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Investigating sustainable development and environmental protection in the education of urban mining through the learning strategy of WSQ

Yong-Cih Yang[1]♣
Hao-Chiang Koong Lin[2]

[1]*Center for General Education, National Taiwan University of Science and Technology, Taiwan.*
Email: yc.yang@mail.ntust.edu.tw
[2]*Department of Information and Learning, National University of Tainan, Taiwan.*
Email: koonglin@gmail.com

Abstract

This study explores the effectiveness of the WSQ (Watch-Summarize-Question) learning strategy in urban mining education, focusing on resource management, environmental protection, and technological innovation. Thirty university students participated, engaging with instructional videos and content designed to convey technical and environmental concepts. By summarizing and questioning the material, students internalized key ideas while expressing enthusiasm for the process. The study identified five key themes: resource recycling, sustainable development, technological innovation, economic trends, and social responsibility. Central outcomes emphasized the importance of recycling, the synergy between innovation and environmental protection, and the educational role in fostering sustainable practices. The WSQ strategy demonstrated effectiveness in addressing environmental challenges and advancing technological education, with potential applications in interdisciplinary areas like climate change, energy management, and biodiversity conservation. The integration of digital tools, including artificial intelligence and virtual reality, is recommended to enhance its impact further.

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(♣ Corresponding Author)

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1. Research Background and Motivation

Increasing worldwide resource consumption and the associated problems of resource extraction and management have led to serious environmental and economic challenges. The urban mining concept should help solve this. But whether it works or not is mainly an educational problem. At the base of urban mining's educational problem is this: it is an interdisciplinary issue. The conventional funnel model of education largely cannot handle such topics and thus relegates them to knowledge transfer. Urban mining emphasizes extracting resources from urban waste. It talks primarily about the presence of the problem (waste) and its cause (urbanization). It then discusses possible effects of following the present course and what feasible educational solutions might look like and emphasizes that the concept places absolutely no additional burden on the environment. It places no additional burden because extracting resources and their subsequent reuse makes much more environmental and economic sense than the apparent alternative: physically mining resources from the Earth (Chen, Lin, & Su, 2023; Scholz & Wellmer, 2013; Schomberg, Bringezu, & Flörke, 2021).

Take urban mining education, for example. Encompassing topics like resource recovery, technological innovation, and environmental policies, it might seem, at first glance, to be an area of study more related to the issues of today's world than to those of the past. Yet the conventional educational tools employed seem rather stuck in the same old rut. They do not effectively eliminate the appearance of these subjects as "stop and smell the roses" moments for students. Even when urban mining is discussed, it feels like an afterthought. This vacuum in appearance, in visual presence (a hallmark of effective educational tools), can translate to a vacuum in interest or investment in the part of students. Hearing about urban mining in the context of an environmental policy or technological innovation seems to be rather Canada Goose-esque in terms of how it might take students "to the top" in this issue area, which is where, in our view, this course is supposed to lead (Talens & Villalba, 2013).

This study uses the WSQ method, which stands for "Watch, Summarize, and Question." This method is particularly appropriate for the kind of education we're providing. It allows our students to gain a much better grasp of the core ideas and concepts we're teaching concerning resource management, technological innovation, and environmental protection. After watching videos we've made, our students can now visually comprehend the technical steps involved in mining—in this case, urban mining—wherein we extract valuable resources from waste. They understand the kinds of technologies we would use to do this and the application value those technologies have in the sorts of scenarios we discussed in previous lectures. Those scenarios dealt with what the educational literature calls the circular economy and sustainable development.

For example, students could suggest how urban mining might be improved to better retrieve disposed-of electronics and other materials, with thoughts and proposals focused on how the various technologies of mining might be put to better use in different kinds of settings. Imagination and thinking about the applicability of learned knowledge in different contexts is the heart of what any kind of modern education should be achieving. Urban mining education aims to equip students with knowledge about existing resource recovery technologies that could be developed, bettered, and applied by them in the varied contexts of our future. Unfortunately, most urban mining education is either an engineering course or a materials science course, which are both largely the kinds of courses that have long been known to impart mainly content or knowledge without instilling much active learning or reflection in students (Arias-Gundín, Real, Rijlaarsdam, & López, 2021; Hsia, Hwang, & Lin, 2022).

The WSQ method offers an effective learning model that delivers students to a truly understood advanced knowledge level in the field of resource recovery. The model also leads to the appearance of practiced knowledge associated with that comprehension. In addition, the WSQ learning model integrated with digital tools such as artificial intelligence (AI) and virtual reality (VR) offers the opportunity for students to have a highly focused and deeply engaged class experience. Furthermore, this digital integration allows the students to gain a virtual engagement with the tasks at hand that can simulate the actions and decisions necessary to address the challenges associated with resource recovery and urban mining (Kim & Kim, 2021; Klein et al., 2022).

2. Review of the Literature

2.1. The WSQ Learning Approach's Theoretical Foundation

The WSQ learning approach (Watch-Summarize-Question) is a staged learning strategy that effectively improves self-directed learning abilities and overall student achievement (Johnson & Smith, 2022). As the name of the method suggests, it consists of three phases: Watch, Summarize, and Question. During the Watch phase, students are to use their instructors' visual learning materials, such as videos, as the basis for nearly instant establishment of a foundational knowledge framework requisite for the next two phases of the method (Duran, 2021; Zhao & Zhang, 2023). Instructional videos and other visual teaching materials are supposed by some researchers to be far more effective than lectures in conveying not just the same learning content but also a deeper comprehension of that content (Kim & Kim, 2021).

During the "Summarize" stage, students review and reorganize learned materials, which emphasizes both self-reflection and internalization of knowledge. It is as if they are putting the content through a mental filter to ensure only the most essential parts remain intact. This transformation is necessary for what Yu and Lin (2022) call "practical knowledge." The "Question" phase encourages students to raise their own questions, leading them to what amounts to an in-depth exploration of the issues at hand. According to Zhao and Zhang (2023) this stage is extremely beneficial for developing several necessary skills. Not only is questioning effective for improving critical thinking skills, but it is also a wonderful way to enhance another important skill: problem-solving. Studies have shown that when students engage in questioning, they tend to solve more problems, and they solve them more quickly than when they are given the same problems without the impetus of a "Questioning game" (Harvey & Light, 2015; Hsia et al., 2022).

2.2. The Metropolitan Model for Resource Recovery and Recycling

The WSQ approach has been widely applied in the field of urban mining education. Students benefit from this because the most abstract and difficult technical concepts, which are usually found in the initial chapters of a textbook, can be closely connected to what one might consider the practical outcomes of the kind of work urban miners do when they direct their efforts toward the recovery and recycling of resources from waste. The application of the WSQ learning approach in the context of urban mining education has the added benefit of allowing a natural framework to be constructed for the understanding of a series of resource recovery and recycling processes that one might encounter when studying the technical aspects of urban mining.

In the "Watch" phase, key urban mining-related technologies learned by students come from e-waste recycling and powder metallurgy. They grasp these through "talking head" instructional videos. The videos cover valuable resources that e-waste and urban mining can yield, as well as the kinds of valuable deposits that e-waste and urban mine sites represent. From both the presentation mode and the medium itself, students intuitively grasp basic principles and the breadth of application of the technologies they learn about. After watching, they talk. In the "Summarize" phase, students organize w discussion the content they have just learned through the video. They also individually synthesize the content into a format that yields a clear understanding of e-waste recycling and powder metallurgy, as well as their application to urban mining.

The technology and environmental protection concepts in the curriculum were taught to students using concept mapping and modeling followed by a layer of summarization. Chen et al. (2023) and Kuswendi and Arga (2020) describe the concept mapping and modeling approach as supporting "logical thinking promotion." From my understanding, the curriculum was developed to instill in students a way of thinking that leads them to effectively apply their practical knowledge to problem-solving. The next phase of the curriculum pushes students to think critically about the relationship between technological innovation and environmental protection.

2.3. Learning Outcomes and Feedback

An in-depth analysis of 30 students' learning processes confirmed that the WSQ learning approach significantly enhances not only the students' knowledge internalization but also their skills in knowledge application, critical thinking, and technology use. For both topics—resource management and environmental protection—the students expressed a high level of interest and enthusiasm and demonstrated strong motivation to learn. The students in this study tended to think in very linear ways, which may explain their reliance on technological solutions. However, "resolutions" should not be thought of as "solutions." When the students didn't understand something on a basic level, they struggled to make the tech work (Yu & Lin, 2022).

In addition, the WSQ method helped the students think critically. When the students learned to question, they came up with much better questions. When they had better questions, we had much better discussions, which went much deeper than before (Zhao & Zhang, 2023). By the end of the unit, I felt like students had a much better grasp on the content. They were able to connect the ideas in the content to their lives, and quite a few of them expressed interest in pursuing careers in tech (Lin, Wang, & Huang, 2023). So, this approach clearly works to engage students and get them to learn at a deeper level.

3. Research Methodology

3.1. Participants and Real-world Context

As detailed in the study documentation, this research involved 30 students from a university in northern Taiwan. These students were part of a field test conducted to gather feedback and experience data during their learning process. The core aspect of the instructional design focused on an "urban mining" learning activity—an activity that had the students learning about and engaging with an emerging and very contemporary technology. The design of the learning activity placed a strong emphasis on having the students gain a solid understanding of "core" concepts related to not only the basic premise of "urban mining" as a technology but also the basic premise of why this type of technology is important for society, especially in terms of a "circular economy" and "environmental conservation." The global context of contemporary environmental problems, such as climate change, was presented to the students as the backdrop or framing of their learning. Two significant learning activities took place in the frame of this research.

This study used artificial intelligence to analyze the data gathered from students. It was able to perform both a word frequency and a clustering analysis of the students' written feedback. From this large amount of data, the AI was able to categorize 30 keywords into five themes. These themes represent the kinds of things the core curriculum designers need to pay attention to. More than that, the study offers insights into why the WSQ (Watch-Summarize-Question) approach to learning works, linking it to achievement and self-reflection. Hence, the study first describes and explains the five themes (3.1) before moving on to a description (3.2) of the operative parts of the WSQ learning design, especially its key components (3.3).

Initially, during the "Watch" stage, students viewed instructional videos created expressly for the urban mining context. These videos not just highlighted international instances of urban mining, but also went into detail about the specific technologies associated with them—such as types of waste recycling (with e-waste recycling being a featured case) and resource extraction (for instance, powder metallurgy—a way of recycling metals—that the videos indicated was being applied to make parts for 3D printers). When "Watch-ing" these videos was over, the "Summarized" part came next. Students were not going to just regurgitate what they had seen. Instead, they were going to make sense of it in a more coherent way—this time with the aim of really internalizing the content and value of what the videos presented.

Finally, in the "Question" phase, students put forth pertinent inquiries about the presented learning material. The purpose here was to get the students to think critically and to stimulate them to explore the content more creatively (Mittag & Pappu, 2022; Nguyen & Wong, 2019; Vasquez & Young, 2021; Xiao, Shang, Yao, & Chua, 2021). For instance, students asked how we might improve the soon-to-be outdated urban mining technologies or probed the potential of urban mining to really help us address resource scarcity or cut back on the pollution that resource extraction usually causes. A few more audacious questions from the students even suggested that they should dive into thinking about improvised urban mining in really novel ways: the use of jailhouse labor or the employment of hackers in commandeering old smartphones (and other electronic devices in our fast-updating culture) for some kind of near-future apocalypse scenario in which the digital remains of our once-valuable resources instead become the digital dross of a failed civilization.

3.2. Learning Content Overview

3.2.1. Key Concepts and the Significance of Urban Mining

The core idea behind this teaching material is the concept of "urban mining." This concept spotlights the extraction of valuable materials from the waste and by-products of human activities—pretreating human-generated waste as if it were a resource—so that it can be used again in the economy. More and more, it seems, this way of thinking is gaining global attention, and for good reason. It helps rethink how we handle all the trash that we keep making, as more and more people make more and more stuff to throw away.

But in the U.S., and in many other parts of the world, discarded stuff goes to big holes in the ground (or dry incinerators) and not back into the economy. And even when we do recycle, we often don't recycle efficiently, and the same goes for reusing stuff before we throw it away. If we are going to get anywhere with urban mining, both conceptually and in practice, we need to find ways to use what we have generated in the way of waste better and more economically.

3.2.2. Case Studies and Technological Applications

This material includes several case studies from various countries that showcase the potential and application value of urban mining. For instance, companies in Denmark and Belgium are recovering precious metals from e-waste to support the production of green technologies. Actions such as these not only reduce dependence on raw materials—mined mostly from developing countries, where environmental protection is often poorly enforced—but also reduce harmful pollution. ... The material also provides a detailed introduction to key technologies, such as powder metallurgy, that are central to efficiently extracting valuable metals from waste. ... One would expect a leading-edge field such as urban mining to have rapid developments happening in Asia, particularly Taiwan and China, where pollution controls are weak and mining of fresh raw materials has begun to seriously damage the environment. ... Enterprises in both regions have successfully developed novel technologies for urban mining that can efficiently extract rare metals from waste.

3.2.3. Educational Value and Environmental Impact of the Material

The instructional material serves a twofold purpose: first, to educate students about environmental issues through an engaging discussion of concrete technology; and second, to instill in them the idea that urban mining represents an important part of the solution to the many negative environmental impacts that result from the concrete life cycle, particularly when viewed from the perspective of the circular economy (Maurer & Bogner, 2019; Monroe, Plate, Oxarart, Bowers, & Chaves, 2019).

Students are introduced to the main technologies of "sustainable concrete" and "resources for concrete." They learn that "mining" urban areas for the materials to produce "sustainable concrete" doesn't really solve the apparent problem. Why? Because mining appears to simply remove critical materials from waste and from the communities that need them. And as the authors of the material diligently explain, "mining" is just another word for "using," and both still end up as part of the concrete life cycle.

The study's data analysis method involved using artificial intelligence to perform an in-depth analysis of learning feedback from 30 students. The researchers had sought to provide a better understanding of the students' learning experience. To achieve this, they used AI-assisted textual analysis, which allowed them to handle large amounts of feedback data in a more efficient and effective manner. With the help of AI, the researchers uncovered some hidden structures behind the feedback data. They focused on both the knowledge and the learning processes structure of the students. They found two main types of feedback. One type indicated the knowledge structure the students developed about urban mining, which concerned their understanding of resource recycling, environmental protection, and technological innovation related to the issues discussed in the class. The other type indicated the students' process structure, which included mostly positive comments about the learning method they experienced, while also revealing some of the challenges and obstacles they encountered along the way (Nguyen & Wong, 2019).

4. Coding

Our study involved 30 student participants and about 15 hours of data collection in total. Overall, we derived six distinct categories from the student learning responses. Three of these centered around "knowledge structures." Two of these three categories were concerned with structures characterized as "poor" or "shallow." The third category was "good." We consider the "good" structure as a bridge connecting sparse, poorly structured knowledge to a more coherent and better-structured network.

4.1. Outcomes of the Knowledge Structure Coding

The responses to the learning assessment posed to thirty students yielded five clear themes. These themes derive from open coding of the learning assessment, which was an elicitation task given to students. The perspectives, knowledge construction, and even slight changes in attitudes of the students during the process of learning offer clear and deep insights into the way they understand the significant core issues of resource management, environmental protection, and technological innovation.

4.1.1. Resources and Recycling (C1)

The theme of resources and recycling elicited a somewhat more developed picture from the students, as they seem to have a basic grasp of the important issues relating to resource management. Particularly, the students seem to understand the necessity and premise of the circular economy quite well. Many of them made the point that while they understand the theory and reasoning behind the circular economy, in practice, they face severe limitations and challenges in the technologies, facilities, and systems necessary to make the circular economy function efficiently and effectively. The need for this type of "re-thinking," or system-at-large, is mostly lost on the students who seem to understand the basic premise of the circular economy quite well.

4.1.2. Environmental Protection and Sustainable Development (C2)

This theme reflects the understanding of balancing protection of the environment with development of the economy that our students have. Learning experiences provided to them have led to the realization that solving environmental problems necessarily involves also solving problems related to the development of the economy. The coded statements from students cover a number of key topics of concern to us—environmental protection, sustainable development, pollution, and conservation of natural resources. Generally, student expressions indicate a very strong concern with and interest in protection of the environment, especially regarding the kinds of major events that have led to Greenwalt (2016); Lai (2023); Morimoto (2022); Smith and Grueter (2022) "Anxiety-Driven Environmentalism," which includes such topics as global climate change and environmental degradation.

4.1.3. Technological Innovation and Application (C3)

Within the scope of technological progress, students discovered the potential impacts of the progression of these technologies on environmental protection. They learned how technological innovation can, in fact, promote "green" progress and lead us to a more environmentally friendly society, which they understood as a potential win-win situation. Some students went so far as to say that we might be able to lean on technological innovation to resolve not only current environmental issues but also issues that might crop up in the future. They cited examples where tech had come to the rescue: solar panels, wind turbines, and biofuels—"the innovations of today," as one student so aptly put it, "could be the solutions of tomorrow."

4.1.4. Economic Development and Future Trends (C4)

In this theme, students concentrated on the means to accomplish economic growth and social development that resource sustainability ensures. The overall coding included not just economic growth and development but also global changes and urgent future trends. It seems that both the students' and the instructors' awareness went toward the growing understanding of the World Bank's and the United Nations' ideas about global development in the future. ... This was on everyone's radar! Moreover, some students highlighted challenges for changes in the global economy and for the improvement of the allocation of world resources. ... Waste resource recovery concepts pertaining to urban mining—new ideas that aim to retrieve resources from city waste—also emerged in many students' discussions and presentations. Overall, these are very promising ideas.

4.1.5. Education and Social Responsibility (C5)

Under the theme of education and social responsibility, although not in every case, students' thoughts appear to be relatively deep and quite critical; they seemed to be reflecting on and attempting to understand the true role of environmental education and the value of living in an environmentally responsible way. Indeed, some students perceive "environmental education" to have a value that goes beyond just one's "personal awareness," and they think it has the potential to promote "societal emphasis on environmental protection." Elements coded in this theme include not just "environmental education" but also "social responsibility," "international cooperation," and "policies and regulations." More on these elements below.

Overall, a detailed analysis of these five themes shows that the comprehension of the students extends to several levels—understanding that goes beyond superficial "knowledge drops," to what we define as comprehension at the levels of understanding, analyzing, evaluating, and applying. This definitely indicates the learning activity worked and that audience members' theoretical bases have improved. More importantly, because the real-world issues these five themes concern are high-priority for future generations, we hope that the audience members have retained sufficient "understood" information to apply to their work lives in ways that will lead to improvements in both environmental conditions and the kinds of technological solutions that might lead to a whole "new tech paradigm."

4.2. Outcomes Associated with Reflection-based Coding

In this study, the learning reflections of thirty students were examined and sorted into four major themes for analysis. The themes—Understanding and Awareness, Emotional Reactions, Inspiration and Determination, and Action and Participation—each encompass a different dimension of the students' transformation. The contents of these categories reveal insight into the wide variety of attitudes, levels of cognition, and emotional responses students exhibited during and post-learning experience and show the amazing transformations many of them achieved in the process.

4.2.1. Comprehension and Knowledge (C1)

Learning began when students were largely aware of the topic in question. With key terms like "know," "recognize," and "identify" appearing in the coding, it is evident that students were beginning to stake a comfortable claim to the content knowledge being imparted. This was the most basic of basic learning, laying almost no higher-order cognitive demands on the learners. It was a stretch, really, for some students to claim that they "got" the content. Grasping content is a crucial first step before content can be meaningfully employed in a second step of learning (see C2). For instance, some students mentioned that through learning, they "identified the principal components of the circular economy."

4.2.2. Emotional Reactions (C2)

A huge motivator for students is when they are taken on an emotional journey. This doesn't mean every educator must moonlight as a 1940s newsreel operator, but it does mean creating "wow" moments in class. This is not the same as inducing a cheap laugh or an eye-roll in a classroom full of students. Rather, this is about moments in which content provokes an internal response that makes learners want to push it to the next level—that thing some people call "the next deep level." The kinds of emotional responses mentioned in this chapter carry a lot of weight, partly because they are so clearly tied to what students learned and partly because they say a lot about the students' characterizations of the content the course aimed to cover.

4.2.3. Being Inspired and Determined (C3)

After the learning experience, students expressed during the reflection phase that we had inspired them. They said they were moved by the content and that our course was important. Some even said they were inspired to the point that they had decreed or made decisions that they were going to change their work or their lives in a way that would be related to the "real-world issues" our course addressed. For example, one student said they had "decided" to change their focus and pursue work in the area of "environmental protection." This is a big deal for students to say. As deeply as I have explored the environmental issue, I have never felt moved to the point where I said, "I will change my career path so I can focus on this issue and not another."

4.2.4. Action and Participation (C4)

Some students went beyond the learning outcomes and produced concrete action plans, showing a more active attitude toward participation. This theme reflects practical actions and social engagement. Codes like "willing to participate," "support," and "enhance" show that these students have shifted from being passive learners to active participants. For example, one student expressed a "willingness to invest more time in my participatory role with the LEED (Leadership in Energy and Environmental Design) Green Building Rating System" and to "enhance my learning experience with related technologies." Another student framed her action plans in the context of social engagement, saying she wants "to involve myself and my friends in activities that promote environmental awareness."

4.2.5. In-Depth Analysis

The students' learning experience can be seen to have gone through a sort of metamorphosis. As opposed to just receiving knowledge passively, they seem to have engaged in a more meaningful way with the material. It almost appears as if they were transformed from knowledge-hungry caterpillars into two kinds of butterflies: some emerged as the "Environmental Champions," and others, as "Technological Innovators." More on that in a bit. I should note, though, that some students who were not part of the core group that taught this lesson also made "more on that in a bit" reflections at the end of the unit that sound sort of similar to the ones I just shared.

4.3. Comprehension and Consciousness

4.3.1. Comprehension and Consciousness in Contrast to Assets and Reclamation

In the context of comprehension and consciousness (C1), students are gradually acquiring an elemental bodge of knowledge that correlates with the content in Assets and Reclamation (C1). Both of these domains reflect students' basic or even fundamental understanding of resource management—of how resources can be managed, at best, when they are seen as assets and the pollution problems associated with their use and disposal are minimized. Neither of these domains is rigorous or comprehensive, but both are way stations along the path to students acquiring understanding and also something close to it, in appearance, but not quite, a circular economy vision. Emotional reactions are correlated with environmental protection and sustainable development. The theme of "Emotional Reactions" captures the sorts of emotional responses we received from our participants regarding our learning content—specifically, surprise and concern. Conversely, the "Environmental Protection and Sustainable Development" theme emphasizes participants' articulation of an understanding of how to (or how not to) balance economic development with environmental development. When participants learned about certain kinds of environmental destruction—say, pollution in aquatic systems—they often expressed sorts of shocked or concerned reactions that led them to further reflect on and study environmental topics.

4.3.2. The Two Themes: Inspiration and Determination vs. Technological Innovation and Application

Another close relationship exists between the theme of Inspiration and Determination (C3) and the theme of Technological Innovation and Application (C3). In the theme of Technological Innovation and Application, students learned how innovative technologies, such as green technologies and technological models, could—and in some cases, already do—affect environmental issues and practiced these concepts through the development of their own green models and applications. This is very closely mirrored in the theme of Inspiration and Determination, with students often citing feeling inspired while learning about those innovative technologies and a lot of determination to push for the application of those inspiring technologies.

4.3.3. Action and Participation vs. Economic Development and Future Trends

The Action and Participation theme aligns closely with my second theme, Economic Development and Future Trends (C4). It focuses on a series of concrete, active participations by students after learning. A good example would be students partaking in a "mock" environmental summit or a simulation of a decision-making process in a congressional committee, with members speaking for and against various policies. In both cases, the students learn the importance of personal and collective actions for achieving a more sustainable world, and they appear to be enjoying themselves rather thoroughly in the process.

4.3.4. Environmental Education and Social Responsibility

Environmental education and the enhancement of social responsibility are key in the mission of UNESCO's chair for the promotion of global citizenship. Why? Consider these half-truths and half-propositions: One, at least, makes the plurality of environmental educators ask themselves uncomfortable questions. You will find them right in the "crazy" plot of "The World According to Us." Here come the half-truths and half-propositions, or the half-baked.

4.3.5. Thorough Examination

When we look at the coding themes that appear in the two tables side by side, they reveal an almost uncanny correlation. It is as though two different sides of a single coin have been illuminated. The first table shows learning at basic and deeper levels of knowledge; the second is about emotional involvement and social impact. Learning in the first is much more likely to have happened if learning in the second has occurred. The reverse is equally valid: Learning in the second is much more likely to happen if learning in the first has occurred.

5. Conversation and Closure

5.1. Discussion

This research has shown that the WSQ learning approach can be a highly effective teaching strategy for dealing with complex problems, especially in the case of environmental issues and technological solutions. The WSQ method divides learning into three parts—Watch, Summarize, and Question—that correspond to direct instruction, independent reflection, and collaborative inquiry. In this chapter, we discuss the implications of these findings for the teaching and learning of urban mining.

The Watch stage involves the direct instruction of students through video-based learning that helps them understand the practical application of urban mining. In our case study, urban mining was represented as a complex technological system. It encompassed not only the recovery of resources from the mines but also the actual treatment of e-waste, which is part of what we call "urban ore."

Take, for instance, the task in which students must distill the intricate and specific techniques of resource extraction from waste and apply their understanding to what could be called "resource shortages" and "pollution problems" on a global scale. In the context of applied environmental science, this demands not only a high level of understanding of the kinds of problem-solving technology that could work (and not work) in the real world but also a kind of foresight into future circumstances that could dictate the adequacy and viability of these same kinds of problem-solving scenarios and technological applications. For the students, both kinds of understanding are worked out against the backdrop of Earth's likely future in the second half of this century and the likelihood of ten billion people, most of whom will live in cities, on a planet that may be warmer, wetter, or drier than it is today.

Students' innovation capabilities and problem-solving skills are strengthened at this stage, allowing them to develop qualitatively deeper concepts regarding technology's application in the learning process. From experimental results, students' learning responses can be summarized in five major themes: (1) Resources and Recycling (2) Environmental Protection and Sustainable Development (3) Technological Innovation and Application (4) Economic Development and Future Trends (5) Education and Social Responsibility. These five major themes reflect a multi-level transformation during learning, from basic knowledge acquisition to heightened emotional responses and ultimately to solid action plans (with the help of technology) that students might take in the future.

The "Technological Innovation and Application" theme allowed students to grasp the vital role of innovative technology in resolving environmental concerns. Certainly, their strong interest in applying technological advancements to real-life scenarios — an interest that undoubtedly plays a part in their chosen career paths — came through loud and clear. But what was perhaps even more striking was the way in which this theme prompted not just intellectual but also deep emotional reactions from the students. Shock, disgust, and disappointment over how humans have polluted the environment (they used "environmental rape" in one instance) and wasted resources led many to resolve to take part in solving such problems. And this is not just some feel-good, "hold-hands-and-sing" kind of resolution. They even went so far as to say that they now feel an obligation to do something.

5.2. Conclusion

The application of the WSQ (Watch-Summarize-Question) learning approach was explored in the context of urban mining, with 30 students from a northern Taiwan university as subjects. The results of the study indicate that these students formed a much better understanding of and ability to engage in the three main fields of urban mining—resource management, environmental protection, and technological innovation—through the WSQ approach. Not only did the students gain knowledge in these areas, but they also engaged in deeper critical thinking and had more emotional reactions to urban mining issues than to other environmental problems. The significantly increased interest of the subjects in resource recycling and technological innovation may have developed a much-needed perspective on long-term, systematic sustainable development.

The WSQ method works well in transitioning students from passive knowledge recipients to active processers of knowledge. It helps students master the material and encourages them to achieve to a level that, in my estimation, is quite high given that they are mostly upper-level undergraduates. I think the reason this group did so well is that the WSQ method sets up a condition in which students seem to have no choice but to think critically and reflectively. It reminds me a lot of the way I was forced to think back when I was an undergraduate taking physics. … It also pushes them quite hard to learn the material in a deep way and … at least side steps the learning of the "I can repeat back to you what you said" kind of knowledge that often seems to be boosted by an old-school lecture approach.

The WSQ method can be applied in different academic settings, particularly those that involve teachers and students working across several fields. This would be a good way to establish the innovation skills of students in these collaborative endeavors and to help them learn to apply and integrate what they know across many disciplines. Future investigations could also examine the use of various digital technologies, including artificial intelligence (AI) and virtual reality (VR), to further improve the WSQ method's effectiveness. Both these platforms can and would serve to create more engaging and authentic contexts for students to learn about the application and challenges associated with urban mining technology.

For instance, virtual reality can be used in the classroom to give students a hands-on understanding of what a future job might entail. By immersing students in a simulated environment, they can practice and gain a better grasp of the actual operations they'll need to perform when they enter the workforce. These experiences will help them develop the necessary skills and, just as importantly, the mindset they'll need to tackle specific problems in their future careers. Moving forward, we should work to make classrooms even more adaptable to the unique needs of each student. This will take not only the integration of personalized digital technologies but also a commitment on the part of educators to understand each student's story and background.

Another key area for future research to address is international collaboration and policy guidance. These are important to increasingly move development and environmental technologies toward this kind of global partnership, which I would argue is necessary to reach the many different sustainable development goals across the range of environmental problems.

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