Engaging STEM Students through Guided-Inquiry: A Validated Laboratory Worksheet for Acids and Bases

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ABSTRACT

This study reports on creating and validating a Guided-Inquiry STEM Laboratory Worksheet designed to teach Acids and Bases to Grade-12 STEM learners. Addressing the demand for engaging and practical instructional tools, the research utilized a quantitative design within a Research and Development framework, guided by the Input-Process-Output Model. The development process included conducting a pre-survey for needs assessment, drafting the worksheet, integrating advisor feedback, and subjecting the material to expert validation. Expert evaluation yielded an overall mean score of 3.76 (SD = 0.43), confirming the worksheet's validity and high quality. Classroom implementation with Grade-12 STEM students further demonstrated strong acceptability and favorable perceptions among students and teachers. Consequently, the study endorses the adoption of the Guided-Inquiry STEM Laboratory Worksheet in teaching chemistry for both Senior and Junior High School STEM programs, while emphasizing the importance of ongoing evaluation, encouragement of student inquiry, integration into instructional practices, and future research.

Keywords: STEM Approach, Guided-Inquiry, Laboratory Worksheet, Acids and Bases

INTRODUCTION

Science education greatly equips individuals with the essential skills to thrive in our technology-driven world. Chemistry, a crucial part of Science, looks at matter's composition, structure, properties, and reactions (Taber, 2020). The ability to grasp basic chemistry concepts is necessary to pursue a career in Science and make informed decisions in daily life (Yurkiv, 2019). Acids and bases, in particular, are fundamental concepts in chemistry with wide-ranging applications. We encounter acids and bases daily, from the citric acid in our orange juice to the baking soda in our kitchen (Wardah & Wiyarsi, 2020). These substances are vital in biological systems, industrial processes, and environmental phenomena. Therefore, a strong understanding of acids and bases is crucial for scientific literacy (Kacan & Celikler, 2016).

Despite their importance, teaching and learning these abstract concepts and complex phenomena can be challenging for students to comprehend. Teachers can then provide leading-edge strategies or utilize innovative instructional materials to engage students and improve their chemistry concepts' understanding effectively. Traditionally, teaching chemistry often uses rote memorization and passive learning approaches, which might be ineffective in engaging students or leading them to understand these scientific concepts better. On the contrary, inquiry-based learning has enhanced critical thinking skills, problem-solving abilities, and conceptual understanding by encouraging students' active participation, question generation, and experimentation (Nasution et al., 2021). As a structured form of inquiry-based learning, the guided-inquiry approach provides students with a structured framework for scientific inquiry, which often involves worksheets or laboratory manuals that provide step-by-step instructions, guiding questions, and prompts to help students develop their inquiry while ensuring they stay on track (Ryker & McConnell, 2017).

On the other hand, Science, Technology, Engineering, and Mathematics (STEM) Education is a crucial approach in equipping students to thrive in the 21st century through advancing innovation, problem-solving skills, and creativity (Kimmel et al., 2014). Integrating guided inquiry learning within a STEM framework can

create powerful learning experiences that promote deep understanding and skill development (Zakiyah et al., 2019).

Despite the recognized importance of guided inquiry learning and STEM education, there remains a need for validated guided inquiry laboratory worksheets on acids and bases that align with these pedagogical approaches. Existing laboratory activities may not effectively engage students in authentic inquiry or may not be explicitly designed to promote STEM-related skills (Faradilla et al., 2018). This study then focused on developing and validating a guided-inquiry STEM laboratory worksheet to aid Grade 12 STEM students in developing an enhanced understanding of the concepts of acids and bases. This study then sought to determine the specific characteristics of a suitable laboratory worksheet for this purpose, assess the validity of the developed worksheet based on expert evaluation, and gauge its acceptability among students.

METHODOLOGY

Research Design

The guided-inquiry STEM laboratory worksheet on acids and bases was developed following the Research and Development quantitative research design, employing the Input-Process-Output model.

Participants and Sampling Technique

Purposive sampling was employed to identify expert validators of the developed Guided-inquiry STEM laboratory worksheet. The panel of validators consisted of three professionals: public secondary school teachers handling chemistry, with experience in conducting STEM-related studies. These experts assessed the validity of the worksheet in terms of content, pedagogy, and alignment with STEM competencies, providing feedback on its readiness for pilot testing.

This study involved only the three validators as they were the only professionals available within the research local context meeting the required expertise.

For the pilot testing and implementation, cluster sampling was used to ensure the suitability and appropriateness of the worksheet among its intended users. Thirty-three grade 12 STEM students from a national high school participated in pilot testing and implementation.

Research Instrument and Data Gathering Procedure

This study utilized three research instruments: a validated pre-survey questionnaire, an adapted rating sheet, and an acceptability scale for the developed Guided-Inquiry STEM Laboratory Worksheet.

The Pre-Survey Questionnaire utilized was a 20-item test questionnaire developed to assess the understanding and proficiency of participants in key learning competencies related to acid–base reactions and equilibria, aligned with the Most Essential Learning Competencies (MELCs) of the Department of Education (DepEd). The instrument measured knowledge of acids and bases, equilibrium concepts, applying Le Chatelier's principle, and interpreting experimental results. Content validity ensured comprehensive coverage of essential concepts, while construct validity confirmed alignment with the intended knowledge, skills, and abilities. The instrument's validity was evaluated using the Survey Instrument Validation Rating Scale by Oducado (2020).

The second instrument used was the Guided-Inquiry STEM Laboratory Worksheet Validity Rating Sheet, adapted from Jumarito (2021). The rating sheet was employed to establish the validity of the developed worksheet. This instrument utilized a four-point Likert scale to evaluate the worksheet regarding content, pedagogy, and alignment with STEM competencies.

Lastly, the Guided-Inquiry STEM Laboratory Worksheet Acceptability Scale, adapted from Tejares et al. (2023), was utilized during pilot testing, where the Grade 12 STEM students were asked to complete. The tool

was modified to fit the present study and underwent expert review and adviser validation before use. The scale measured the acceptability of the laboratory worksheet in terms of clarity, relevance, and overall usability for Grade 12 learners.

Moreover, this study adopted the Input–Process–Output (IPO) Model (Rogayan et al., 2019) as the framework for developing and validating the Guided-Inquiry STEM Laboratory Worksheet.

1) Input: The inputs included: (a) the K to 12 Senior High School STEM Curriculum Guide for Chemistry, explicitly focusing on *Acid–Base Equilibria*; (b) results of a needs analysis through a pre-survey administered to Grade 12 STEM students to determine learning gaps; and (c) guided-inquiry learning principles, which emphasize active, student-centered engagement through orientation, exploration, concept formation, application, and closure (Sesen & Tarhan, 2013; Schwichow et al., 2016). These inputs provided the foundation for crafting the laboratory worksheet aligned with the Department of Education's Most Essential Learning Competencies (MELCs).

2) Process: The development and validation of the guided-inquiry laboratory worksheet on Acid–Base Equilibria followed four key stages. First, the worksheet was crafted to include experiments, critical thinking prompts, and opportunities for exploration, analysis, and communication of findings. Next, the initial draft underwent expert review and validation, beginning with the adviser's feedback and then evaluation from three experts in STEM education and pedagogy. Revisions were made based on their recommendations to enhance clarity, alignment, and instructional quality. The third stage involved pilot testing with 33 Grade 12 STEM students (5 males and 28 females) from a public national high school. Students evaluated the worksheet using an acceptability scale adapted from Tejares et al. (2023), which measured clarity, usefulness, format, and overall suitability; the findings from this phase informed further refinements. Finally, the revised worksheet was fully implemented with the same student participants through hands-on experimentation, emphasizing critical thinking, collaboration, and scientific inquiry. The same group was chosen for the implementation to ensure continuity and to assess the effects of the revised version accurately. Since these students were already familiar with the worksheet's context and structure, they could provide more focused feedback, allowing the researchers to evaluate whether the revisions addressed earlier concerns. Using the same cohort also helped control for variability in prior knowledge, learning environment, and teacher facilitation, thereby strengthening the reliability of the validation process.

Pre-test and post-test were not conducted in this study as the research was limited to the development and validation phase of the instructional material. The primary objective was to design, construct, and evaluate the validity and acceptability of the Guided-Inquiry STEM Laboratory Worksheet on Acids and Bases, rather than to determine its effectiveness in improving student learning outcomes. Accordingly, the study focused on ensuring that the material met standards on content accuracy, pedagogical soundness, and alignment with STEM competencies through expert validation and user acceptability assessment.

3) Output: The output of the study was a validated and pilot-tested Guided-Inquiry STEM Laboratory Worksheet on Acid–Base Equilibria for Grade 12 STEM students, aimed at enhancing conceptual understanding, problem-solving, and critical thinking skills, while aligning with the K–12 STEM curriculum standards.

RESULTS AND DISCUSSION

The laboratory worksheet developed has been validated by experts and tested for acceptability. The results of the assessment are as follows:

Experts' Validation

The developed laboratory worksheet was validated by three experts who are Grade 12 STEM teachers handling chemistry and are experienced in conducting STEM Education research. Below is the result of their assessment of the developed material.

Table I. Experts' Validation of the Guided-Inquiry STEM Laboratory Worksheet

Components	M	SD	QD
A. Learning Objectives	*4.00*	*0.00*	*Excellent*
A.1 SMART - the learning objectives were Specific, Measurable, Attainable, Relevant, Time-bounded	4.00	0.00	Excellent
A.2 The learning objectives were expressed in behavioral terms.	4.00	0.00	Excellent
A.3 Appropriate learning goals/objectives based on the content of Evidence of Acids and Bases.	4.00	0.00	Excellent
B. Learning Content	*3.56*	*0.53*	*Excellent*
B.1 Offers a clear, concise, detailed, and accurate description of the lesson concept(s).	3.67	0.58	Excellent
B.2 Organization of content is in logical order.	3.33	0.58	Excellent
B.3 Based on the context and developmental level of the students.	3.67	0.58	Excellent
C. Guided-Inquiry STEM	*3.80*	*0.41*	*Excellent*
C.1 Relevant, Creative, and connected to "real world" problems or scenarios.	3.67	0.58	Excellent
C.2 The content of the laboratory worksheet is accurate and relevant.	4.00	0.00	Excellent
C.3 Students' activity or task within the study would not likely be tackled outside a school setting.	3.67	0.58	Excellent
C.4 Does the laboratory worksheet allow students to design and conduct experiments, collect data, and draw conclusions?	4.00	0.00	Excellent
C.5 Does the laboratory worksheet encourage students to ask questions, investigate the subject matter, and make connections to real-world applications?	3.67	0.58	Excellent
D. STEM Lesson Stages	*3.71*	*0.46*	*Excellent*
D.1 Identification of social issues.	3.67	0.58	Excellent
D.2 Identification of potential solutions.	3.67	0.58	Excellent
D.3 Need for Knowledge	4.00	0.00	Excellent
D.4 Decision-making	3.67	0.58	Excellent
D. 5 Development of prototype or product	3.67	0.58	Excellent
D. 6 Test and evaluation of solution.	3.67	0.58	Excellent
D. 7 Socialization and completion decision stage	3.67	0.58	Excellent
Overall	*3.76*	*0.43*	*Excellent*

Legend: 1.00 – 1.75 = Needs work, 1.75 – 2.5 = Good, 2.5 – 3.25 = Very Good, 3.25 – 4.0 = Excellent

Table II. Validators' Overall comments and suggestions on the Guided-Inquiry STEM Laboratory Worksheet.

Laboratory Worksheet	
Expert's comments and suggestions	*Action taken*
Unpack the Lesson Objectives	The researchers analyzed and broke down the lesson objectives based on the competency code to better understand and assess student

Add pictures for each material. Add more precautions when you use dangerous materials.	learning outcomes. The researchers added pictures of every material needed, making it easier for the students to identify them. The researchers added more precautions when handling the dangerous acid and base materials.
STEM Lesson Plan	
The time frame should be emphasized	The time frame in all stages of the lesson plan was well-emphasized and organized.

The results in Table 1 indicate that the developed Guided-Inquiry STEM Laboratory Worksheet is excellent in its design and implementation across various components. In terms of learning objectives, they were found to be well-structured, specific, and relevant to the subject matter. The learning content contained clear descriptions of concepts, although there was room for improvement in the organization aspect. The Guided-Inquiry STEM Laboratory Worksheet aspect scored well, demonstrating relevance to real-world problems and providing hands-on experimentation and critical thinking opportunities. Additionally, the STEM lesson stages were well-developed, addressing various aspects of problem-solving and innovation. Overall, the worksheet performed excellently, with a mean score of 3.76 and a 0.43 standard deviation, indicating its effectiveness in facilitating meaningful learning experiences for students.

Moreover, Table 2 shows the overall corrections and recommendations from the validators before the pilot testing and implementation. The revisions taken by the researchers were necessary to improve the developed laboratory worksheet.

Acceptability

Table III. Acceptability of the Guided-Inquiry STEM Laboratory Worksheet

Statements	Students=33		Teachers=3	
	Mean	Interpretation	Mean	Interpretation
Clarity	3.64	Excellent	3.50	Excellent
The laboratory worksheet is clear to understand.	3.76	Excellent	3.33	Excellent
The content is organized logically.	3.52	Excellent	3.67	Excellent
Usefulness	3.72	Excellent	3.89	Excellent
The laboratory worksheet provides relevant and practical information.	3.79	Excellent	4	Excellent
The laboratory worksheet effectively supports the learning objectives.	3.73	Excellent	4	Excellent
The laboratory worksheet can be applied effectively to real-world situations.	3.64	Excellent	3.67	Excellent
Suitability	3.63	Excellent	4	Excellent
The content is appropriate for the intended audience.	3.64	Excellent	4	Excellent
The laboratory worksheet content matter is aligned with the learners' existing knowledge and abilities.	3.61	Excellent	4	Excellent
The laboratory worksheet caters to different learning styles and preferences.	3.67	Excellent	4	Excellent

The laboratory worksheet is culturally sensitive and inclusive.	3.61	Excellent	4	Excellent
Adequacy	3.72	Excellent	4	Excellent
The laboratory worksheet covers all the necessary topics and subtopics.	3.64	Excellent	4	Excellent
The content includes appropriate depth and breadth for the topic.	3.76	Excellent	4	Excellent
The laboratory worksheet has no significant gaps or omissions in the content area.	3.76	Excellent	4	Excellent
Timeliness	3.74	Excellent	4	Excellent
The information presented is up-to-date and relevant to the current context.	3.76	Excellent	4	Excellent
The laboratory worksheet incorporates recent research, trends, or developments.	3.73	Excellent	4	Excellent
Language, Style, and Format	3.77	Excellent	4	Excellent
The language used in the laboratory worksheet is engaging and easy to understand.	3.76	Excellent	4	Excellent
The laboratory worksheet utilizes appropriate terminology for the subject matter.	3.82	Excellent	4	Excellent
The formatting, layout, and organization of the content are effective.	3.73	Excellent	4	Excellent
Illustrations	3.73	Excellent	3.78	Excellent
Visual aids, diagrams, or charts are used to prompt understanding.	3.70	Excellent	3.67	Excellent
The illustrations presented effectively support the textual content of the subject matter.	3.76	Excellent	4	Excellent
The images, charts, or diagrams are clear, visually appealing, and relevant.	3.73	Excellent	3.67	Excellent
Presentations	3.67	Excellent	4	Excellent
The presentation was delivered clearly and well-delivered.	3.67	Excellent	4	Excellent
The visuals, audio, and overall presentation quality are satisfactory.	3.67	Excellent	4	Excellent
Overall	3.70	Excellent	3.9	Excellent

Legend: 1.00 – 1.75 = Needs work, 1.75 – 2.5 = Good, 2.5 – 3.25 = Very Good, 3.25 – 4.0 = Excellent

Based on the respondents' views, the above result indicates that the laboratory worksheet is highly acceptable and suitable. The acceptability of the Guided-Inquiry STEM laboratory worksheet suggests positive implications for student engagement, critical thinking skills, and long-term knowledge retention. Therefore, widespread acceptance and implementation of the Guided-Inquiry STEM Laboratory Worksheet in educational settings can increase student engagement, enhance critical thinking skills, and improve long-term knowledge retention in STEM education. This aligns with Khasanah et al. (2017), who found that students engaged in guided-inquiry science activities demonstrated higher levels of interest, motivation, and active participation than those in traditional lecture-based classrooms. Additionally, Ural (2016) analyzed various studies on guided-inquiry learning in science education and found that guided-inquiry approaches significantly enhanced

students' critical thinking skills, problem-solving abilities, and conceptual understanding compared to traditional instructional methods.

CONCLUSION

This research was undertaken to help Grade 12 STEM students understand chemistry concepts better. Based on the needs assessment, experts developed a guided-inquiry STEM laboratory worksheet on acids and bases, validated, pilot-tested, and implemented among identified students. Validity and acceptability assessment results showed positive validity and acceptability of the developed instructional material. Results further show that the developed laboratory worksheet as a resource material could promote enhanced conceptual understanding, develop critical thinking, improve problem-solving abilities, and increase engagement and motivation in Chemistry.

Despite the strong potential of the developed guided-inquiry STEM laboratory worksheet as an effective instructional material, it is nonetheless recommended that the material be assessed vis-à-vis the academic performance of students to ensure its effectiveness in enhancing conceptual understanding of students on acids and bases. Insights provided by this study could also be avenues to encourage further exploration and development in other related areas of study.

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