Epistemic Insight Inspiring Critical Thinking and Interdisciplinary Learning: The Case of Student Teachers Engaging in 'Water Droplets' Experiment

Maureen Kanchebele Sinyangwe, Berry Billingsley

Kwame Nkrumah University-Kabwe, Zambia

DOI: https://dx.doi.org/10.47772/IJRISS.2025.908000217

Received: 27 July 2025; Accepted: 04 August 2025; Published: 04 September 2025

ABSTRACT

Epistemic Insight (EI) not only involves appreciating the power distinctiveness of an individual subject area as well as its limitations, but also extends to identifying how one individual subject area is linked to other subject areas. This therefore implies that EI teaching approach accommodates critical thinking and a multi-disciplinary approach in teaching/learning and solving of real life and real world problems. Twelve (12) primary student teachers (PSTs) at Kwame Nkrumah University in Kabwe, Zambia participated in this study through doing the 'water droplets' experiment which is one of 'hands on' science investigation under the *Essential Experiences in Science research project of the* Epistemic Insight (EI) Initiative. They also wrote some reflective points on the experiment and participated in the follow up interviews and discussions. This engagement can be viewed as having had a two-pronged learning strategy through the 'water droplets' experiment. The first was to engage student teachers in activities that inspire critical thinking and personal interdisciplinary learning experiences. The second prong of the learning strategy was to inculcate the growth mindset, in student teachers, for exploring knowledge and being prepared to do the same in and with the learners they will be teaching in the future. The PSTs engagement and perceptions of the experiment have been presented and reflections on it shared. The possibilities of using EI teaching/learning approach in a primary teacher education context in a Zambian context have been discussed too.

Keywords: Epistemic insight, Student teachers, interdisciplinary learning, water droplets experiment

Epistemic insight

Epistemic Insight (EI) involves appreciating the power and distinctiveness of an individual subject area as well as its limitations. It extends to identifying how one individual subject area is linked to other subject areas thus expanding one's knowledge base and using multi-disciplinary in solving of real life and real world problems. Epistemic Insight pedagogical and learning framework (Billingsley, 2017; Billingsley, 2022) is an important approach to seriously consider for teacher education where there seems to be a focus more on individual subject areas in isolation and not as much on interdisciplinary approach to the different subject areas and bodies of knowledge. EI approach can give opportunity for student teachers to consider how the content in individual subject areas/courses they are taking as part of their teacher preparation programme can work together with content in other subject areas to solve problems from different perspectives (Sinyangwe, 2023). This works in that different subject areas contribute in some way(s) to addressing the real-world's problems. EI helps in one articulating the similarities that are there between or among subjects but also their unique or distinctive features. This implies that the uniqueness of each subject area/course is explored as is the interconnectedness of the subject areas/course especially as it relates to applying of the knowledge gained to dealing with real life situations (Billingsley, 2022; Sinyangwe, 2023).

Epistemic Agency and Agentic Learning

Agency generally relates to capability to actively engage in and intervene in or influence learning environments (Klemenčič, 2017). Agency can be considered as '…both a requirement and as a target in teacher education and may create a strong basis for epistemic agency' (Heikkilä, Hermansen, Iiskala, Mikkilä-

Erdmann & Warinowski, 2023, p.455). Epistemic agency (EA) extends to the capacity to and responsibility to acquire, generate and advance knowledge in context (Erkunt, 2010; Heikkilä et al., 2023). It is taking an active and productive position and responsibility toward knowledge (Damşa, Kirschner, Andriessen, Erkens & Sins, 2010). It not only depicts important constituents of being intentional and purposeful in knowledge creation and development (Jääskelä, Heilala, Kärkkäinen, & Häkkinen, 2021) but also in shaping one's (research) identity and learning practices in its different contexts (Vähäsantanen, Paloniemi, Hökkä & Eteläpelto, 2017; Heikkilä et al., 2023). Thus it can also be said to have a contributory role to play in shaping one's lifelong learning and knowledge development practices. It can be argued that EI and EA is key to the preparation of a future generation of teachers and learners that are self-directed and enthusiastic about engaging in their own learning and engaging collaborations, at different levels, to gain and extend knowledge in a multidisciplinary manner. Once students' agentic learning is ignited, nurtured and supported a solid foundation for applying agentic approaches investigation in the lab and extending this to investigating and address out-of-school issues or challenges would have been created.

In today's knowledge-intensive world, PSTs are expected to have a sense of epistemic agency and be epistemically insightful. Moreover, in this world faced with complex life situations and problems teacher education is called upon to redefine and set new requirements for understanding and addressing such complex problems (Heikkilä et al., 2023). As already stated use EI approach in teacher education can give opportunities for PSTs to consider how knowledge gained in individual subject areas/courses they are taking as part of their teacher preparation programme can work with knowledge gained in other subject areas, which are also part of the programme, to solve complex problems. If school learners' agency is to be developed, then PSTs must themselves first develop a sense of agency (Edwards, 2017). This also suggests that if school learners are to be epistemically insightful, then the PSTs must first also be epistemically insightful. Student teachers and learners who have experienced agentic learning and developed agentic behaviour are highly likely to adopt an agentic perspective on solving community related challenges than those who have not.

Agentic learning can be promoted in the classroom. Researchers such as Vaughn (2021) and Heikkilä et al. (2023) have given ideas in context on how this could be done. Experiments can engage learners in their learning and contribute to critical thinking, creative and multidisciplinary learning. For this to be possible the teachers must have been prepared to make this a reality for the learners. The 'water droplets' activity or experiment is one of the 'hands on' science investigation under the *Essential Experiences in Science research project of the* Epistemic Insight (EI) Initiative and it was considered as one that primary student teachers at Kwame Nkrumah University (KNU) could engage in Key to EI approach is exploring the knowledge interaction of science with other disciplines (Billingsley *et al.*, 2018) as a multidisciplinary perspective and approach is crucial for answering life's questions, dealing with challenges in communities and in understanding and improving the world we live in. In the case of this study the 'water droplets' experiment was considered as a way of exploring and contributing to critical thinking and multidisciplinary learning among the PSTs at KNU.

Zambia' s Education Curriculum and Epistemic Insight Approach

Zambia's education curriculum was reformed in 2013 because of the need to prepare learners for future challenges in the rapidly changing world (MOE, 2013). Zambia revised the content-based curriculum to a competence-based one with the aim of producing self-motivated, life-long learners, independent, holistic learners with the values, skills and knowledge to help them to succeed in school in particular and in life in general (Zulu, 2015; Mulenga & Kabombwe, 2019). It is this same competence-based curriculum that has been maintained in the recently revised curriculum (MOE, 2023) now with the expectation that learners at all levels of education will acquire vital knowledge, skills and values necessary for the actualisation of Zambia's vision 2030 and for the nation's sustainable development. There is an indication of preparing learners to be active players in their personal lives and in the community.

Based on what has already been shared above, it can be deduced that EI Approach can have a way of contributing toward the development of values and competencies highlighted in Zambia's now revised 2013 Education Curriculum Framework (ZECF) too. To exemplify this, EI approach has high potential for the development of key values and competencies such as collaboration, citizenship, innovation and creativity,

critical and analytical thinking plus problem solving which the 2023 ZECF has emphasized that they be developed and nurtured in learners. It is also in line with the calls of ZECF for learners to be equipped with knowledge, skills, positive values and competencies for further learning, leading productive lives and being able to respond to their individual needs as well as those of society. In addition, and with respect to teacher education, there is an emphasis on teacher education 'preparing competent educators who can positively influence individuals and societies…in our constantly evolving world' (MOE, 2023, p.29). The expectation is that teacher education will contribute to producing educators/teachers possessing and exhibiting diverse skills and attributes including analytical thinking, collaboration, communication, citizenship, creativity and innovation, emotional intelligence and problem solving among others.

EI approach can give opportunities for PSTs themselves to have a sense of epistemic agency and be epistemically insightful and equip them to positively influence learners and contribute to learners' being critical, creative and epistemically insightful too. This not only to reflect in the activities or experiments in the classroom environment, but extending beyond that and stretching to dealing in dealing with complex problems in our constantly evolving world. Under the EI framework there is a recognition of the value of each discipline, its strengths and weaknesses, its preferred questions as well as methods of inquiry and how the different disciplines can interact and hence promote and draw from the benefit of multidisciplinary enquiry. World problems can be solved by adopting a multidisciplinary enquiry (Billingsley, 2022: UNESCO, 2019). In the case of this study, the Primary student teachers (PSTs) were engaged in the 'water droplets' activity or experiment as a way of learning for themselves, expressing their epistemic agency and also as a way of preparing them to engage learners in learning through experiments as presented under the EI learning approach. Their engagement in and perceptions of the water droplets activity have been presented below.

METHODOLOGY

The Twelve (12) student teachers pursuing their four-year primary teaching degree programme at Kwame Nkrumah University (KNU) had an opportunity to engage in the 'water droplets' experiment- a 'hands on' science experiment. At the time they were in their second year of study taking foundational course content in Mathematics, Literacy and Languages, Physical Education, Integrated Science, Social Studies, Creative Technology Studies including Home Economics and from which they would choose the one(s) they are to specialize in from their third year of study. The 'water droplets' experiment involves observing water droplets falling onto a coin. What is generally needed to do the 'water droplets activity is water, a pipette, a coin and a plate or surface on which to place the coin. In this particular context a pipette was not used as it was not available. A straw was used instead. To create droplets of water with a straw, the straw was dipped into water, a finger was put over the end so that air could not get in at the top and then the straw lifted from the water. The water droplets were allowed to drop onto a coin. The coin was to be covered with water droplets and the students were to see, among other observations to be made, how many droplets the coin could hold before it started flooding.

The PSTs were engaged in the experiment during the Mathematics lecture session and wrote some reflection notes on the activity. This was followed-up with individual interviews and whole class discussion some of which was done outside lecture time. The activity was done during the lecture sessions on 'Estimations and Approximations' by which time they had already covered other topics such as counting and shapes in their Mathematics course. The lecture time opportunity was seized to engage the PSTs in the experiment as it provided an opportunity to revise the already covered course content, apply content already learnt in Mathematics to what presented as a real life situation and with the hope that it would extend their reflection to other disciplines too.

Presentation and discussion of student teachers' engagement and perceptions of the water droplets activity

The PSTs engagement in and perceptions of the water droplets activity as linked to Mathematics, Emotions, Science, Religion have been presented and discussed below.

PERSPECTIVES LINKED TO MATHEMATICS

From a mathematics perspective, the PSTs had to estimate the number of water droplets that could be added to a coin before it overflows. They were also engaged in counting how many water droplets ccould be added to a coin before it overflows. From a science perspective they had an opportunity to engage in an actual experiment or hands on activity *'…and that is what scientists do'* they argued. In addition, they were making considerations of and using words related to the concentration or composition of the water, the density of plain water compared to the density of water mixed with another substance varying. One PST's reflection notes included: *'there is something that can change about the water itself-the concentration or density affecting the movement of the droplets through the straw when we mix the water with something else…'*. They also made reference to the slow or fast movement of the water in the straw and when this could (not) happen. Such can be argued to making it possible for them to challenge unscientific beliefs about water that could exist among themselves and in the general population.

Perspectives linked to emotions/ awareness of emotions associated with learning

The PSTs also made reference to their feelings and emotions during the experiment. These included feelings of excitement as they were looking forward to see the actual number of droplets in comparison to their predicted number of droplets that needed to be added to the coin before it overflew. One PST recalled that *'I was looking forward to being right, my guess of the number of droplets to be right'*. Feelings of disappointment and appreciation were also experienced. One PST stated that *'… I was disappointed when I found out that my prediction was all wrong…but I found the activity to be very engaging…and made me to start rethinking my earlier stand'* A sense of accomplishment was also noted. '*It felt good to be a part of the experiment. I was doing it myself and learning for myself*' one stated. Some levels of agentic learning (Montenegro, 2017) and agentic engagement (Reeve & Shin, 2020) seemed to have been sparked in the students. In this instance it was not about checking what it was/is that was written in a textbook somewhere about what actually happened. It was about the students themselves wanting to know: *'I want to know. I want to know by trying it out myself and see what happens when the water has been mixed with something else like food colour…'* indicated one PST thus arguing for having had an opportunity to know for oneself and not being told or reading from another source. It was similar to challenging already written textbook 'notes' or scripts such as that can be found in textbooks and which can be a barrier to agentic learning. The PSTs can be said to have experienced and thus likely to think about how they could also support learners' agentic engagement during their times of classroom instruction in future than those who may not have been exposed to such activities.

Science perspectives

The activity appeared to have provoked the PSTs' abilities to think as Scientist may. They asked more scientifically logical and well-reasoned out questions such as: What would happen if the water used was drawn from a borehole or the kind that has not been purified with whatever chemicals they use for purifying it…' Other questions included: If I added sugar-more sugar to the water or less sugar, then what would happen to the movement of the liquid and to the actual droplets on the coin'? 'What would changing the size of the coin mean? Does the kind of material the coin is made up of matter in this case? Their inquiry levels as would one carrying out an experiment.

Real life perspectives

Several Associations with real life experiences were made too. Some PSTs made reference to real life situations in their questions and questioning. These included 'I am now trying to think about how this relates to real life, like the Lukanga water and sewerage company [which provides water services in Kabwe town where the university is situated] how and what they consider when purifying the water, storing it and distributing it…' Another made reference to 'flavoured water' that is sold in the local supermarkets when he stated '… water is considered pure, but how pure or healthy is the flavoured water like lemon-flavoured water that is sold…' The activity ignited the PSTs curiosity and is highly likely to do the same with the primary school learners. If prepared to engage learners in schools such as in this manner, it can lead to encouraging

learners' curiosity in Big Questions which explore the knowledge interaction of science with other disciplines as explained by Billingsley *et al* (2018).

Spiritual perspectives

Some PSTs talked about the experiment from the spiritual perspectives or in relation to a spiritual being when they each noted that:

'I was praying to God to help me have the patience I needed to wait for the number of droplets that had to be added to a coin before it overflows…'

'God must have thought about all such properties of water… during creation…

Engaging in the 'water droplets' experiment at the level they did appears to have given the student teachers an opportunity to discuss associations between science related activity and spirituality or a spiritual superior being. Such perceptions speak similar to the relationship between science and religion which researchers such as Billingsley, Taber, Riga & Newdick (2013); Billingsley, Abedin & Nassaji (2020); Ferngren (2022); Billingsley, Cullimore & Simpson, 2023) have explored in detail.

Reflections on student teachers' engagement and perceptions of the 'water droplets' experiment

The reflections on student teachers' engagement and perceptions of the 'water droplets' experiment relate to possible learning gains in EI initiative in general and the 'water droplets' experiment specifically. Did the 'water droplets' experiment encourage agentic behaviour among the PSTs in the selected teacher education institution in the Zambian context?

The 'water droplets activity presented the student teachers with opportunity to take control of their learning and proactively seek knowledge and make connections between and among the concepts that they had learnt. Their 'what if…' questions demonstrated that they were proactively seeking knowledge, where self-directed in their learning and where confident enough to work through and find solutions to the challenges that could come their way in the process. It sparked critical thinking in that the PSTs were now asking questions that reflected critical thought in the context of the experiment and beyond. Questions that included aspects of 'what if' or 'what would happen if or when…' are evidence of this and to some extent indicate that PSTs where reflecting and thinking deeply and critically about the experiment/activity they had engaged in. Their consideration of mixing the water with other substances such as sugar or salt or food colour or fruit juice or fruit juice concentrate which are generally considered readily available in their context- shows that the PSTs' curiosity was sparked and thoughts further provoked by engaging in the 'water droplets' activities. The PSTs had opportunities for taking responsibility of their learning and extending their thinking and hence their learning. With such exposure and experience, the chances of PSTs engaging in EI approaches and doing such an experiment with learners in the schools could be said to be relatively high.

The experiment appears to have provided an opportunity to engage student teachers in knowledge generation and captures their curiosity: They demonstrated that they wanted to learn more about water, about *'what made the water to go up the straw*' for instance, and *'what made water droplets join together when they touched on the coin…'* as well as *'the shape water makes or takes up…'* This indicates that more opportunities for further exploring the properties of water were created which they could have probably at some point only read about in the textbooks without meaningful understanding. It also presented an opportunity for challenging unscientific beliefs among themselves such as the points that it was witchcraft that made the water droplets to behave as such. It illustrates and captures epistemic curiosity, critical thinking and multidisciplinary learning and thinking that can result.

In addition, the experiment contributed to the development of appreciation of the value of multi disciplinality in learning and solving problems. Multidisciplinary learning comes in in the sense that this was a Mathematics lesson that was being used to explore ideas not only in Mathematics, but also other disciplines. It is also the case in the sense that the PSTs were demonstrating that they could do the same activity, but (each)

focus on different aspects of it for the purpose of learning to be and knowing better. The water droplets activity provided the students the 'hands-on experience' that generally is absent in a Mathematics class set up. It availed them an opportunity to apply knowledge obtained in learning mathematics topics such as counting, knowledge of shapes and solids, as well as estimation and approximations among others in a different context of a science experiment. They practised 'thinking like scientists' about what the experiment told them about the observed (first-hand) properties and behaviour of water. The PSTs were able to ask and investigate the natural world first hand and experience the curiosity of scientists for instance. They had an opportunity to think like individuals in other disciplines extending beyond mathematics and science too. Their thinking was stimulated in more ways than it would have been if they did not engage in this activity. Through the activity they were inspired to be more intentional about engaging in their own learning and planning more practical, hands on lessons and increase learner engagement when they start teaching in future.

A look at the future

The above presented PST perceptions of the 'water droplets' experiment and reflections could be said to highlight examples of benefits that could result in adopting EI teaching/Learning approaches in primary teacher education contexts such as at KNU in Kabwe, Zambia. Where to from now? Serious consideration and actions to be taken along the lines of adopting EI and agentic teaching/learning approaches. There are, however, some concerns that may need to be addressed if this adoption is to be actualised. Some of these are presented below.

As earlier explained, the 'water droplets' activity was done during a mathematics lecture time with a maths lecturer. It was more like a case where the maths lecturer enabled the 'need' for the maths lesson/learning to emerge in the science related experiment. It was evident through the PSTs engagement and shared perceptions that there was a transfer of knowledge from/to other subject areas among which Science and Geography were included. This demonstrates that if well planned and structured, including through collaboration with lecturers of other subjects, the transfer of knowledge across subjects or content integration could be further enhanced, and students may be helped to gain a deeper and meaningful understanding of material/content covered in the other subject areas. The success in multidisciplinary learning and thinking as well as interlinking the education curriculum content as emphasised in the 2023 Zambia Education Curriculum Framework (ZECF) can be achieved through collaboration among the teacher educators.

It can also be realised through targeted Continuing Professional Development (CPD) initiatives for teacher educators in teacher training institutions and eventually for in-service teachers. It is through such that teachers will be guided on what an interlinked curriculum entails and strategies for facilitating interlinked curriculum work with learners. It is through such that teacher educators would be guided on EI and agentic teaching/learning approaches entails and upskilled in the appropriate agentic teaching and learning. If teacher educators in teacher training institutions do not upskill, then the preparation of school teacher educators will be negatively affected too. The lack of in-servicing of teacher educators about EI can negatively affect teacher preparation and adoption/implementation of EI in the system. It is likely to have backwash effects on the implementation since the graduating teachers will not be well prepared for the curriculum and teaching/learning approach that they will have to be implemented.

Further, the successful implementation of knowledge and skills acquired by teacher educators through targeted CPD may also need to be accompanied with adequate supplies of EI learning/education support materials. To start with, the use of readily available resources in the teaching/learning context as encouraged by MOE (2023) is needed. However, supplies of EI learning/education support materials which may not be readily available in context may be needed too. To be specific, in the context of the 'water droplets' experiment, straws were used instead of pipettes as they were more accessible. The use of the straw made the experiment so much more accessible to the student teachers but had its own challenges-one being difficulty in controlling the size of the water droplets. Adequate supply of support materials could lead to eliminating such difficulties and focussing more on the learning to be done.

REFERENCES

1. Billingsley, B. (2017). Teaching and learning about epistemic insight. School science review.
2. Billingsley, B. et al. (2018). 'A framework for teaching epistemic insight in schools', Research in Science Education, 48, pp. 1115–1132.
3. Billingsley, B. (2022). 'The EI Curriculum Framework (Updated version 2022)', Available at The EI Curriculum Framework (Updated version 2022) | Zenodo Accessed 11/12/2023
4. Billingsley, B., Taber, K., Riga, F., & Newdick, H. (2013). Secondary school students' epistemic insight into the relationships between science and religion—a preliminary enquiry. Research in Science Education, 43, 1715-1732.
5. Billingsley, B., Abedin, M., & Nassaji, M. (2020). Primary school students' perspectives on questions that bridge science and religion: Findings from a survey study in England. British Educational Research Journal, 46(1), 177-204.
6. Billingsley, B., Cullimore, M., & Simpson, S. (2023). Relating science and religion. In Debates in Religious Education (pp. 199-210). Routledge.
7. Damşa, C. I., Kirschner, P. A., Andriessen, J. E., Erkens, G., & Sins, P. H. (2010). Shared epistemic agency: An empirical study of an emergent construct. The Journal of the Learning Sciences, 19(2), 143-186.
8. Edwards, A. (2017). The dialectic of person and practice: How cultural-historical accounts of agency can inform teacher education. The SAGE handbook of research on teacher education, 269-285.
9. Erkunt, H. (2010). Emergence of Epistemic Agency in College Level Educational Technology Course for Pre-Service Teachers Engaged in CSCL. Turkish Online Journal of Educational Technology-TOJET, 9(3), 38-51.
10. Klemenčič, M. (2017). From student engagement to student agency: Conceptual considerations of European policies on student-centered learning in higher education. Higher education policy, 30, 69-85.
11. MOE (2013). Zambia Curriculum Framework. Lusaka. Zambia
12. MOE (2023). Zambia Curriculum Framework. Lusaka. Zambia
13. Mulenga, I. M., & Kabombwe, Y. M. (2019). A competency-based curriculum for Zambian primary and secondary schools: learning from theory and some countries around the world.
14. Ferngren, G. B. (2022). Science and religion. In The Routledge History of American Science (pp. 200-214). Routledge
15. Heikkilä, M., Hermansen, H., Iiskala, T., Mikkilä-Erdmann, M., & Warinowski, A. (2023). Epistemic agency in student teachers' engagement with research skills. Teaching in Higher Education, 28(3), 455-472.
16. Jääskelä, P., Heilala, V., Kärkkäinen, T., & Häkkinen, P. (2021). Student agency analytics: Learning analytics as a tool for analysing student agency in higher education. Behaviour & Information Technology, 40(8), 790-808.
17. Montenegro, A. (2017). Understanding the concept of student agentic engagement for learning. Colombian Applied Linguistics Journal, 19(1), 117-128.
18. Reeve, J., & Shin, S. H. (2020). How teachers can support students' agentic engagement. Theory Into Practice, 59(2), 150-161.
19. Sinyangwe, K. (2023, August). Epistemic Insight Teaching Approach: An approach for preparing students in Higher Education institutions to be relevant to the community. In Zambia Association of Public Universities and Colleges (ZAPUC) Conference (Vol. 3, No. 1, pp. 43-46).
20. Stenalt, M. H., & Lassesen, B. (2022). Does student agency benefit student learning? A systematic review of higher education research. Assessment & Evaluation in Higher Education, 47(5), 653-669.
21. Stenalt, M. H., & Lassesen, B. (2022). Does student agency benefit student learning? A systematic review of higher education research. Assessment & Evaluation in Higher Education, 47(5), 653-669.
22. UNESCO (2019). Broadening the application of the sustainability science approach. Broadening the Application of the Sustainability Science Approach – Bifrost (bifrostonline.org) (Accessed: 13/12/23).
23. Vaughn, M. (2021). Student agency in the classroom: Honoring student voice in the curriculum. Teachers College Press.
24. Vähäsantanen, K., Paloniemi, S., Hökkä, P., & Eteläpelto, A. (2017). Agentic perspective on fostering work-related learning. Studies in Continuing Education, 39(3), 251-267.
25. Zulu, C. (2015). New School Curriculum to Empower Learners. Times of Zambia, 1.