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Navigating complexity: teaching sustainability through wicked problems in higher education

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ABSTRACT

This article aims to explore the integration of wicked problems into sustainability education, within the context of antimicrobial resistance (AMR) in Zimbabwe. As a complex health challenge, increased microbial resistance disproportionately impacts Southern Africa, including Zimbabwe. Engaging AMR in higher education institutions (HEI) requires a relational One Health approach, which integrates human, animal and environmental health through interdisciplinary collaborations. Using a participatory research workshop method, operationalising case vignettes, this study analysed discussions among participants on AMR education exploring how aspects of Biesta's educational functions were expressed. Results showcase how holistic education can be developed through interdisciplinary collaborations using real-world cases, offering students broader perspectives and connections. Holistic education can enhance AMR awareness across HEI by including the complexities of wicked problems. This would support students developing key competencies of critical engagement, interdisciplinary collaborations and ethical reasoning, equipping them with expertise as future practitioners to address AMR. The article contributes by highlighting the need for contextual relevant engagements with wicked problems within HEI sustainability education, requiring interdisciplinary collaboration to develop innovative and sustainable solutions to wicked problems. The article's approach aligns with holistic and post-normal education, expanding educational purposes beyond knowledge acquisition to critical engagement with sustainability challenges such as AMR.

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Introduction

This article explores the integration of wicked problems into sustainability education within the context of antimicrobial resistance (AMR) in Zimbabwe. It focuses on how students in higher education institutions (HEIs) can develop knowledge and skills and engage with sustainability challenges. Using AMR as a case of a wicked problem, this article highlights the need for interdisciplinary approaches that engage with the health of humans, animals and the environment.

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AMR is a mounting challenge to global health as bacteria and viruses develop resistance to antimicrobial drugs and risk undermining modern medicine (Bratti et al. 2023; Cars et al. 2021). As a wicked problem, AMR is characterised by complexity and the lack of straightforward solutions. Resistance leads to treatable infections becoming life-threatening with increased risks during deliveries extensive surgeries and cancer treatments (Chinemerem Nwobodo et al. 2022).

The sustainability challenge of AMR is especially severe in Southern African countries, such as Zimbabwe, with increased resistance in tuberculosis, HIV/AIDS and malaria. In Zimbabwe, socio-economic factors drive unregulated antimicrobial sales and use complicating AMR efforts. Limited healthcare resources, weak monitoring systems and dependency on agriculture for economic stability and food security add further pressure on healthcare and food security (CDDEP 2017; Mshana et al. 2021). AMR disproportionately affects low- and middle-income countries and solutions should consider these socio-economic factors (Elton et al. 2020; Sartorius et al. 2024).

Addressing AMR requires a One Health approach that integrates the health of humans, animals and environments (Zinsstag et al. 2024). Health is thus distributed among humans, non-human animals and environments as interwoven health bearers. Such an interdisciplinary health approach engages with the social, ecological, political and economic that contribute to AMR (Littmann, Viens, and Silva 2020; Meisner et al. 2024; Rickard et al. 2023).

To prepare future practitioners, sustainability education in HEIs must incorporate real-world case studies and interdisciplinary learning. These methods enable students to engage with the complexities of AMR while developing critical thinking, adaptive learning, and problem-solving skills (Cross and Congreve 2021; McCune et al. 2023). Educational methods, such as cross-disciplinary seminars and experiential learning, foster collaboration across disciplines (Mickelsson et al. 2023). These engagements also support the co-creation of socio-economic and infrastructurally relevant knowledge (Mickelsson et al. 2023; Oljans et al. 2024).

Interdisciplinary collaboration using real-world case studies provides students with broader perspectives and interdisciplinary connections (Mahmoudi et al. 2012; Miller 2007; Miseliunaite, Kliziene, and Cibulskas 2022; Sáez de Cámara, Fernández, and Castillo-Eguskitza 2021). Improving the institutional of AMR in health, veterinary and agricultural sciences is key (Arbeiter and Bucar 2020). When students make interdisciplinary connections, they acquire the necessary expertise to address wicked problems. Holistic education is furthermore key for AMR communication campaigns and the promotion of responsible antimicrobial use among health practitioners and communities (Caron et al. 2023; Dambre et al. 2022). Strengthening interdisciplinary linkages and holistic education prepares students to address AMR in line with national and global action plans (MOHCC 2017; WHO 2015).

While education can engage with wicked problems, there is an implementation gap in HEI between understanding wicked problems and addressing these problems in practice. Sustainability education needs to connect with the everyday experiences of teachers and students (Noordegraaf et al. 2019). This approach enables meaning-making, aligning with Biesta's (2010) theory of educational functions. Crucially, sustainable development education efforts go beyond knowledge acquisition. It extends to critical political and ethical engagements in solving sustainability challenges that involve uncertainty, scientific controversy and competing values (Block, Van Poeck, and Östman 2019).

This article aligns with calls for interdisciplinary perspectives on educational purposes and knowledge content (Cole, Eskdale, and Paul 2022; Kamenshchikova et al. 2020). Third-party facilitators can enable interdisciplinary workshops to co-develop AMR educational approaches (Amelink et al. 2024; Kligyte et al. 2019; Plummer et al. 2022). Engaging with wicked problems teaches students valuable skills of critical thinking, ethical reasoning, adaptive learning, collaboration and complex problem-solving (Cross and Congreve 2021; Earle and Leyva-de la Hiz 2021; McCune et al. 2023). Students and educators need to draw from multiple disciplines in

developing innovative and sustainable responses to the challenge of AMR (Lönngren and Van Poeck 2021). Acknowledging the need for systemic solutions enhances the relevance of sustainability education in HEI (Littmann, Viens, and Silva 2020). Integrating wicked problems into sustainability curricula is thus a key pedagogical imperative (Kawa et al. 2021; Sharp et al. 2021).

Research aim

This article aims to explore the integration of wicked problems into sustainability education, within the context of AMR in Zimbabwe. This is done through understanding how aspects of Biesta's educational functions are expressed in participants' discussions on AMR education as addressing a pressing sustainability challenge. One main research question is articulated along with three sub-questions,

- What aspects of educational functions can be identified in the participants' discussions about AMR education?
- How are aspects of qualification for developing AMR knowledge and skills articulated in the discussions?
- How are aspects of socialisation re-producing AMR norms and values articulated in the discussions?
- How are aspects of subjectification for engaging critically with AMR articulated in the discussions?

In the article, we will also discuss how interdisciplinary collaborations in sustainability education can contribute to preparing students for their future careers and societal roles.

Theory

This article draws on Gert Biesta's educational functions of qualification, socialisation and subjectification (Biesta 2010, 2015a, 2015b, 2020) as a theoretical framework uniquely contributing to a more contextually relevant understanding of AMR education. Crucially this moves AMR education beyond acquiring knowledge and skills to encompass developing values and critical reflection. As the most prevalent educational function, qualification centres on students developing reflective knowledge and skills to become members of society. In relation to AMR education, the function involves developing biomedical knowledge and skills to understand and engage with AMR challenges through primarily technical competence. Socialisation, meanwhile, moves the educational focus towards AMR education as a process of value development. As part of giving the content of qualification meaning, students are also integrated into the cultural, social and political values and norms of a particular society in line with the educational purpose of re-producing norms and values around AMR. Socialisation in AMR education thus promotes practices that value resistance prevention and the sense of shared responsibility to address AMR.

The key concept of subjectification highlights how students through education can become critical and independent participants, able to use normative reasoning to guide their practices as part of contributing to a better future. As part of AMR education, subjectification emphasises the need for students to develop agency to question and reframe values and norms and critically engage with AMR practices adapting them to contextual conditions and needs. This is particularly relevant in Southern African contexts, where economic, social, and institutional determinants of health can differ significantly as part of engaging in AMR education and practices. This third educational function has been further nuanced to highlight its character of both adaptation and resistance by Van Poeck and Östman (2019). They argue that subjectification together with identification constitutes personality formation that occurs through identification.

The latter is the process by which students draw on the educational content, its norms and values, in constructing and reconstructing their identity. Identification can thus be constituted as social belonging where people choose not to follow prescribed practices from qualification and socialisation into academic disciplines and biomedical norms and values as they are identifying with the social belonging of family, community and culture. Meanwhile, subjectification highlights the importance of critical resistance on the part of the students in questioning prescribed roles and the value of them developing into independent subjects.

By integrating wicked problems into their sustainability education in HEI, students are faced with sustainability challenges that require more than the application of existing knowledge as they need to learn to critically evaluate different knowledge claims, acknowledge uncertainty and make value judgements. Biesta's theory (Biesta 2010, 2015a, 2015b, 2020) becomes a useful analytical tool in which different educational functions can be identified all the while acknowledging how they are often enacted together in educational practice (Van Poeck and Östman 2019). As highlighted by Biesta (2010) in exploring practices and how conditions constitute different ways of interacting with each other through learning, speaking and doing, further insights can be gained regarding how transformation can occur in the future. This aligns with the notion that it is necessary for education to explore what is worth achieving and feasible to implement in practice, rather than its most prominent (Biesta 2010). Through the attention given to values, contextual relevance and critical engagement Biesta's framework contributes to a holistic understanding of AMR education that accounts for the lived experiences of the students.

Materials and methods

The study was conceptualised around two one-day participatory research workshops at two HEI, Midlands State University, Gweru, and the University of Zimbabwe, Harare (Bergold and Thomas 2012; Ørngreen and Levinsen 2017; Spinuzzi 2005) with input from researchers at the study sites, strengthening the methods and piloting materials for linguistic accessibility and comprehension. Development and preparation of workshops drew on previous research (Mickelsson, Kronlid, and Lotz-Sisitka 2019) and was guided by the aim of exploring AMR education as a sustainability challenge. Workshops were co-facilitated by the authors along with note-taking from colleagues at respective universities.

The study included sixty interdisciplinary participants, 10 educators and 20 students conveniently sampled from each university. This generated spaces for engagement and knowledge co-creation among educators and students from across such diverse fields as medicine, pharmacy, veterinary science, education, agriculture, environmental science, and policy to work on AMR case vignettes (Converse et al. 2015; Kathiresan and Patro 2013; Payton and Gould 2022; Veloski et al. 2005). Key in choosing to operationalise case vignettes is their potential through narratives to explore participants' conceptual and ethical reasonings around different aspects of AMR. The vignettes were constructed based on experiences from research and practice around antimicrobial use and the emergence of resistance in the Zimbabwean context. Initial vignette drafts were constructed with fictional names and shared with research colleagues from different disciplines with knowledge and experience of AMR in Zimbabwe. Based on their feedback, case vignettes were improved for further contextual relevance and linguistic clarity. The integration of case vignettes as a key component of the workshops constituted an original and novel approach.

The workshop followed a structure of introducing the purpose of the workshop to explore knowledge co-creation regarding the intersections of health, food and antimicrobial resistance (AMR). The case vignettes address different aspects of the intersections between health, food and AMR, focusing on the use of antibiotics and antiretroviral drugs respectively by small-scale farmers in the line of food production and its impact on the health of humans, animals and ecosystems. Vignettes were presented in two parts with the first part outlining the initial

situation of antimicrobial use in farming animals followed by participants discussing in groups and interpreting the situation while drawing on their diverse expertise and experiences. Afterwards, the second part of the vignette presented the impact of antimicrobial use on the individual, the animals, the local community and the environment. Participant groups were then prompted to re-discuss the case with added questions focusing on ethical aspects of the situation and how the situation could be addressed. Each case vignette was finally discussed in a joint plenary where the diverse insights and reflections from the groups were brought together to highlight how the wicked problem of AMR could be understood in the Zimbabwean context. Through the case vignettes, the wicked problem of AMR was introduced to the participants through the use of storytelling. This enabled engagement with the spectrum of AMR as a wicked problem while leaving space for participants to draw on their diverse expertise and experiences to fill in the details and together create contextual richness to the challenges highlighted by the vignettes.

As participants engaged with the case vignettes in the participatory workshops, discussions took the form of third-person statements. Meanwhile, participants positioned themselves as health practitioners with a role to communicate and educate around AMR in sustainability education within the HEI and beyond throughout society. The participatory research workshop method provided structure for the data collection and created conditions for knowledge co-creation on the relationship between health literacy and AMR. Workshops were audio recorded and transcribed by the authors with support from contemporary notes for improved depth and accuracy in the transcripts. These notes made during the workshop followed the main points made and were used as part of the transcription process to clarify any uncertainties in the audio recordings.

Ethical considerations

This research obtained ethical approval from the Medical Research Council of Zimbabwe (MRCZ/A/2920). In planning the study, permission was sought to conduct workshops with health education practitioners and students at respective universities. The study adhered to the principles of informed consent and voluntary participation. Participants were provided consent forms and information sheets detailing the research aims, the workshop process as well as collection and management of research data. Opportunities were provided for participants to raise any questions regarding the research and workshop before going through and signing the consent form, with further opportunities offered during the workshops. The global code of conduct for research in resource-poor settings (Trust 2018) was adhered to in the study. Participant codes were used, and no participant names were recorded as part of the data collection.

Analytical approach

The analysis was based on Biesta (2010, 2015a, 2015b, 2020) which provided the foundational structure for identifying aspects of educational functions in the empirical material. In the analysis process, we used Braun and Clarke (2006, 2021) six steps of thematic analysis to identify, analyse, and report on patterns (themes) within the data. The first step focuses on data generation and transcription of recordings from the workshop discussions focusing on incorporating wicked problems into sustainability education. The thematic analysis was carried out in separate but interrelated steps. Inductive readings and re-readings were key for the second step, creating data overviews emphasising identifying and further studying patterns and regularities. The focus of the third step was on deductive re-reading the data and drawing on the concepts related to qualification, socialisation, and subjectification as educational functions outlined by Biesta (2010, 2015a, 2015b, 2020). This was followed by step four where these concepts were used analytically in structuring and categorising the transcript in three themes based on Biesta's

educational functions. As part of step five, we correlated the identified themes with the empirical materials to ensure that all key dimensions of the workshop discussions were covered by the themes. Illustrative examples were drawn from the material as part of the final, sixth, step to support our analytical argument and conclusions as aligned with the research aim and questions of the article.

Through this analytical process, we identified examples in the transcript data that represented the discussions as a whole and illustrated how aspects of the educational functions of qualification, socialisation, and subjectification a) included multiple aspects and b) often overlapped within the quotes, reflective of the argument presented by Biesta (2015b) regarding how educational situations are seldom clean-cut but a combination of two or more educational functions. The result section is analytically structured around how aspects of qualification, socialisation and subjectification were expressed in participants' discussions. While it was possible to study qualification and socialisation as offers of meaning in the educational content, subjectification needed to be analytically distinct to not merge with socialisation due to its unpredictability centred on how students become subjects with agency. This meant that when engaging with subjectification as part of workshop discussions, the results focused on what actions and lifestyles on the part of the students were promoted as desired educational outcomes.

Results

As part of the results, three themes were identified regarding how aspects of educational functions were expressed in participants' discussions about AMR education. These included: 1) the qualification function – antimicrobial knowledge and skills, 2) the socialisation function – good and bad antimicrobial habits and 3) the subjectification function – antimicrobial steward.

Theme 1: the qualification function – antimicrobial knowledge and skills

In this theme, the focus is on how aspects of educational functions were expressed as people learning factual knowledge, competencies and skills enabling qualified action in the use of antimicrobials. This entails basic biomedical concepts and knowledge about the use of antimicrobials for human and animal consumption in preventing and treating disease. But also, biomedically understanding the health impact for humans, animals and the environment when antimicrobial use results in the development and spread of AMR. The key to this educational function is learning how to navigate the meanings and consequences of antimicrobial use for the health of all. In this first quote from the participants' discussions, the biomedical understanding of antibiotics as a category of antimicrobials is exemplified where these pharmaceuticals are tools for infection and disease prevention.

> Antibiotics are used to prevent infections in several diseases in biology.

The focus of this quote is on the factual knowledge that antibiotics are effective in preventing health risks. The insight that antimicrobials are key in infection and disease prevention is further expanded upon in the following quote focusing on knowing how to use antimicrobials to prevent diseases in cows is highlighted by the participants,

> We need to discuss it because it's really important to know how to prevent these diseases before cows are infected.

The discussion emphasises the need for discussions about the prevention of diseases through antimicrobial use. This dynamic of antimicrobial use is further nuanced in the quote below where participants discuss the risks of antimicrobial use in animals.

> Medication for the poultry might lead up to antimicrobial resistance. If you are about to take medication, you must take it in the right dose. Otherwise, due to some mutations or whatever that may have been the cause of the disease, it might get resistant to that type of medication.

Participants highlight the potential of antimicrobial use in poultry leading to resistance in cases where prescriptions of dosage are not followed. In the quotes, participants talk about the importance of having basic facts and basic skills in preventing the misuse of antimicrobials as part of medical, veterinary, agricultural and social science practices. The importance of eating a balanced diet and knowing that human health, animal and environmental health are connected in addressing AMR.

Theme 2: the socialisation function – good and bad antimicrobial habits

Within this theme, the focus is on how aspects of educational functions were expressed in the workshop discussions as educational content being made understandable in relation to the reproduction of values and norms. Participants' discussions articulated contextually produced norms and values as either right or wrong habits, suggesting a dichotomous valuation of the act of using antimicrobials, as exemplified below,

> I have noted that there is misuse of the antiretroviral drug, whereby the intended purpose of the antiretroviral drug is for boosting the immune system of the patient who has been diagnosed. Or HIV AIDS. But instead of taking that drug, the drug is also being taken to feed the chickens that are going to be consumed by the humans.

> If you go to the context of the case study, you would see most of these cases, the antibiotics that are supposed to be used for other things are being overused, which is actually abuse, a lot of misuse.

Participants used words that were described in value-laden terms; words such as *preventing*, *promoting*, *care*, and a focus on *us* and the *environment* which were seen as 'good habits', while *overuse* and *misuse* were seen as 'bad habits' and associated with words like *non-accountability, greedy, cheating, focusing on their own profit* and *abuse*. As illustrated in the following quote, the correct habit of antimicrobial use is discussed by the participants as,

> educate the farmers about how they can use medication so that they can use it appropriately and avoid overusing it, which will lead to antimicrobial resistance and will also be a threat to their lives, for they will be consuming food, like for the cattle, they will consume food which will be unhealthy since the cattle might suffer from the infections, and also they are young.

The quote illustrates that the participants view that appropriate use includes avoiding overuse that drives AMR as well as underuse that might undermine the health of the cattle resulting in unhealthy food from infected cattle.

Furthermore, the incorrect habit of antimicrobial misuse is illustrated by the distribution and redistribution of medicines to especially animals without consideration for the long-term impacts of driving resistance and contributing to societal costs and environmental impacts on ecosystems.

> Also, with the zeal to have more of the cattle, this could even cost the country. Because if the bacteria were now resistant, it means they would need more money to make better drugs, which could then be used for the treatment of the outbreaks that were happening in the community. So it was unethical in a way because besides costing the community, it now also cost even the country in terms of the drugs which were supposed to be used for treating different ailments.

> And also, some of the antibiotics are going to be released into the environment. What is going to happen to the natural microbes that are in the environment? If these antibiotics are released into our water systems, what is going to happen to our aquatic microbiology? So, this could actually cause a negative impact on our environment.

> We know what happens in the long run of not taking your meds and HIV and AIDS, and we're also considering that he's no more involving himself alone, but then the whole family, because I mean, he's impacting environment, he's impacting the ecosystem.

As highlighted in the quote, antimicrobial misuse has ethical implications as individual decisions to have more cattle impose costs for the community and the country as a whole by undermining the effective treatment of different ailments in both humans and animals. Furthermore, environmental impacts are emphasised, especially for local water ecosystems.

This theme of socialisation around good and bad habits is further emphasised in the following two quotes where participants identify the cause of these habits in ignorance and lack of education.

> So yes, they are maximizing their profit when the chickens are growing but at what cost? So the issue of ignorance is our main problem.

> They should take accountability for their actions and know that there's no cheat code for anything, there also should be education on this.

> He just applied the antivirals to the poultry farm. And that's where the cycle started. It started from the poultry. So to the environment, to the fish, and to the humans. So that's how it happened.

This theme regarding habits of incorrect misuse extends to the more immediate consequences it has not just for human health but to the health of animals and environments as part of a holistic understanding of health.

Theme 3: the subjectification function – antimicrobial steward

In this theme, the focus is on how aspects of educational functions were expressed by participants as engagement with antimicrobials and AMR by learners becoming holistic acting subjects that enact knowledge for today and the future. Actions thus become contextual in terms of understanding who is acting within certain situations alongside other subjects. The subjectification function of education is to develop the skills to act together with others in addressing challenges such as AMR in context. The educational content is thus making possible certain ways of living in a society with resulting spaces for actions. To act responsibly regarding antimicrobials is not limited to conducting prescribed actions but rather to acting together with others in shared stewardship of the shared resource of effective antimicrobials for the health of humans, animals and the environment. As seen in the following quote, the farmer is responsible but not alone in this responsibility. Rather actions around antimicrobials are taken in a system of rules and regulations that also need to be clear in their communication with farmers around antimicrobial use.

> It's not only the farmer's fault. And those responsible for withholding such laws, you know, people from the Faculty of Science who address legislation are also responsible for not being able to withhold those laws on faith that the farmer should be able to mix such ethical. So basically what I'm saying is that it's not only the farmer's fault, but the people who withhold those laws, who should push forward those laws on what a person can do or not do.

As noted by the participants, there is a need to consider both who is at fault in terms of being to blame for some aspect of the current wicked problem, and who is responsible as acting subjects need to be seen in the context of available knowledge, information and relationships with authorities who frame the ongoing actions of for example responsible farming practice, consumer awareness and actions, traceability and transparency within and between stakeholders. Furthermore, the following quote about the farmer acting based on partial but correct biomedical information illustrates how subjectification should not be limited to certain disciplinary domains such as veterinary science.

> He was well-informed because he actually knew how to counter this infectious disease which was in the region. So I think one of the measures that we need to put in is that these different disciplines, health, food, this agriculture should work hand in hand. Different disciplines should work hand in hand, give each other knowledge and pass on knowledge.

Participants note that the educational function of subjectification in order to address wicked challenges such as AMR needs to be holistic in incorporating knowledge-informed actions from different disciplines relevant to the emergence and addressing of AMR. As seen in this quote, antimicrobial stewardship in education engages with the subject of the consumer as much as the subject of the farmer in addressing AMR. The educational function of subjectification around AMR is thus not limited to specific groups of people but is a concern for all.

> It also has to affect us, who are buying the product. When we see a chicken like a goat, we should ask ourselves, how is this happening? Education has to come to us all. And to understand that we can't buy this product because it has consequences later. I encourage people to eat the roadrunners.

Participants highlight how consumer choices, including buying or omitting to buy unnatural large chickens or meat from 'Belgian Blue' cattle have an ethical dimension in what kind of acting subjects students become through education. If animals are fed feed containing antimicrobials, this promotes growth and animals may become abnormally large, as exemplified in the quote above where a chicken that grows abnormally fast becomes more comparable in size to a goat, and (simultaneously) risk of spreading AMR do to miss use of antimicrobials in animal feed. Encouraging a road runner (a free-range chicken) in this case means a more sustainable alternative in many ways. Free-range chickens also contribute to better animal welfare, which reduces stress and risks of disease, and thus the need for antibiotics to cure infection.

Finally, illustrated in the following quote the educational function of subjectification links the immediate challenge of AMR to socio-economic conditions and how people and communities can become acting subjects with control over their own lives in terms of finances and food security.

> So I also think it [feeding antimicrobials to chickens] was because of that pressure to get enough income to sustain these families. So maybe we need to educate again the community and maybe help them in doing other projects which can help them to raise money and control. To realise that taking these education isn't maybe just doing good things. I think that was just my conclusion.

Participants thus emphasise how subjectification in education cannot be limited to just developing antimicrobial stewards but also needs to consider people and communities' holistic subjects with priorities and needs beyond an interest in addressing AMR. As such, education that aims to address the wicked problem of AMR also needs to account for the need for economic stability and food security and how promoting these needs through education is a key part of promoting learners and communities to become antimicrobial stewards. This role of education is further emphasised as key for community empowerment around medication in the following,

> We start by empowerment, by raising awareness and educating. I think it all starts with education. Educate about the type of food to take which will be healthy for them and maybe even how they will take medication so that they will avoid overuse or misuse of the medication.

Crucially, education is positioned as the foundation for everyday practices around food and medication to avoid overuse and misuse.

Discussion

In this section, we discuss how aspects of Biesta's educational functions were expressed in participants' discussions on AMR education. Furthermore, the section addresses how

interdisciplinary collaborations in sustainability education can contribute to preparing students for their future careers and societal roles.

Education along with communication and training is key to improving awareness, understanding and ability to address AMR both globally (WHO 2015, 2022) and nationally (MOHCC 2017). As a pressing challenge to health and sustainability, AMR educational efforts can be productively linked to relational One Health approaches that emphasise the necessity of expanding our concerns beyond human health. The results highlight, through the theme of socialisation function how good and bad antimicrobial habits are crucial knowledge, since misusing and abusing antimicrobials in animal farming results in the flow of antimicrobials into the environment, especially water ecosystems, with impacts both for the aquatic microbial state of the environment and the risk of the emergence of resistant microbes impacting the health of animals and environments. As part of AMR education, subjectification emphasises the need for students to develop agency to question and reframe values and norms and critically engage with AMR practices adapting them to contextual conditions and needs. As previously explored in Mickelsson et al. (2023), education emerges as having a key role in realising these AMR efforts across society. Within sustainability education, there is thus a need to develop AMR educational purposes and educational content that acknowledges its wicked and interdisciplinary character both in terms of the kind of sustainability challenge AMR poses as well as the forms of approaches and actions that are needed to comprehensively and convincingly address this emerging challenge.

In this study, Biesta's (2010, 2015a, 2015b, 2020) theory of educational functions was operationalised in the explorative analysis of discussions among participants in HEI to add depth and nuance to their articulations of the purposes and content of AMR education. Biesta's framework contributes to a holistic understanding of AMR education that accounts for the lived experiences of the students. The functions allowed us to identify as part of participants discussions how they saw AMR education as entailing (1) qualification of students through the attainment of antimicrobial knowledge and skills, (2) socialisation of students into values and norms for the building good and bad antimicrobial habits, and (3) subjectification of students in developing contextual agency in becoming antimicrobial stewards.

As showcased in the results, holistic efforts to engage and address wicked sustainability problems such as AMR necessitate interdisciplinary collaborations between university faculties. In the study, these interdisciplinary collaborations were facilitated through the use of case vignettes to create common ground among diverse disciplines (Calvo-Villamañán, San Millán, and Carrilero 2023) as part of participatory research workshops. The case vignettes enabled the participants to engage with real-world examples of AMR in a knowledge co-creation process that drew on their diverse expert knowledge and experiences, operationalising them in contextual readings of a wicked sustainability problem (Littmann, Viens, and Silva 2020; Rickard et al. 2023).

Meanwhile, the study highlights three principal limitations with the chosen methodological approach, firstly the risk of group and plenary discussions leading to an overemphasis on reaching consensus and overlooking minority or divergent perspectives. This was addressed by documenting the participants' discussions through audio recordings rather than just documenting their presentations as groups during the plenary sessions. Secondly, a limitation was power dynamics among participants where dominant personalities or institutional hierarchies could hinder contributions from participants. We attempted to address this limitation by having each participant first write their initial reflection on the case vignette questions and read it aloud for the group before engaging in joint discussions. The third limitation related to the oversimplification of the wicked problem through the use of case vignettes. We endeavoured to address this using iterative vignettes where new information and complexity were presented progressively, encouraging participants to broaden and adapt their reflections as the vignette evolved thus better reflecting the unpredictability and complexity of wicked problems such as AMR.

Based on the results that highlight the potential outcomes of such interdisciplinary engagements, curriculum development becomes key. It is through curriculum that such interdisciplinary perspectives and approaches to shared sustainability challenges can be institutionalised and thus integrate AMR educational purposes and content as part of relevant higher sustainability education programs. As noted by Littmann, Viens, and Silva (2020), understanding and addressing such wicked problems necessitate holistic and interdisciplinary approaches marked by innovation and contextual sensitivity. In the Zimbabwean setting this entails considerations for the disproportionate risks in low- and middle-income countries where AMR exacerbates the pressure of health and food security systems (Elton et al. 2020; Sartorius et al. 2024). When applied to HEI such approaches would enhance the real-world relevance of sustainability education. Holistic approaches where human, animal and environmental health are interconnected cannot be catered to by any single or small group of academic disciplines but require interdisciplinary collaborations such as the one exemplified in this study to fully consider and engage with the wickedness of AMR.

As highlighted in the results, education aimed at addressing the wicked challenge of AMR in Zimbabwe needs to be contextually relevant with regards to the intersections of a healthcare system under severe pressure, high dependency on agriculture for economic activity and food security, weak monitoring and surveillance and challenging socio-economic conditions for a large part of the population (CDDEP 2017; Mshana et al. 2021). AMR education in Zimbabwe needs to engage people as holistic beings with priorities and needs of economic stability and food security in addition to stewards of antimicrobials and subjects in addressing AMR. Integrating AMR educational purposes and content as part of sustainability educational programs in HEI has the benefit of institutionalising One Health principles in HEI in which programs and courses are designed around interdisciplinary components such as shared lectures, collaborative projects and joint case studies. In line with Kligyte et al. (2019) and Amelink et al. (2024), the operationalisation of pluralistic educational content in third-party mediated spaces such as workshops provides opportunities for integrated and collaborative research and education. Implemented as part of holistic education in HEI (Arbeiter and Bucar 2020; Mahmoudi et al. 2012; Miller 2007; Miseliunaite, Kliziene, and Cibulskas 2022; Sáez de Cámara, Fernández, and Castillo-Eguskitza 2021), offering students opportunities to engage and learn together across disciplines, One Health approaches and learning outcomes thus form the basis for the development of key student competencies in addressing wicked sustainability challenges. As seen in the results of this article, for AMR these competencies include awareness and knowledge of resistance development and spread across the interconnected areas of human, animal and environmental health. Furthermore, this includes, an understanding of the role of environmental factors in both resistance development and spread as well as a solid grasp of and ability to apply principles of antimicrobial care and stewardship. As highlighted in theme 3: The subjectification function, the focus is on how aspects of educational functions were expressed by participants as engagement with antimicrobials and AMR by learners becoming holistic acting subjects that enact knowledge for today and the future this is crucial to develop antimicrobial stewardship. The development of these competencies across relevant courses and programs aligns with Kamenshchikova et al. (2020) and Cole, Eskdale, and Paul (2022) call for interdisciplinary perspectives on AMR purposes and knowledge content in seeking collaborative innovations and synergistic solutions. It involves having curriculum components engaging with pluralistic knowledge content, health policy and antimicrobial stewardship frameworks to create conditions for students to develop key competencies in navigating ethical dimensions of responsibilities and thus become antimicrobial stewards. This pluralistic educational perspective with the aim of enabling students to act within diverse contexts is aligned with previous research (Block, Van Poeck, and Östman 2019; Lönngren and Van Poeck 2021; Van Poeck and Östman 2019).

Through interdisciplinary collaborations, HEI is thus able to create spaces for productive discussions on the (mis)use of antimicrobials and contribute to equipping students for their

future careers and societal roles as the health practitioners of tomorrow. This entails developing essential knowledge, skills and networks to collaborate across professional boundaries in addressing the complexity of AMR as a wicked challenge and contributing to AMR literacy beyond HEI.

Conclusion

This article explored AMR as a wicked problem especially relevant for Zimbabwe considering the challenges posed by the spread of resistance among pathogenic microbes and limited access to antimicrobials. Our results have demonstrated that AMR education in sustainability education necessitates holistic and interdisciplinary approaches. Leveraging the strengths of multiple disciplines as part of One Health is key to understanding AMR. Holistic education around wicked challenges offers a way forward as a cornerstone in effectively addressing one of the most critical public health challenges of our time. Current AMR addressing efforts promoted by WHO and enacted by Zimbabwe has so far focused on communication and information efforts as exemplified in radio broadcasts. Sustainability educational efforts could create the conditions for co-development of contextually relevant actions that consider the diverse economic, social, and cultural conditions of different regions, particularly in low- and middle-income countries that are disproportionately affected by AMR.

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Transparency declaration

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