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Disciplinary variations in the diffusion of heutagogical use of mobile technologies among student-teachers

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Abstract
Whilst teacher education in Malawi seems to be afflicted by numerous challenges emanating from financial inadequacy and human resource constraints, widespread ownership of mobile technologies among student-teachers and versatility of the devices offer prospects for an improved academic environment. This study examines disciplinary variations in the diffusion of heutagogical use of mobile technologies among student-teachers at Domasi College of Education in Malawi. It is a case study involving 394 student-teachers whose design included a situational analysis, intervention and follow-up phase. Data was collected across the phases using semi-structured interviews, two questionnaire surveys, focus group discussions and participant journaling. Notwithstanding discipline, the findings reveal ubiquitous access to mobile technologies among the student-teachers as well as positive attitude towards academic usage of devices. Subject-based disparities, however, became apparent during the situational analysis in relation to actual usage although they were levelled during the intervention. Additionally, the occurrence of heutagogical practices increased significantly over the intervention period.

Keywords Mobile technologies · Heutagogy · Teacher education · Discipline of study

1 Introduction

The integration of mobile technologies in education presents an inestimable opportunity to enrich teaching and learning processes in tertiary education. Previous studies have shown that students learning in techno-savvy institutions not only use computers more frequently but report higher rates of engagement and

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intellectual development than students in other institutions (Aldahdouh et al., 2020; Eze et al., 2020). The benefits of technology-based education seem more prominent in the developing world where a myriad of problems encumber the achievement of scholastic goals. In Malawi, institutions are faced with teaching staff shortage, scarcity of learning resources, inadequate physical facilities and underfunding (Nkhokwe et al., 2017). The ubiquitous nature of mobile technologies and their universality among tertiary students (MACRA, 2015) provide prospects for a better teaching and learning environment. The present study was conducted at Domasi College of Education in Malawi and examined the diffusion of heutagogical use of mobile technologies among student-teachers. Heutagogy is a refined form of andragogical learning in which learners 'learn how to learn' by defining their own learning paths and identifying appropriate learning styles (Hase, 2009). Through this approach, learners develop the ability to manage their own learning and become able to reflect upon what is learned and how it is learned (Booth et al., 2016).

Despite the global widespread proliferation of mobile technologies among students (Ahmad, 2020), there seems to be glaring variations in the way science and humanities students use the devices for study purposes. Biglan (1973) segments academic programmes in the natural and physical sciences as belonging to the "hard" category with more clearly delineated paradigms. Those in the humanities and social sciences, having less-developed paradigms and low consensus on knowledge bases and modes of inquiry, fall under the "soft" category. Contradictions exist in previous studies on how students perceive technology usage in class. Whilst some studies indicate striking similarities in students' perceptions towards the usefulness of technology-based education (Lam et al., 2014; Pinto & Leite, 2020), others reveal notable perceptual variances (Almaiah et al., 2020; Karaseva et al., 2015). Analysing whether these promulgations apply in teacher education would be an interesting aspect. Experts contend that academic fields that have a highly politicized and tightly controlled research culture (such as the sciences) will develop a coherent field–based strategy for the uptake and use of information and communication technologies (ICTs), whereas domains that are pluralistic and have a loosely organized research culture (such as the humanities) will appropriate ICTs in an ad-hoc localized manner (Fry, 2006). This assumption in this study was that there would significant differences in the application of mobile technologies between the science and humanities student-teachers, with the former demonstrating increased, systematic and innovative engagement with devices than the latter.

Whereas Williams et al. (2017) acknowledge the value of technology in enabling students studying science to simulate or undertake scientific processes such as observing and reviewing which permit the multimodal expression of emerging ideas, Conole et al. (2008) argue that science students exhibit the ability to manipulate data since this field is underpinned by mathematics. In contrast, those studying humanities and other related subjects, some of which are fundamentally built on dialogic principles, apply a more subjective or relativist perspective (Conole, et al., 2008). Despite the fact that use of subject-specific resources and websites was evident across all the disciplines in their study, Conole, et al. note that the students' use of tools varied and could be linked to the nature of the subject discipline. Although

the student-teachers in this study were not limited in the range of devices and tools to be used in their teaching and learning activities, the analysis did not include differences with respect to usage of subject-specific resources.

2 Conceptual framework

Three theories provide the foundation of this research: Heutagogical principles (Blaschke, 2014; Hase, 2009, 2014), Diffusion of Innovations (DoI) theory (Rogers, 1995), and Unified Theory of Acceptance and Use of Technology (UTAUT) advanced by Venkatesh et al. (2003). Three heutagogical principles of interdependent learning, double- and triple-loop learning and participation in communities of practice (CoPs) were applied to examine the student-teachers' heutagogical use of mobile technologies. The term 'heutagogical use', as used in this study, relates to a learner's ability to utilise mobile technologies as tools for self-determined learning in which decisions about where, when and how to learn are defined by themselves.

2.1 Heutagogical principles

Hase (2014) defines interdependent learning as the process in which individuals learn on their own through practices such as exploration, discovery, research, hypothesis testing, validation and collaboration. Although Meirink et al. (2010) point out the need for more research on the relationship between interdependence and learning, other experts acknowledge the role of interdependent learning in enhancing the degree of interaction between a learner and peers (Campion et al., 1993) as well as quality of interaction (Runhaar et al., 2014). Meijrink et al. (2009) argues that a learner's interaction with others enhances the exchange of ideas, experiences and practices, which in turn may lead to reflection on one's own practice and underlying assumptions. Laal (2013) adds the concept of positive interdependence as a basic element of collaborative learning. The underlying principle being that the success of a learner is dependent on the success of the group when they work in a collaborative setting. Previous studies identify various types of interdependence which may occur in collaborative settings such as goal interdependence, task interdependence, resource interdependence, role interdependence and identity interdependence (Laal, 2013; Runhaar et al., 2014). Through goal interdependence, learners may support one another in their goals and aspirations. As the student-teachers in the present study share a similar goal of completing their diploma or degree programme, they are likely expected to relate well to one another and form strong interpersonal bonds.

Task interdependence leads to learners feeling greater responsibility for each other's task outcomes. Resource interdependence concerns learners bringing together their knowledge, information and other resources or materials required for a particular task in order to accomplish the shared goal. Each individual may have only a part of the information, resources, or materials needed for a particular task. Identity interdependence relates to learners' shared identity expressed

upon a common name, motto, principles or vision which increases friendship and affinity (Johnson & Johnson, 1999). Role interdependence is met when particular roles are assigned to group members (Laal, 2013). Whilst the role of each member is complementary, combined roles and responsibilities are required for the group to fulfill a common task (Johnson, & Johnson, 1999).

Double-Loop Learning helps people acquire and integrate new information and develop new skills, to question and possibly discard familiar and perhaps dysfunctional ways of thinking, feeling, and acting (Cartwright, 2002). It entails changing one's habits of thinking, challenge and restructure deeply-held assumptions, and act in new and unfamiliar ways. In double-loop learning, learners are able to reflect on the learning process itself, whether the 'unwritten rules' of the learning process themselves have been broken and should be changed, and how to correct them if necessary. This type of learning often helps the learners understand why a particular learning style or path works better than others to solve a problem. Whereas double-loop learning is focused mainly on the intellectual and cognitive domain and its dynamics, triple-loop learning touches the existential level to make profound change happen through reflection about one's attitudes, values and habits (Cartwright, 2002). Triple-loop learning involves 'learning how to learn' by reflecting on how we learn in the first place. The learners reflect not only on whether the 'unwritten rules' should be changed but how they think about the 'rules' of learning. Such a process assists the learner to understand more about him/herself and others regarding beliefs, values and perceptions. Triple-loop learning might be understood as double-loop learning about double-loop learning.

CoPs can be considered to be places where a process of social learning occurs between people with a common interest in a subject or problem who collaborate over longer periods of time to share and exchange ideas, find solutions and build knowledge (Kirschner and Lai (2007). Gannon-Leary and Fontainha (2007) present a set of critical success factors which could work for both virtual and non-virtual CoPs. One factor concerns ensuring that participants have the technological provision and necessary information, communication and technology (ICT) skills to support mutual engagement (Moule, 2006). Another one focus on the role of communication in building unity and cohesion. Communication is essential in the development of trust and the community as it facilitates growth and achievement of objectives. Trust is built through continued interaction developing common values and a shared understanding (Gibson & Manuel, 2003). The success of CoP is further re-inforced by having group members who possess prior knowledge of each other to help consolidate membership and develop trust (Andrews & Schwarz, 2002). CoP members also need to hold a sense of belonging (Brown & Duguid, 2002), and must pay attention to cross-national and cross-cultural dimensions in international online communities which adds to the complexity, challenges and value in such an accomplishment (Trayner et al., 2006). A CoP must have a purpose which its leadership must sustain through sensitivity in monitoring, regulating, maintaining boundaries and responding to change (Stuckey & Smith, 2004). Additionally, there is need for etiquette and modelling of good practice as well as proper implementation of

guidelines by facilitators to avoid cultivating a culture of fear among novices which may inhibit contributions (Trayner et al., 2006).

2.2 Diffusion of innovation theory

Rogers (2003:5) defines diffusion as "the process in which an innovation is communicated through certain channels over time among the members of a social system". He identifies four fundamental components of the diffusion of innovations: innovation, communication channels, time, and social system. He describes an innovation as an idea, practice, or project that is perceived as new by an individual or other unit of adoption" (Rogers, 2003, p. 12). An innovation therefore relates to any invention which individuals may perceive as new regardless of the time when it was developed. However, it is important to note that an innovation is defined simply as that which is perceived to be new – but not necessarily better – by potential adopters (Dearing & Cox, 2018). Thus, unworthy innovations do sometimes diffuse, while effective ones get stymied. Schuster and Kolleck (2020) ascertains the fact that an innovation may be new to one individual and not another one within the same community due to timing differences on its first use or discovery. To reduce uncertainty to adopt innovations, there is a need to inform individuals about its benefits and weaknesses so that they are aware of all its consequences. Communication concerns the process in which participants create and share information with one another through channels in order to reach a mutual understanding" (p. 5). Rogers notes that diffusion is a unique kind of communication which includes an innovation, two individuals or other units of adoption, and a communication channel. Whilst communication channels comprise mass media and interpersonal communication, he observes that interpersonal channels are more powerful to create or change strong attitudes held by an individual since diffusion is a very social process that involves interpersonal communication relationships. However, he adds that the diffusion of innovations requires some degree of heterophily – with interacting individuals being different in certain attributes – as well as homophily, with individuals holding similarities in certain attributes. The presence of both sets of characteristics enriches interpersonal interactions, and in turn stimulates the adoption process.

Time is a component that Rogers singles out as often ignored in most behavioral research despite the fact that it arises in the innovation-diffusion process, adopter categorization, as well as rate of adoption. There are five adopter categories and these are: (1) Innovators – who are about 2.5% of any social system, (2) Early adopters – 13.5%, (3) Early majority – 34%, (4) Late majority – 34%, and (5) Laggards – 16%. The social system is "a set of interrelated units engaged in joint problem solving to accomplish a common goal" (Rogers, 2003, p. 23). He argues that diffusion of innovations is influenced by the social structure of the social system since it takes place within the social system. He adds that the nature of the social system affects individuals' innovativeness, which is the benchmark for categorizing adopters along the innovator-laggard curve. Despite its popularity in helping to predict the spread of innovations in communities, the DoI has got some limitations. Dearing and Cox (2018) observe that one of the most well-documented, albeit frustrating,

principle of this theory is the fact that the process of diffusion can take a long time to produce tangible impact. They cite an example of the Extension for Community Healthcare Outcomes (ECHO) project which focused on diffusing an innovation in how academic medical centres could partner with rural primary care clinicians to extend specialty care in the US. Although the project began at one site in New Mexico in 2003 and increased with 4,134 Medicare-certified rural health clinics in 2015 and 15,583 certified nursing facilities in the US in 2016, it still had not reached 'takeoff' or a tipping point even after 14 years on a national diffusion curve.

Diffusion has the potential to worsen social inequality. Resource-rich communities tend to adopt innovations early relative to poor ones, and such changes may manifest as differences in knowledge and disproportionate access to government and commercial services (Dearing & Cox, 2018). They add that "even when low-income communities also benefit from innovation adoption, gaps between the haves and the have-nots can widen" (Dearing & Cox, 2018, p. 185). Members of poor communities may possess less potential to embrace innovations at the same rate as those in rich communities.

2.3 Unified theory of acceptance and use of technology

The Unified Theory of Acceptance and Use of Technology (UTAUT) is a unified model that integrates alternative views on user and innovation acceptance. It combines eight main theoretical models drawn from research in different disciplines such as information technology, sociology and psychology (Ayaz & Yanartaş, 2020). This diversity increases the explanatory power of the model to predict behavioural intention to use technology across various disciplines. The UTAUT advocates that four constructs – performance expectancy, effort expectancy, social influence and facilitating conditions – are direct determinants of behavioural intention and ultimately behaviour. It further suggests that these constructs are moderated by gender, age, experience, and voluntariness of use (Venkatesh et al., 2003). The basic argument advanced by this model is that examining the presence of each of these constructs in real settings enables scholars to assess an individual's intention to use a specific technology. Venkatesh et al. (2003) defines performance as the degree to which the user expects that using the system will help him or her to attain gains in job performance. They observed that the relationship between performance expectancy and behavioural intention was proven to be moderated by gender and age, meaning that the effect of the predictor is stronger for younger people and men.

Effort expectancy relates to the expected complexity of a particular technology and the degree of energy required to use it. Venkatesh et al. (2003) contends that the effect of effort expectancy on behavioural intention is moderated by gender, age and experience. Thus, the influence is more significant for women, older people and less experienced workers. Social influence concerns the degree to which an individual perceives that important others believe he or she should use the new system. The effect of this construct tends to be great among women, older people and those with lower levels of experience. It is further significant in contexts where there is non-voluntary use. Facilitating conditions refer to the degree to which an

individual believes that organisational and technical infrastructure exist to support use of the technology. The effect of facilitating conditions seems to be significant for older people and those with high levels of experience. There are two outcome variables in the UTAUT: behavioural intention and the behaviour (actual use). Whilst behavioural intention is basically a desire or a purpose to use, behaviour is the actual usage. The four constructs of the UTAUT were applied in this study but the moderating factors were not. Instead, discipline of study was used as the moderating factor. Chen et al. (2020) argue that the UTAUT has certain limitations for research in certain fields since its initial variables were mainly designed to study the acceptance of information systems.

It can be well-appreciated that both theories have some inherent challenges despite their proven efficacy in predicting technology adoption. In relation to the DoI, Dearing and Singhal sums up by noting that there are neat and tidy theories in the social sciences but the diffusion theory is not one of them (2020, p 307). They argue that although the expansive nature of the DoI can contribute to paradigmatic persistence, it is not necessarily a positive attribute. It embraces several supporting theories to the extent that its vastness leads to considerable confusion and criticism from those who use it (Kincaid, 2004). Vejlgaard (2018) also highlights the fact that not all aspects of the DoI have been fully investigated hence the need to continue to seek validation of its propositions. Similarly, the UTAUT model is only capable of explaining the use of technology by 70%, thus allowing a considerable margin for unreliable results in certain situations. Previous studies also indicate significant contradictions on the effects of the model's four major constructs in influencing technology acceptance and use (Rahmaningtyas et al., 2020; Tamilmani et al., 2020; Chen & Hwang, 2019; Nadlifatin, 2019). According to Wan et al., 2020), recent studies on the UTAUT yield inconsistent results for the same research question on understanding processes regarding individual technology adoption. Future researchers may consider integrating elements of the DOI and UTAUT theories together, or indeed with those of other theories to better comprehend innovation-adoption processes (Magsamen-Conrad & Dillon, 2020). Such a procedure could help to eliminate the individual weaknesses of these theories while at the same time enhancing the reliability and validity of the results.

3 Methodology

This is a case study conducted at Domasi College of Education in Malawi which adopted the mixed-methods design. It employs both quantitative and qualitative methods for data collection and analysis procedures.

Data collection comprised three sequential phases focusing on situational analysis, intervention, and follow-up. The situational analysis involved semi-structured interviews with the College Principal, two Deans and one Head of Department as well as an initial questionnaire survey with student-teachers. The intervention included workshops on heutagogy and implementation activities while the follow-up involved a second questionnaire survey, focus group discussions (FGDs) and participant journaling. The situational analysis comprised 201 science and 193 humanities

student-teachers (totaling 394). During this phase, the data collected related to the background of the college, ownership of mobile technologies, attitudes towards academic use of devices and extent of usage. The first section of the questionnaire comprised demographic variables related to year of study, gender, discipline and location of work. The second section included questions regarding computer access and use, possession of mobile devices, attitudes and intentions, daily use of devices in studies, independent use of mobile applications, use of mobiles after class and heutagogical practices.

The intervention involved a subset of the situational analysis participants comprising 50 science and 50 humanities student-teachers (totalling 100) who were selected through purposive sampling based on their ownership of internet-enabled devices as well as discipline of study. The intervention was modelled after Cochrane et al.'s (2013) heutagogical framework on mobile social media integration in tertiary education. The student-teachers were trained for five days through workshops which were scheduled in the afternoons outside the class period. The workshops focused on the heutagogical use of mobile devices. Thus, they included a discussion on how mobile devices could be used to access online resources and how they could facilitate collaboration amongst peers or between lecturers and student-teachers. After the workshops, the participants were asked to independently implement the knowledge and skills gained on heutagogical use of mobile technologies over a period of four weeks.

During the follow-up, the second questionnaire survey was conducted to explore the extent of mobile device use for academic purposes and emergence (if any) of heutagogical practices among the student-teachers. The same variables investigated during the situational analysis were used in the follow-up questionnaire. Similarly, the same variables were examined during 12 semi-structured interviews which were also held with randomly-selected participants. The interviews provided the participants an opportunity to explain their experiences in detail and any clarify complex occurrences. Furthermore, three focus group discussions (FGDs) involving 18 student-teachers were conducted to complemented the questionnaire survey and interviews. The FGDs allowed the participants to discuss, as a group, issues concerning the major thematic areas of the study such as experiences and challenges faced during the implementation phase of the intervention. In so doing, they were able to identify new issues as well as forgotten aspects related to their practices and experiences. The participant journals were also collected for analysis. Data analysis involved the use of the N-Vivo Version 11 software for data management as well as the Chi-square statistical test for calculating correlations on the study variables. The framework for interpreting the results was based on the three heutagogical principles. Aspects of the Diffusion of Innovations theory (Rogers, 1995) and UTAUT were also applied in the interpretation.

4 Results and discussion

Mobile phone ownership is widespread (98%) among the student-teachers. A majority of both the science and humanities student-teachers, with an insignificant gap (p-value = 0.93639), own at least one mobile phone. The results are consistent with Margaryan and Littlejohn (2008) who observe that mobile phones are one of the most ubiquitous devices used by university students in the United Kingdom (UK) as they are considered low cost and convenient. There was also a minor difference between science student-teachers and those studying humanities with regard to ownership of internet-enabled devices (p-value = 0.2143) as well as tablets (p-value = 1) respectively. Similarly, the variance between the science and humanities student-teachers in terms of laptop ownership is negligible (p-value = 0.302343). Table 1 below shows ownership of mobile devices among the student-teachers.

Like it is the case in most educational institutions in Malawi (Nkhokwe et al., 2017), there is an acute shortage of computers at Domasi College. One student-teachers observes that "I use the computer lab in our faculty when I need a computer. Normally, there are too many students there but I wait until I get my chance". Laptops tend to compensate the shortfall in institutional computers at the college. In a previous study, except for ownership of portable media players and games consoles, Margaryan and Littlejohn (2008) also found minor disparities in hardware ownership among students based on discipline across a range of eight devices. Despite the narrow gaps in device ownership between the two disciplines in the present study, there are notable differences with regard to usage. Students in the sciences mostly consider the devices as tools for accessing electronic learning resources whilst those in the humanities tend to use them for communicative functions.

The student-teachers tend to regard academic usage as the most important function of their mobile devices regardless of discipline (p-value = 0. 6,276,258). The results were similar during the intervention (p-value = 0.760368). In addition, both the science and humanities student-teachers hold a positive attitude towards using their mobile devices for study purposes (p-value = 0.7103466). However, one humanities student–teacher complained about the problem of studying using small phones. He noted that "my phone is small so I fail to read well because the letters are not clear…in fact, I plan to obtain another smartphone with a bigger screen in order to be able to read better". The participant's analysis is linked to the UTAUT's construct of effort expectancy as he shows consciousness of how small devices are difficult to use for study purposes. The present study coincides with Dresselhaus and Shrode (2012) who observed minor differences in students' perceptions towards the usefulness of these e-learning strategies based on disciplinary orientation. The

Table 1 Ownership of mobile devices

	Mobile phone (%)	Internet-enabled devices (%)	Laptops (%)
Science student-teachers	93	91	52
Humanities student-teachers	89	75	42

student-teachers acknowledged the usefulness of integrating mobile devices in their studies and the impact in improving their learning processes. Such remarks underline the UTAUT's construct of performance expectancy in which users expect to achieve academic gains as they apply mobile devices in their learning processes.

On independent use of mobile applications, both the science and humanities student-teachers exhibited high usage during the situational analysis (p-value = 0.845975) as well as the intervention phase (p-value = 0.878088). The results entail that independent use of mobile applications is neither influenced by discipline nor intervention. Similar results are presented in Margaryan and Littlejohn (2008) in which a major proportion of engineering students than those studying social work extensively used the institutional virtual learning environment and other technologies in all their modules. The students used discussion groups, virtual chats, video conferencing, online assessments, simulations and games, general websites, Google, Wikipedia, YouTube and text messaging to support their formal learning. Czerniewicz and Brown (2007) augments by noting that students in the hard disciplines of science and engineering make more frequent use of ICTs for teaching and learning than those in the soft disciplines of business and humanities.

There was a significant difference between the science and humanities student-teachers with respect to computer usage during the situational analysis as most of those studying science showed higher usage of computers than their humanities counterparts (p-value = 0. 0,002,299). However, the variance dissipated during the intervention (p-value = 0.376344) as student-teachers in both disciplines demonstrated great computer usage. Previous studies further reveal a high use of computer-based narrative media occurring in the hard disciplines, which employ a higher frequency of laboratory and practical teaching modes, than the soft disciplines (Czerniewicz & Brown, 2007). However, they discern that engineering and science students tend to report less frequent use of computers for participating in online discussion compared to students from other disciplines. This is consistent with the fact that hard fields place greater emphasis on common paradigms and have more tightly structured courses with highly related concepts and principles whereas soft fields focus on development of critical perspectives and communicative ability, and have open structures that are more loosely organised (Neumann, 2001). Czerniewicz and Brown (2007) further portends that students in the hard disciplines of Science, Engineering and Health Science have a higher frequency of use of computers for productive media purposes than the soft disciplines of Humanities and Business (Czerniewicz & Brown, 2007).

In relation to interdependent learning, student-teachers in both disciplines (p-value = 0.9165119) indicated during the situational analysis that they learn independently to a less extent. Despite the fact that the gap between the two disciplines remained narrow during the intervention, the rate of engagement in interdependent learning rose significantly from approximately 46% to 69%. During the FGDs, the participants presented instances which demonstrate the development of self-efficacy as they were able to explore mathematical problems and obtain multiple methods of solving them. In one case, a participant noted that "we managed to access online notes which provided several ways of solving linear equations that contain brackets or fractions. There were two ways of doing it, and

we're able to select what we thought was the best way". Consistent with Hase's (2009) postulations about heutagogy, the participants were able to define their own learning paths, choose appropriate learning styles and collaborate with each other. Self-efficacy is key to the development of capability. Along the same line, a humanities student–teacher stated that he learnt important skills on how to effectively take full control of his learning activities. He added that: "For example, I am (now) able to properly define my learning activities and match them with my lifestyle". Such adjustments relate to double-loop learning as the student–teacher demonstrates ability to make academic choices that suits his way of living.

Additionally, there was a significant difference on engagement in double- and triple-loop learning across the disciplines during the situational analysis with most science student-teachers and fewer of those in humanities (p-value = 0.0183207) indicating that they engage in the practice. However, the gap disappeared during the intervention with increased engagement manifesting in both disciplines (p-value = 0.376344). During interviews, one participant observed that "I was able to use my tablet to download an online book. However, I've noticed that it's hard to read a book on a phone. I have now made a plan to be downloading the books on my phone and printing them somewhere for use". He further articulated the intention to be analysing the materials obtained through the phone to gauge their usefulness. This instance exhibits attempts by the participant to determine his learning needs and styles. In addition, it portrays the triple-loop learning process pertaining to innovative strategies of addressing problems related to online access of academic resources. A science student–teacher asserted that the intervention provided him the opportunity "to download up-to-date and well-structured teaching materials using my tablet. I was able to edit the online teaching notes and adapt them accordingly…I like my tablet more because it has large a screen. I read without problems". This case portrays a tablet's easiness of use related to the DoI's device characteristic of complexity under which innovations with low complexity tend to be highly adoptable.

In terms of membership in communities of practice (CoP), most of the science student-teachers as well as those studying humanities (p-value = 0.7353167) indicate that they are members of at least one CoP. One science student–teacher stated that:

> I networked a lot with my classmates. I feel more comfortable to participate in communities made up of students only because we're all at the same level. I don't think of joining one which includes lecturers because I may fear to participate freely. However, I can add that I only participate in these communities when I'm here on campus because the phone network is very poor where I work…so I make sure that I participate more during the time I stay at the college.

The results suggest that the student-teachers prefer homophilous communities despite the fact that diversity in personal characteristics is crucial for the success of CoPs. The student-teachers further indicate that they extensively participate in CoP activities and are currently active members of such communities. During the intervention, the participants highlighted the fact that mobile devices were valuable in enhancing their study experience as they were able to interact with both local and international experts. One student–teacher commented that experts

"continuously share resources which I use to supplement what I learn in class". He added that he was able to share the acquired knowledge with other student-teachers. This case depicts capability development as the student–teacher demonstrates the ability to apply knowledge and skills from one situation to another. Furthermore, there seems to be a shift towards heterophilous CoPs during the intervention as student-teachers moved out of their comfort zones and interacted with experts outside their college.

Furthermore, the science student-teachers pointed out that they frequently use their mobile devices for academic activities after class more than those in the humanities (p-value = 0.0001). Surprisingly, the difference became insignificant during the intervention as student-teachers in both disciplines registered high usage rates (p-value = 0.879487). Figure 1 below depicts usage of mobile devices after class among the student-teachers during the situational analysis as well as intervention.

In relation to the DoI, one humanities student–teacher acknowledged the relative advantage of using mobile devices at night rather than during the day. He pointed out that:

> For me, I can say that the use of mobile devices for academic functions is effective at night. The internet becomes fast at night due to low traffic. Over the past three weeks, I have downloaded big files for all the subjects which I am studying.

Furthermore, a science student–teacher applauded the portability of mobile devices observing that they can conveniently be used anywhere and anytime. He pointed out that the intervention "was very beneficial. I have seen that mobile devices would be very beneficial in learning. They are portable to carry and have a

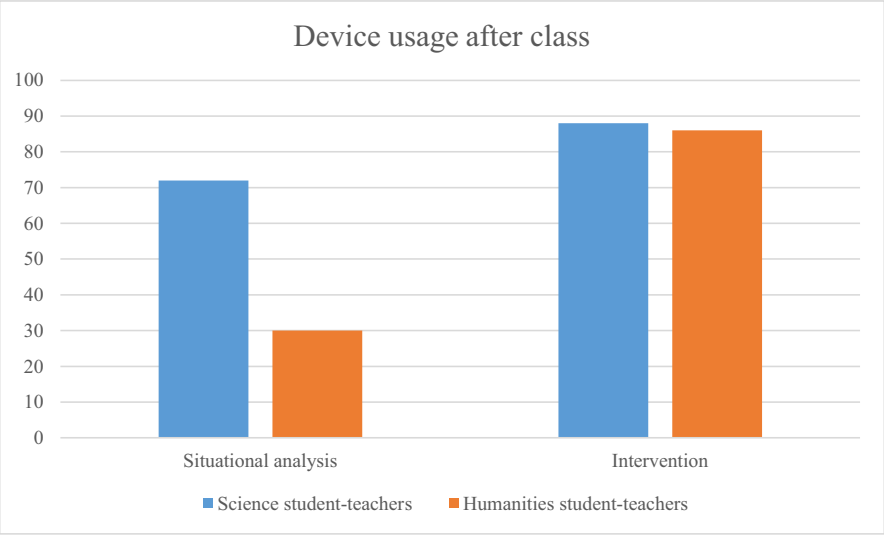

Fig. 1 Mobile device usage after class

large storage capacity". The tendency to use the devices after class increased during the intervention and some student-teachers seemed to have reached the confirmation stage of the DoI's innovation-decision process as they felt motivated to use their devices more after class. In addition, these remarks shows that mobile devices seem to be compatible with the student–teacher's academic values and needs. In line with the present study, Margaryan and Littlejohn (2008) point out significant differences in the level of use of digital technologies for learning outside the courses between engineering and social work students with respect to social networking, blogs, video and audio clips, Wikipedia and YouTube. Another science student–teacher remarked that: "After every class, I always feel the urge to read online resources to improve my understanding of concepts; it is very useful and I learn a lot. I always give priority to the subjects in which I don't perform well". This student–teacher demonstrated independent thinking in his choices regarding what to study beyond the classroom. In as far as the adopter categorisation is concerned, these two cases suggest that the science student-teachers appear to be innovators in the use of mobile devices for academic purposes unlike their counterparts in the humanities.

The student-teachers also indicate great intention to use mobile devices in their own teaching both during the situational analysis and intervention (p-value = 1 respectively) regardless of their field of study. However, the average rate increased from 36 to 90% across the two phases. A participant of the FGDs observed that the versatility of mobile devices "enables me to access teaching materials anytime and anywhere without the hindrance of being confined in the library. I find mobile calls equally useful for engaging in real-time academic interactions with either my fellow students or lecturers". The student–teacher highlights the relative advantage of using mobile technologies for study purposes. His sentiments were echoed by another participant who expressed interest to use his mobile phone in his teaching activities after graduation. During the intervention, one participant "realised that the same activities I did at the college (with his mobile device) could also help me in teaching". Transferability of skills from familiar to unfamiliar situations is evidence of double-loop learning. However, one student–teacher felt that using the devices for teaching purposes was not useful. He pointed out that he had never seen a teacher using mobile devices in their teaching "so I have no evidence that they can work with me." This student–teacher's attitude is characteristic of laggards who tend fixated on the past and are cautious in accepting new innovations.

5 Conclusion

Mobile phone ownership was almost universal among the student-teachers whilst laptops were comparatively few due to the cost factor. There was a general positive attitude towards mobile technologies usage regardless of discipline. However, remarkable differences were observed with regard to usage during the situational analysis with the science student-teachers using their devices for academic activities after class more than those in the humanities. The science student-teachers typically used their devices to access electronic resources whilst those in the humanities used theirs for communicative purposes. Despite the fact that these differences

disappeared during the intervention, the science student-teachers seem to lean towards innovators along the adopter categorisation continuum whilst their humanities counterparts likely lie at the opposite edge comprising the late majority and laggards. Heutagogical practices were generally low during the situational analysis although the science student-teachers engaged more in triple- and double-loop learning than their counterparts in the humanities. These practices became commonplace during the intervention with both disciplines displaying increased self-efficacy, development of competence and capability, and engagement with experts beyond Malawi. Teacher educationists in the developing world could take advantage of the broad positive attitude among student-teachers to enrich scholarship through integration of mobile technologies as learning tools. Teaching and learning processes could further be enhanced by modelling to the student-teachers how devices could be heutagogically utilised to perform various academic tasks.

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Declarations

Conflict of interest There is on conflict of interest in this research.

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