scaffolding, which causes students to fail to connect laboratory observations with scientific conclusions (Hartono, 2021; Ardhiani, 2025).

The redesign of E-LAPD is therefore urgently needed for three interconnected reasons. First, the current E-LAPD operates solely as a content delivery tool — providing material summaries and practice questions — without embedding the inquiry process that SPS development requires (Wahyudi & Santoso, 2023; Fitriani, 2019). Second, the abstract and submicroscopic nature of electrolyte concepts demands scaffolded, step-by-step exploration that static digital documents cannot provide, causing students to resort to rote memorization rather than scientific reasoning (Sari & Putra, 2018; Rasmawan et al., 2021). Third, in the Industry 4.0 era, digital learning media must evolve beyond passive content repositories into interactive platforms that guide students through observation, hypothesis formation, and evidence-based conclusion drawing — functions that the existing E-LAPD at SMA Muhammadiyah 4 Sidayu demonstrably lacks (Prasetya & Lestari, 2020; Rosa et al., 2022). Preliminary data from questionnaires and tests at SMA Muhammadiyah 4 Sidayu confirmed that 60% of students were in the very low SPS category and 40% were in the low category, with no students reaching the medium or high levels. Eighty percent of students considered abstract material difficult to understand without interactive media, while 70.8% assessed that the current E-LAPD did not support exploration (Fitriani, 2019; Prasetya & Lestari, 2020). This gap reflects the failure of digital media to facilitate the inquiry process, resulting in students being trapped in memorization rather than scientific application (Rasmawan et al., 2021).

This study aims to identify the SPS profile of grade XI students on the topic of electrolyte and non-electrolyte solutions assisted by conventional E-LAPD at SMA Muhammadiyah 4 Sidayu, Gresik, as an empirical basis for developing guided inquiry-based E-LAPD. The urgency lies in the need to improve SPS for student readiness in the Industry 4.0 era, where 65% of high school chemistry students are still below the national standard. The novelty of this study is an in-depth analysis of the specific SPS profile of electrolyte material within the context of conventional E-LAPD use, which has not been comprehensively explored in rural Muhammadiyah schools, thereby complementing previous studies with locally grounded empirical data (Prasetya & Lestari, 2020; Wulandari, 2023).

METHOD

This study used a qualitative and quantitative descriptive approach with a preliminary study design to identify students' science process skills (SPS) profiles on electrolyte and non-electrolyte solutions. This mixed approach was chosen because it allowed for triangulation of data from essay tests, questionnaires, and interviews to provide a comprehensive picture of SPS achievement (Creswell & Creswell, 2023; Sugiyono, 2022). The descriptive design was appropriate to describe the actual condition of students' SPS assisted by conventional E-LAPD before the development of guided inquiry media, as recommended in similar studies (Emzir, 2021; Sudaryono, 2023). The study was conducted at SMA Muhammadiyah 4 Sidayu, Gresik, for one month with a focus on analyzing individual and group student profiles.

The research instrument included a six-item essay-based KPS test measuring six key indicators: observation, classification, measurement, communication, prediction, and conclusion drawing, with a Cronbach's Alpha reliability of >0.80. A student response questionnaire (25 items, 4-point Likert scale) and a semi-structured interview with a chemistry teacher complemented the primary data collection, validated by learning media experts (Wahyudi & Santoso, 2023; Fitriani, 2019). The data analysis technique used a descriptive statistical approach with Azwar's (2020) categorization based on the mean (X̅) and standard deviation (SD), resulting in five category intervals from very low to very high. Qualitative content analysis was conducted on the essay answers to identify patterns of conceptual errors, following the procedures of Sugiyono (2022) and Emzir (2021). Data were processed using SPSS version 26 for percentage presentation and distribution diagrams.

The study population was all 75 eleventh-grade students of SMA Muhammadiyah 4 Sidayu, Gresik. Twenty-five students of class XI MIPA 1 were selected through purposive sampling, a technique deliberately chosen because the primary objective of this preliminary study was to obtain a focused and information-rich profile of SPS among students who were most representative of the problem being investigated, rather than to achieve broad statistical generalization (Creswell & Creswell, 2023; Sudaryono, 2023). Purposive sampling was particularly appropriate here because the study required participants whose learning conditions directly reflected the limitations of conventional E-LAPD, ensuring that the resulting SPS profile could serve as a valid empirical foundation for subsequent media development. The 25 students were selected based on four explicit criteria: (1) enrolled in class XI MIPA 1 as the class with the lowest average midterm exam scores in chemistry among all three XI MIPA classes; (2) having actively used conventional E-LAPD as their primary learning medium throughout the electrolyte and non-electrolyte solutions unit; (3) demonstrating consistently low SPS indicators as identified from previous midterm examination rubric analysis by the subject teacher; and (4) willing to participate voluntarily and provide informed consent. This sample size is representative for a preliminary study and meets the assumption of normality of distribution (Creswell & Creswell, 2023; Sudaryono, 2023). The sample demographics were dominated by female students (60%) aged 16–17 years with average academic abilities, reflecting the general characteristics of rural Muhammadiyah schools (Hartono, 2021; Kusuma, 2022).

The research procedure began with two weeks of initial observations of chemistry lessons to identify the use of existing E-LAPD, followed by questionnaire administration and teacher interviews in the third week. The KPS test was administered in the fourth week after learning about electrolyte and non-electrolyte solutions using conventional E-LAPD, with a duration of 60 minutes and strict supervision to maintain validity. Data were collected sequentially for triangulation, analyzed over three days, and validated through member checking with subject teachers. Research ethics were maintained through informed consent and confidentiality of respondents' identities, in accordance with educational research standards (Sugiyono, 2022; Prasetya & Lestari, 2020). This procedure ensured a logical flow from problem identification to media development recommendations.

FINDINGS AND DISCUSSION

This study aimed to determine students' achievement in science process skills from a competency perspective. The test consisted of six essay questions. The test sheet included indicators of science process skills, namely observation, prediction, classification, measurement, communication, and conclusion drawing. These science process skills were developed through a guided inquiry learning model that facilitated students' observation of problems, formulation of questions and tentative assumptions, collection and analysis of data, and systematic drawing of conclusions.

Based on data obtained from the test results given to 25 students, they were grouped into very high, high, medium, low, and very low categories. Based on the assessment using these criteria, skill scores varied among students. However, no students achieved a medium or high skill level. The distribution of these skills is presented in Figure 1.

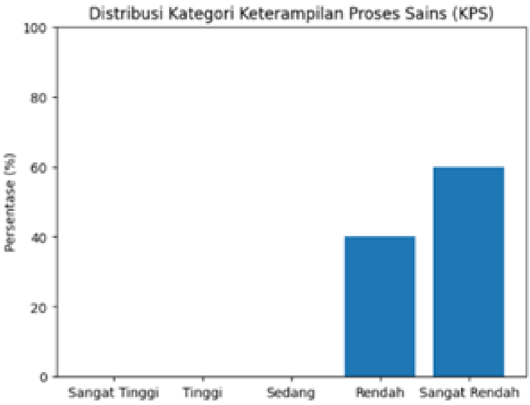


Figure 1. Diagram of the KPS Level of Muhammadiyah 4 Sidayu Gresik High School

Based on data obtained from test questions given to 25 students, they were grouped into high, medium, and low categories. Based on the assessment using these criteria, skill scores varied among students. Interestingly, no students achieved a high level of proficiency.

1. Berdasarkan hasil uji elektrolit terhadap larutan X dan Y, bagaimana Anda menjelaskan perbedaan intensitas nyala lampu dan jumlah gelembung gas yang terbentuk pada kedua larutan tersebut? Analisislah jenis elektrolit masing-masing larutan berdasarkan data yang diperoleh dan simpulkan faktor-faktor apa saja yang dapat mempengaruhi kuat atau lemahnya daya hantar listrik suatu larutan.….

Figure 2. Question 1 Observation

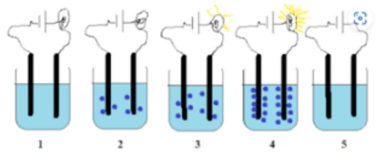
As seen in the example question in Figure 2, students were able to identify the difference in the light intensity and the number of gas bubbles formed in solutions X and Y as indicators of strong or weak electrical conductivity. Some students stated that the difference was caused by the type of electrolyte in each solution. However, the answers given were still incomplete because students had not clearly linked the intensity of the light intensity and the number of gas bubbles with the degree of ionization or the number of ions formed in the solution. This indicates that students' conceptual understanding of the relationship between electrolyte type, number of ions, and electrical conductivity is still partial and not fully able to explain the phenomenon scientifically and comprehensively.

2. Berdasarkan data hasil uji daya hantar listrik terhadap larutan X, Y, dan Z yang menunjukkan perbedaan jumlah gelembung gas dan intensitas nyala lampu, analisislah hubungan antara sifat elektrolit masing-masing larutan dengan daya hantarnya. Kemudian, jelaskan mengapa larutan Y memiliki daya hantar listrik yang paling kuat dibandingkan X dan Z.……..

Figure 3. Question 2 Classification

Based on the example question in Figure 3, students are able to group solutions X, Y, and Z based on their electrical conductivity as indicated by the difference in the intensity of the light and the number of gas bubbles formed. Some students have classified solution Y as a strong electrolyte, solution X as a weak electrolyte, and solution Z as a non-electrolyte according to the results of their observations. However, some answers are still not accompanied by the correct classification reasons based on the number of ions produced in the solution. This shows that students' classification skills have developed, but their understanding of the basis for grouping solutions based on their electrolyte properties still needs to be deepened.

3. Perhatikan gambar di bawah inii!



Berdasarkan gambar di atas, tuliskan narasi singkat mengenai apa yang kamu lihat!

Figure 4. Question 3 Predicting

Based on the example problem in Figure 4, students were able to predict the tendency of a solution's electrical conductivity to be strong or weak based on the initial information provided. Some students were able to predict that a solution that produces more ions would exhibit a brighter light and more gas bubbles. However, some predictions were still general guesses and not based on a precise understanding of the concept of electrolytes. This indicates that students' prediction skills have begun to develop, but still need strengthening in linking predictions to relevant scientific concepts.

4. Sebuah tim siswa melakukan eksperimen terhadap tiga jenis larutan: air gula, larutan asam cuka encer, dan larutan NaCl. Mereka mengamati intensitas nyala lampu dan jumlah gelembung gas yang terbentuk saat setiap larutan diuji dengan alat uji elektrolit. Data hasil pengamatan ditunjukkan sebagai berikut:

Larutan	Nyala lampu	Gelembung gas
Air gula	Mati	Tidak ada
Asam cuka encer	Redup	Sedikit
Larutan NaCl	Terang	Banyak

Analisislah hubungan antara hasil pengamatan daya hantar listrik dengan sifat kimia dari masing-masing larutan tersebut. Berdasarkan data di atas, jelaskan bagaimana perbedaan jenis ikatan dan derajat ionisasi dari ketiga larutan tersebut memengaruhi kemampuan menghantarkan listrik. Gunakan konsep elektrolit kuat, lemah, dan non-elektrolit untuk mendukung penalaranmu!

Figure 5. Question 4 Measurement

Based on the example question in Figure 5, students have demonstrated the ability to understand the results of measuring the electrical conductivity of solutions, as indicated by the intensity of the light and the number of gas bubbles. Some students were able to compare the measurement results between solutions well. However, there were still some answers that did not interpret the measurement results quantitatively or systematically. This indicates that students' measurement skills have developed sufficiently, but accuracy in reading and interpreting measurement results still needs to be improved.

5. Asam sulfat (H_2SO_4) digunakan sebagai elektrolit dalam aki kendaraan bermotor karena mampu menghantarkan listrik dengan sangat baik. Jelaskan secara ilmiah mengapa asam sulfat memiliki kemampuan tersebut, dengan mengaitkan proses ionisasi dalam air, kekuatan elektrolit, serta dampaknya terhadap efisiensi kerja aki. Bandingkan juga dengan senyawa lain yang bukan elektrolit dan jelaskan mengapa senyawa tersebut tidak cocok digunakan dalam sistem penyimpan daya seperti aki!

Figure 6. Question 5 Communication

Based on the example question in Figure 6, students were able to communicate the results of their observations and analysis of the electrical conductivity of solutions in writing. Some students were able to convey their answers coherently and used appropriate terminology, such as strong electrolytes, weak electrolytes, and nonelectrolytes. However, some answers were less systematic and did not clearly present the relationships between variables. This indicates that students' scientific communication skills have developed, but still need to be improved in terms of clarity of delivery and accuracy of terminology.

6. Dina ingin membuat minuman isotonik buatan sendiri. Ia mencampurkan air hangat dengan sedikit garam dapur (NaCl) dan gula pasir. Sebelum diminum, ia penasaran apakah larutan tersebut bisa menghantarkan listrik. Untuk itu, ia membandingkan tiga jenis larutan:
   1. Air gula
   2. Air garam
   3. Campuran air gula dan garam

   Ia menggunakan alat uji daya hantar listrik sederhana yang ia buat dari baterai, kabel, dan lampu kecil. Hasil pengamatannya:

Larutan	Lampu Menyala?	Keterangan Tambahan
Air gula	Tidak	Tidak terlihat perubahan
Air garam	Ya (terang)	Lampu menyala jelas
Campuran gula + garam	Ya (redup)	Lampu menyala sedikit redup

   Berdasarkan hasil pengamatan tersebut, simpulkan:
   1. Jenis larutan (elektrolit kuat, lemah, atau non-elektrolit) dari ketiga sampel.
   2. Mengapa lampu pada campuran gula dan garam menyala redup dibandingkan air garam murni?

Figure 7. Drawing Conclusions

Based on the example question in Figure 7, students were able to draw conclusions regarding the relationship between solution type and electrical conductivity based on their observations. Most students concluded that solutions with a greater number of ions had stronger electrical conductivity. However, some of the conclusions presented were general and not fully supported by specific observational data. This indicates that students' conclusion-drawing skills were quite good, but their ability to directly link conclusions to observational data still needed strengthening.

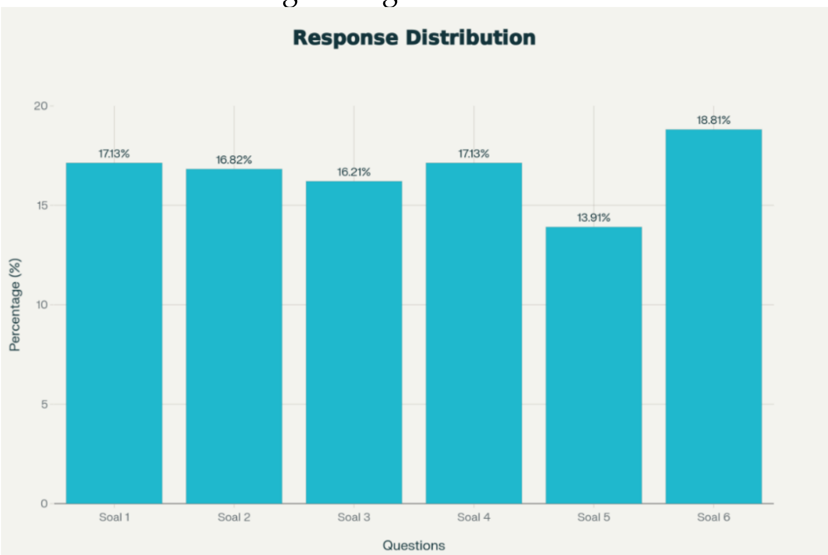


Figure 8. Percentage of KPS at Muhammadiyah 4 Sidayu Gresik High School

The results of Figure 8 are that 17.13% of students are able to observe, 16.82% of students are able to classify, 16.21% of students are able to predict, 17.13% of students are able to measure, 13.91% of students are able to communicate, and 18.81% of students are able to draw conclusions.

Electrolyte and nonelectrolyte solutions are chemistry topics for 11th grade high school students that encompass conceptual, factual, and procedural knowledge. Eighty percent of students stated that this topic is difficult to understand because it deals with the submicroscopic and abstract nature of electric current. Furthermore, 70.8% of students stated that the current LAPD only contains a summary of the material and practice questions, thus not optimally facilitating the science process skills required by students.

The results of the study indicate that the profile of students' science process skills (SPS) in the electrolyte and non-electrolyte solution material is still dominated by the low category, with no students reaching the high category. Students are better able to interpret experimental data compared to designing investigations and explaining phenomena scientifically, which indicates that concrete data-based skills are easier to master than skills that require complex reasoning. This finding confirms the results of the initial questionnaire which showed that the material is still understood because it is related to the submicroscopic and abstract nature of electric current so that the use of E-LAPD based on guided inquiry is relevant as a medium that is able to provide scaffolding through material summaries, guiding questions, and simple practicums, and is supported by positive responses from students and teachers towards its application in learning.

CONCLUSION

This study concludes that the science process skills (SPS) profile of eleventh-grade students of SMA Muhammadiyah 4 Sidayu, Gresik, on electrolyte and non-electrolyte solutions using conventional E-LAPD is still very low, with all students distributed only within the very low and low categories, and none reaching the medium or high level. The highest achievement was found in conclusion drawing while the lowest was in communication, confirming that students are more proficient in concrete observation-based skills than in complex scientific reasoning such as prediction and classification. These findings confirm the failure of the existing E-LAPD, which only contains material summaries and practice questions, in facilitating scientific inquiry, leaving students with a partial and fragmented understanding of the concepts of ionization and electrical conductivity. The urgency of developing guided inquiry-based E-LAPD cannot be overstated. In the Industry 4.0 era, students are demanded to possess not merely content knowledge but the capacity to think scientifically, construct evidence-based arguments, and solve complex problems — competencies that are precisely what SPS encompasses and what conventional E-LAPD has demonstrably failed to cultivate. The complete absence of any student reaching even a medium SPS level signals that the current learning medium is fundamentally inadequate, and that without deliberate redesign toward a guided inquiry framework, students will remain trapped in passive, memorization-based learning patterns that are misaligned with both national curriculum standards and the demands of contemporary scientific literacy. Guided inquiry-based E-LAPD is therefore not a supplementary enhancement but a critical and immediate pedagogical necessity, as it provides the structured scaffolding — through guided questioning, step-by-step investigation tasks, and reflective conclusion prompts — that directly addresses each identified SPS weakness in a systematic and contextually grounded manner. Limitations of the study include a small sample size from a single rural school, a cross-sectional design that limits generalizability, and the potential for subjective bias in essay assessment despite expert validation. These limitations, however, further reinforce the need to act swiftly: the findings from this preliminary study provide sufficient empirical grounding to justify the development and testing of guided inquiry-based E-LAPD without delay. Practically, chemistry teachers and curriculum developers are advised to design guided inquiry E-LAPD with gradual scaffolding, beginning from the direct observation of electrical conductivity phenomena and progressively guiding students toward ionization hypothesis formulation, so that each SPS indicator is systematically and measurably developed. Future research is recommended to apply a quasi-experimental design with pre-post tests across multiple schools to empirically test the effectiveness of guided inquiry E-LAPD on SPS improvement, as well as to integrate structural equation modeling (SEM) to identify moderating factors such as digital literacy levels and student learning styles that may influence the impact of the redesigned medium.

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