4.3. Findings from laboratory reports

The lab reports showed evidence of conceptual gain (not shown in this article) by well-structured and communicated lab reports which scored higher marks than before this study. Students demonstrated their understanding of sustainability and humanitarian challenges through their context-based hands-on activities lab reports and provided solutions or mitigating alternatives for identified challenges.

4.4. Interpretive findings

Interpretive analysis of gathered findings from administered questionnaires, observation schedule, conversation and laboratory reports revealed many findings, some which confirm that identified by other researchers. A few are listed below:

- Chemistry practical activities/labs could be extended outside the walls of school labs.
- Microchemistry has the potential for enhancing the principles of humanitarianism and sustainability as identified by Hanson and Hanson [3].
- Humanitarian challenges could be solved through chemical education as also found by Mahaffy et al. [15].
- Constructive teaching approaches that are context-situated could be encouraged through the use of microchemistry kits as opined by Bell [8] and Arroio [17].
- Hands-on and real-life projects with microchemistry kits makes the learning of chemistry and principles of humanitarianism and sustainability joyful as it removes the fear and drudgery of conventional labs and practices [9].
- Increased self-directed learning.
- Need to enforce waste disposal management plans in school labs and communities [16].
- Awareness of implications of chemical waste heightened.
- Step up exposure to real-life challenges for the practice of humanitarian and sustainability principles as proposed by Hanson and Hanson [1] in other studies.
- Increase in systems thinking competence.

5. Recommendations

Based on gathered data and conclusions that were drawn from the findings, the following recommendations are made:

- There is a possibility of embedding principles of sustainability, humanity, neutrality, impartiality and independence into chemistry courses in the Ghanaian university that participated in the study
- A multidisciplinary approach to teaching is recommended
- Chemistry labs/projects/challenges must be conducted with fun and contextualized for students to appreciate the relation between chemistry, theories and day life
- Chemistry teachers must create awareness of effects of environmental pollution among their students
- Sustainable approaches to performing chemistry labs such as the use of micro science equipment and green chemistry should be more than regular/conventional labs so as to minimize the generation of chemical and other wastes.

6. Conclusion

The use of project- and inquiry-based micro activities with embedded sustainability and humanitarian principles in regular labs through a system thinking approach could build connection between chemistry theories/labs and real-world challenges as students demonstrated adequate understanding of desired principles through practical applications. They performed their assigned labs/projects with joy, collaborated, communicated findings coherently, and learned to manage waste better, as they understood its immediate and long-term implications on humans, other organisms and the physical environment. The students also demonstrated the acquisition of cognitive, sustainability, and humanitarian concepts and skills that are required to manage themselves, other people, their communities and the wider world to make it a better place to live in now and for future generation. It could therefore be concluded that the adopted constructivist lab practices and systems thinking strategies had the potential to enhance concept formation that could link the application of chemical knowledge to humanitarian and sustainability issues.

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Appendix A

Lab Challenge (Project)

A farm manager has succeeded in getting rid of pests on his vegetable patch and produced bigger, plentiful yields of healthy-looking okra by applying a propoxur-based pesticide, besides fertilisers monthly. Other community farmers close to the river along the farm that supplies the community with water have lodged complaints that activities on the said farm have contaminated their source of water and must be sued.

Follow up questions for identified challenge

Find out if there is any truth in the assertion/complaint made by the inhabitants.

Produce evidence to support your answer. (Use micro kit if lab works must be performed).

Consider the immediate and long-term effects of your response on both the university and the community as well as remediation activities/processes if necessary.

Consider the structure of propoxur and propose other ways by which a safer and eco-friendly chemical could be produced for use on farms.

Show a scheme for the preparation of the new 'green' product that can replace propoxur.

Appendix B

Sample close and open items from the questionnaire

(Guiding instruction and options not shown)

<table>
<tr><td colspan="3">Sample of close item</td></tr>
<tr><td>No.</td><td>Item</td><td>What to assess</td></tr>
<tr><td>1.</td><td>I am able to detect environmental and humanitarian challenges and prescribe possible solutions</td><td>Anticipatory, normative, strategic and critical thinking competencies</td></tr>
<tr><td>2.</td><td>I prefer to work with minimal volumes and quantities of chemicals than with standard resources</td><td>Self-awareness, strategic and normative competencies</td></tr>
<tr><td colspan="3">Sample of open item</td></tr>
<tr><td colspan="3">1.How will you disseminate policy on environmental preservation to your colleagues and community members?
Why would it be necessary to do disseminate such information?
This will involve analysis of the policy and the adoption of a systems thinking competency approach.</td></tr>
<tr><td colspan="3">2.The situation in Ketekrom concerning famine, lack of water and outbreaks of diseases has become an international concern. As a student of this course embedded with sustainability and humanitarian principles, how could such a problem have arisen and how do you anticipate its solution?
This problem could be tackled from an integrated problem-solving competency, critical thinking and humanitarian principles.</td></tr>
</table>

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