USING A DESIGN-BASED RESEARCH APPROACH FOR A SUPPLEMENTARY INSTRUCTION PROGRAMME: A PEDAGOGICAL INTERVENTION DURING THE COVID-19 PANDEMIC

T. Mutanda*
Department of Nature Conservation
https://orcid.org/0000-0002-9539-9231

P.R. Gumede*
Teaching and Learning Development Centre
https://orcid.org/0000-0002-0755-0705

*Mangosuthu University of Technology
Durban, South Africa

T. Mayisela**
Centre for Innovation in Learning and Teaching
https://orcid.org/0000-0003-4182-1983

D. Ng'ambi**
https://orcid.org/0000-0001-7281-2292

**School of Education
University of Cape Town, South Africa

ABSTRACT
The study focused on the implementation of supplementary instruction as a suitable and effective pedagogical intervention for assisting at-risk students enrolled in an Advanced Research Methodology core course in one of the South African higher education institutions (HEIs). Supplementary instruction (SI) has been purported to be an effective technique for assisting at-risk students undertaking high-risk core modules. The educational challenge of at-risk students in higher education has been worsened by the emergence of the COVID-19 pandemic where high-risk core modules implementing e-learning posed serious challenges for at-risk students thereby negatively affecting pass rates and throughput. The design-based research (DBR) approach was used to guide the design of the intervention and research its effectiveness. The article reports on the design principles that yielded these results. After one cycle of DBR, it was established that SI had a positive impact on the pass rates of this particular course. The article argues that the use of the proposed designed principles in SI interventions has the potential to increase higher mean grades, lower failure and withdrawal rates, and higher retention rates of students. However, this study recommends that further iterations must be undertaken to refine design principles for an SI programme of this nature. The pedagogical significance of the current study in the prevailing circumstances and post COVID-19 pandemic is implementing a robust SI intervention in all core

Mutanda, Gumede,
Mayisela, Ng'ambi

Using a design-based research approach for a supplementary instruction
programme: A pedagogical intervention during the COVID-19 pandemic

modules at the University of Technology.

INTRODUCTION

The emergence of the global pandemic, Covid-19, brought in its wake a plethora of educational challenges requiring innovative digital interventions in the South African higher education space. The traditional face-to-face teacher-centric approaches used at several universities in South Africa were replaced by hybrid learning systems in 2020 due to lockdown regulations aimed to mitigate the spread of the deadly Covid-19 contagion. This transition was not unique to South African higher education but globally as countries were forced by COVID-19 restrictions to move to remote multimodal teaching and assessment (Nerantzi 2020). The introduction of various online learning platforms caused some serious challenges to students and academics at several higher education institutions (HEIs), ranging from inadequate digital pedagogies, technological hindrances, and end-user technophobia. Besides various challenges including the digital divide, disadvantaged students from South African HEIs did not fully benefit from digital educational technologies' potential (Mpungose 2020). Also, the severity of the teaching and learning challenges was most manifested at previously disadvantaged HEIs in South Africa.

An analysis of 2019, 2020, and 2021 module metrics for a core course taught at a University of Technology, show that the pass rates dropped drastically after the introduction of multimodal online learning platforms, hence, requiring some educational interventions. Supplementary instruction (SI), generally known as peer-assisted learning or peer-assisted study sessions is defined as a powerful pedagogical model to support identified at-risk students in higher education, thereby improving student performance and class retention in high-risk courses (Dawson et al. 2014). Supplementary instruction has the potential to foster deep learning and effectively improve student performance in their assessments. The at-risk student is a student who needs ongoing scaffolding for them to succeed academically. The introduction and promotion of hybrid learning at the University of Technology in 2020 immensely contributed to serious challenges in general and in particular for ill-prepared learners who were intimidated by new technology that rapidly replaced traditional face-to-face learning. High numbers of these students at-risk were observed in 2020 during synchronous and asynchronous learning in the Advanced Research Methodology module. Consequently, students achieved average and low pass marks resulting in low overall throughput and often dropping out of the Advanced Research Methodology module. This is a serious problem in the current context

because students are failing to progress to the next level. After all, this is a core module and a prerequisite for entry into the Postgraduate Diploma programme.

As educators, it is disheartening to see students' life and career just crumble at this stage in their academic development. In consultation with all practitioners, i.e., SI leaders and students, the lead author developed a supplementary instruction intervention based on four design guidelines: contextual, constructional, flexibility, and collaborative and interactive learning (Van der Merwe 2019). Design-based research (DBR) approach was used to guide the design of the SI intervention and research its effectiveness, in terms of student pass and retention rates in the Advance Research Methodology course. The DBR approach aimed to develop and refine design principles for implementing SI as an educational interventional measure in the Advanced Research Methodology core module hence determining the efficacy and feasibility of the scope of this strategy.

DESIGN-BASED RESEARCH APPROACH

Design-based research was conceptualized after some educational scholars realized that educational research *per se* rarely improved classroom practices and solved a wide range of learner educational predicaments (Armstrong, Dopp, and Welsh 2020). It was observed that the reported educational research was done in controlled, laboratory-like settings and that this laboratory-based research setting was unconstructive and not useful to learning practitioners. One school of thought postulated that educational research is most often alienated from actual practice because of two problems: (a) practitioners do not realize the benefits of the researchers' work and (b) research results could be inaccurate since they could not account for context (Armstrong et al. 2020). Learning practitioners do not realize the full benefits from the researchers' work if the research is separated from their practice. However, practitioners can realize full benefits from the research after they establish how the research can inform and enhance their learning designs and practices (Armstrong et al. 2020). On the other hand, another school of thought lamented that some practitioners believe that educational research is often too theoretical to be of use in real-life contexts (Armstrong et al. 2020). Research findings and theories can be inaccurate by not accounting for context, hence, may not accurately reflect what takes place in empirical educational settings (Armstrong et al. 2020). According to Herrington and Reeves (2011), at every step of the research process, initial and refined design principles inform and guide the direction and shape the intervention being developed, as well as its implementation and testing with the final crafting of suitable draft guidelines into refined design principles to become a key outcome of the research.

DBR aims to isolate variables to test and refine theory: (a) to understand contexts, (b) to

Mutanda, Gumede,
Mayisela, Ng'ambi

Using a design-based research approach for a supplementary instruction
programme: A pedagogical intervention during the COVID-19 pandemic

design effective systems, and (c) to make meaningful changes for the subjects of the study (Armstrong et al. 2020). The outcomes of the traditional methods of research are refined understandings of how the world works, thereby indirectly affecting practice. Hence, in DBR, the research process is intentional to both refine theory and practice (Collins, Joseph, and Bielaczye 2004). According to Collins et al. (2004), in DBR, researchers assume the dual roles of "curriculum designers, and implicitly, curriculum theorists". As informed experts, the educational designs may include curricula, practices, digital software, or real objects useful to the learning process (Armstrong et al. 2021). In addition, DBR researchers are involved in the refinement of extant theories about learning while concomitantly isolating themselves from the subjects of their study, allowing the researchers to draw dispassionate observations from testing and refining their cognition of the world around them. The research subjects critically contribute and collaborate in the DBR process, and are viewed as observational components or experimental tools, indicating a one-way relationship between the educational researcher and the research subject (Armstrong et al. 2020). The research subjects have the key role of being available and genuine to effectively facilitate the researcher to make meaningful observations and collate precise and accurate data. According to Armstrong et al. (2020), research subjects help to formulate the questions, make refinements in the designs, evaluate the effects of the experiment, and report the results of the experiment to other educators and researchers. Therefore, the research subjects are co-workers with the researcher, iteratively progressing the study into the future. The principles of DBR are its pragmatic nature because its goals are solving current authentic and empirical world problems by designing and formulating feasible interventions in conjunction with learning theories and refining design principles. Essentially, the typical characteristics of the DBR are to address complex problems in authentic contexts by collaborating with educational practitioners; developing guidelines and refining design principles to generate workable solutions; conducting a rigorous and reflective inquiry through iterative cycles of design, and enactment, analysis, and redesign.

The debate on what constitutes DBR is still ongoing. Nonetheless, Wang and Hannafin (2005) capture its critical characteristics as a systematic but flexible approach focusing on improving educational practices through sequential phases of iteration, refinement and analysis, project design, development and evaluation, and implementation of the intervention. The theoretical underpinning of the DBR approach is the fostering of collaboration among researchers, subjects, and practitioners in a real-life setting, led by contextually sensitive design guidelines and theories. In other words, DBR is a framework of both qualitative and quantitative research methods and techniques that are commonly used in education research. In education, DBR is regarded as interventional since researchers purposefully conceptualize transformation

Mutanda, Gumede,
Mayisela, Ng'ambi

Using a design-based research approach for a supplementary instruction
programme: A pedagogical intervention during the COVID-19 pandemic

by developing practical solutions contributing to measurable change and positively influencing practice (Meyers, Jacobson, and Henderson 2018; Reeves 2011; McKenney and Reeves 2012). The process of DBR involves the development of pragmatic solutions to address real educational challenges and is an invaluable approach for improving both the theoretical ramifications and public notions of educational technology investigations (Herrington et al. 2007). The developed educational interventions are subsequently tested and validated to establish their efficacy and feasibility through actual experiments with either qualitative or quantitative results. All this, in turn, contributes to the development of theory. It is in this context that Dolmans (2019) posits that a theory can generally be regarded as a way of pedagogical ideation on the functional attributes of an entity and is made up of a complement of design principles to define or analyze a complex problem from a particular viewpoint. In principle, a theory can allow us to contextually grasp a certain problem and provide answers to solve the problem from a particular standpoint. A complement of theories is commonly required to comprehend and solve a particular problem (Dolmans 2019). The typical DBR framework described by Reeves (2006) is depicted in Figure 1.
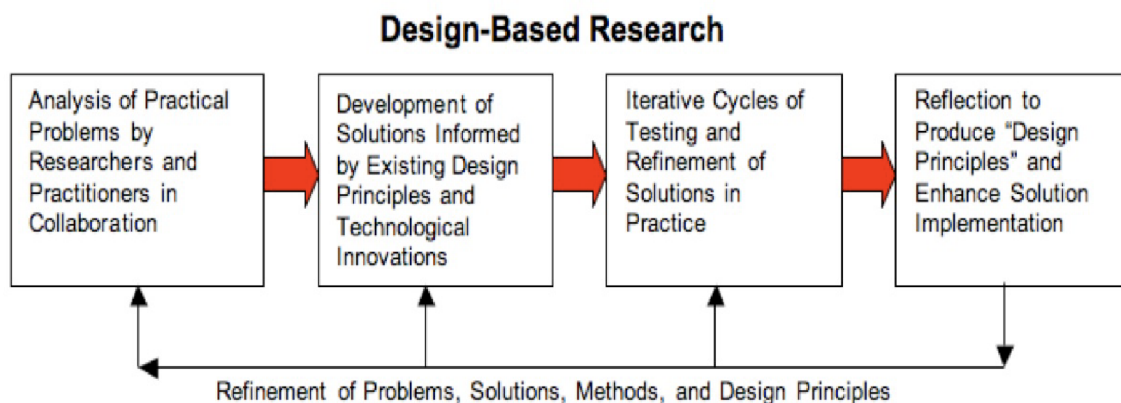

Figure 1: Four phases of the DBR approach (Reeves 2006).

The DBR approach has been applied in pedagogical interventions related to mainstream instruction in various disciplines, for instance, teacher facilitation through flipped learning and social inquiry learning (Jong et al. 2022), development of a flexible learning environment for the application of theoretical knowledge learned in a radiography program (Van der Merwe 2019), designing constructionism-based coding activities in a school subject context (Papavlasopoulou, Giannakos, and Jaccheri 2019) and peer-assisted reflection to improve student success in calculus (Reinholz 2015). However, to date, there are no reports on the combination of DBR and supplementary instructions. This study draws on learning theories and draft design guidelines from literature to inform the SI intervention. However, the limitation of this study was that only one iteration of the DBR cycle was completed: (Phase 1) Analysis and

Mutanda, Gumede,
Mayisela, Ng'ambi

Using a design-based research approach for a supplementary instruction
programme: A pedagogical intervention during the COVID-19 pandemic

exploration of a problem, (Phase 2) Development of solutions using an existing design, (Phase 3) Implementation and evaluation in iterative cycles, and (Phase 4) Reflection to produce design principles (Figure 2).
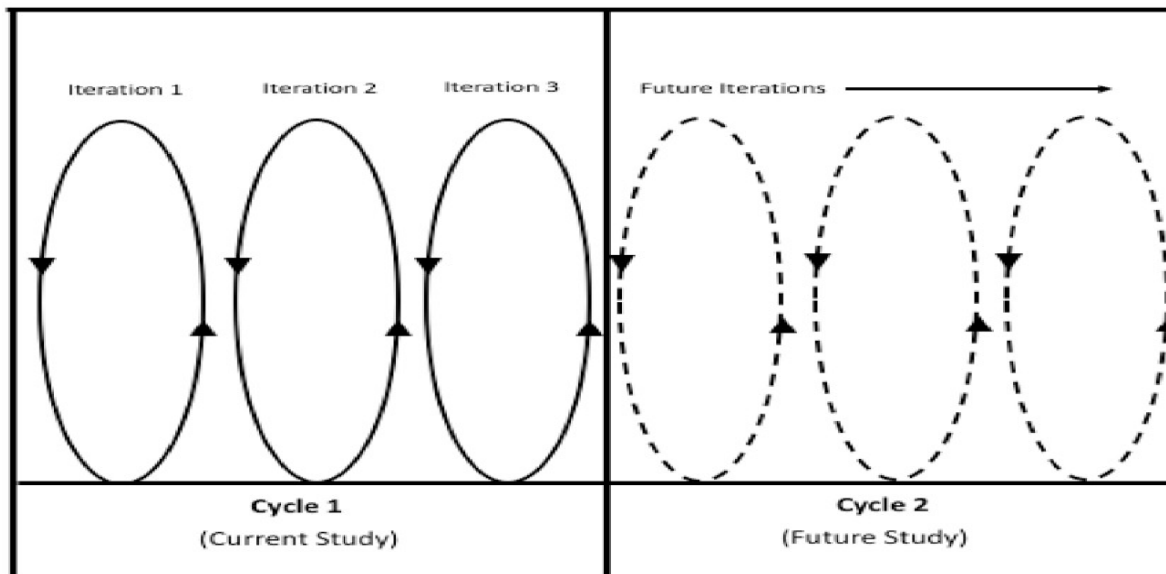

Figure 2: Schematic presentation of cycles and iterations used in the current and future DBR studies (Zydney, Warner, and Angelone 2020).

ANALYSIS OF A PRACTICAL EDUCATIONAL PROBLEM: PRACTITIONER CONSULTATION AND DATA COLLECTION

Globally, the framework of design-based research has been used by other researchers to address various educational problems. According to Jong et al. (2022) the advantage of DBR in educational technology research is that it has a strong emphasis on the collaboration between researchers and practitioners to co-develop pragmatic knowledge to be used in real-world contexts. In the current research, the lead author proposed an educational intervention to arrest the falling pass rates and low student throughput in the Advanced Research Methodology module. An intervention of this nature has never been done to deal with this complex problem at the current institution. However, most academics in the Faculty of Natural Sciences have experience with this problem so their engagement and views on this intervention were elicited through consistency with DBR Phase 1 Additionally, student marks for 2019 (before the pandemic) and 2020 (during the intervention) were analyzed; they dropped by 30 per cent and this could be mainly attributed to the online provision of the module, therefore, justifying SI intervention. A summary is provided in Table 1.

Drawing from the above, the overarching research goal of the research study was guided by the following research question: What intervention can guide us to implement an SI

Mutanda, Gumede,
Mayisela, Ng'ambi

Using a design-based research approach for a supplementary instruction
programme: A pedagogical intervention during the COVID-19 pandemic

intervention that facilitates an authentic, socio-cultural learning environment that enhances flexibility, collaborative and interactive learning among the Advanced Research Methodology students?

Table 1: The number of students and pass rates for Advanced Research Methodology

	2019 Data	**2020 Data**
Online Students	0	48
On-campus Students	46	0
Total (N)	46	48
Pass Rate (%)	95	65

LITERATURE REVIEW AND DESIGN FRAMEWORKS

In Africa and globally, research has articulated the digital divide as a hurdle to students realizing the full benefit of e-learning, posing a serious threat to learners excelling in educational programmes (Mpungose 2020). With the introduction of multimodal learning platforms, various challenges have surfaced in African higher education institutions, requiring concerted digital educational interventions and solutions. In principle, supplementary instruction is recommended as the panacea to this educational quagmire. However, it is difficult to design effective SI interventions that influence student learning outcomes, and so merely using SI may not guarantee intended outcomes, hence this study. To encourage scholars to adopt this framework, Herrington et al. (2007) posit that DBR is a plausible approach and that postgraduate students, specifically doctoral students, should be encouraged to engage in this pedagogical approach. Furthermore, in their paper, Herrington and co-workers (2007), detail the specific sections of a thesis proposal that utilizes the DBR methodology in the context of educational technology research. Shattuck and Anderson (2013) used DBR to identify the design principles to equip instructors with the requisite skills and knowledge to teach effectively online. Their proposition was specifically engineered as a potentially workable solution to the difficulty experienced by several higher education institutions in providing quality, accessible training for mostly contract instructors who are novices in using online teaching. Their educational project investigated the implications of the training course and its impact on the participants' subsequent teaching practice. The major outcome of their investigation was the identification and development of suitable design principles that can be applied by other researchers and practitioners who are designing online teaching content. Ford, McNally, and Ford (2017), unpack the DBR methodology used by the Centre for Innovation in Learning and Student Success (CILSS) at the University of Maryland, University College (UMUC) to

Mutanda, Gumede,
Mayisela, Ng'ambi

Using a design-based research approach for a supplementary instruction
programme: A pedagogical intervention during the COVID-19 pandemic

enhance the performance of the learning models of the institution. Briefly, CILSS conducts applied research focusing on continually improving the university's curricula, learning models, and student support to pinpoint effective innovations as pedagogical tools and practical interventions, thereby increasing student retention, giving rise to high student turnovers and high throughput, and development and promotion of novel ideas and breakthroughs in learning. Scott, Wenderoth, and Doherty (2020) corroborate other researchers and suggested that design-based research from the learning sciences is a compelling methodology that effectively investigates the "learning ecologies" that move student cognition toward mastery.

According to Scott et al. 2020 the "learning ecologies" are grounded in learning theories that produce measurable changes in student learning, generate design guidelines, the development of instructional tools, and are enacted using extended iterative teaching experiments. Furthermore, Scott and co-authors (2020) discuss how design-based research can extend work already done in biology education research to foster interdisciplinary collaborations among cognitive and learning scientists, biology education researchers, and instructors. The educational challenges associated with this methodological approach are succinctly explored. Recently, Zhao, He, and Su (2021) undertook a study premised on the DBR, a task-driven instructional investigation in a flipped classroom to instill relevant and innovative skill sets in students. After 3 iterative cycles, the research findings showed that students in the experimental group (flipped learning instruction) obtained better scores on both formative and summative assessments than those in the control group (lecture centred instruction), suggesting a significant difference in students' performance between the two groups.

Therefore, from this wide consultation of other researchers, there is a consensus with the educational intervention we propose to implement to arrest the falling pass rates and student throughput in the Research Methodology module. To the best of our knowledge, an intervention of this nature has never been done to deal with this complex problem at the University of Technology in South Africa. However, most academics have an experience with this problem so their engagement and views on this intervention were interrogated. The main advantages of SI are that it is flexible, and fosters collaborative and interactive learning. The instructional scaffolding by the SI leaders enhances and augments the socio-cultural merit of the SI programme.

INITIAL DBR DESIGN GUIDELINES AND PRINCIPLES

Authentic learning can take place where there are provisions of authentic activities and a multiplicity of roles and perspectives to highlight how knowledge is used in real life. In the

Mutanda, Gumede,
Mayisela, Ng'ambi

Using a design-based research approach for a supplementary instruction
programme: A pedagogical intervention during the COVID-19 pandemic

current context, the design guidelines were formulated to encourage at-risk learners to attend the supplementary instruction programme, enabling active participation and interaction with the learning materials. The SI programme fostered the creation of empathy and trust through at-risk student support through guided cognitive instruction. In addition, this fostered complex problem-solving capacity through higher-order thinking skills in the supplementary instruction group and knowledge construction through the constructivist theory of learning. Lastly, this prompted collaboration and group interaction using the sociocultural theory of learning. The draft design guidelines adopted for the current study were derived and modified from published literature (Van der Merwe 2019). In the current study, Table 2 and Table 3 depict the draft design guidelines and reflected in practice respectively.

Table 2: The draft design guidelines for the current DBR study

Draft Guidelines (DG)	Reference
DG1. Flexibility and blended nature of supplementary instruction.	Van der Merwe (2019).
DG2. Authentic supplementary instruction (SI) tasks reflect the usage of the knowledge in real life by the SI students.	Van der Merwe (2019).
DG3. Promote collaboration and student interaction in SI class.	Van der Merwe (2019).
DG4. Deep learning through the constructionist and socio-cultural learning via peer collaboration.	Van der Merwe (2019).
DG5. Solving complex tasks over a period in class with the help of the SI leaders.	Van der Merwe (2019).

THE SOLUTION IN PRACTICE AND RESEARCH

The DBR protocols used by Zydney, Warner, and Angelone (2020), and Reeves, (2006) were modified and applied for the current investigation. From the formative assessments, students at risk were identified (average score <52%) and advised to attend the SI and tutorship programme for the Advanced Research Methodology module. Two dedicated and experienced SI leaders were recruited and underwent a rigorous facilitator-training programme to equip them with digital pedagogical and technological skills to conduct supplementary classes using WhatsApp video class, MS Teams, Zoom, and Blackboard. The tutors were provided with all the learning materials to conduct SI classes. Supplementary instruction and learning and an online SI programme using e-tools were designed, developed, and implemented to create a conducive environment for the students at-risk to learn and improve their grades. The SI leaders were equipped with skills for Learner Management Systems (LMS) e.g., MS Teams, Zoom, and WhatsApp video class.

The learning environment drew on the teaching and learning theories of constructionist,

Mutanda, Gumede,
Mayisela, Ng'ambi

Using a design-based research approach for a supplementary instruction
programme: A pedagogical intervention during the COVID-19 pandemic

socio-cultural theory, and cognitively guided instruction. In the current study, the theoretical framework underpinning the DBR research are TEDDIE, Laurillard's conversational framework, the constructivist, sociocultural theories, and Bloom's higher-order thinking skills (HOTS). The TEDDIE model unlocks learning design, involving thinking like an online learning designer phase, exploration phase, design phase, development phase, and finally the evaluation phase. The current DBR study specifically applies the design phase involved looking at the learning theories e.g., constructivist and sociocultural theories that are closely aligned to the current educational context, learning intervention, and in this case, individual as well as the collaborative approach to learning via online platforms in addition to the Laurillard's conversational framework. Therefore, the constructivist, sociocultural learning theories and cognitively guided instruction are used to develop draft principles to guide the design of the interventional measure of instructional intervention. Briefly, the intervention of the learning challenge is supplementary instruction of the at-risk students of Advanced Research Methodology using online learning platforms. The at-risk students were identified from the class and students with an average score of less than 52 per cent were advised to attend the supplementary instruction programme. The supplementary instruction programme was finally implemented and evaluated for its efficacy in facilitating the at-risk student to excel in the module and ultimately increasing the module pass rate and throughput.

The idea of SI is viable because it is not too ambitious, the method is pragmatic, feasible, not too expensive, and easy to implement for both small and large synchronous and asynchronous classes. For the current DBR approach to work, the process of implementation involved meticulous supplementary instruction design, data collection, analyses, and interpretation. The supplementary instruction class was implemented with 2 well-trained SI leaders, and the learning environment was thoroughly researched using both qualitative and quantitative research methods. Where possible, experimental data were analyzed and subjected to descriptive and inferential statistics, interpretive goals, and qualitative methods. To gather authentic evidence about whether the intervention addressed the problem, data were collected over the 4-week supplementary instruction period of implementation and interview period. Questionnaires were administered, and responses were computed qualitatively. Throughput, dropout rates, and module pass rates were computed quantitatively from 2019, 2020, and 2021 academic years (Cycle 1 with 1 iteration). Table 3 illustrates the draft design guidelines of the SI intervention modified from the design guidelines from Van der Merwe (2019).

A video recording of the supplementary instruction class in session for promotional purposes was generated and stored in the database. Data were analyzed using descriptive (graphing, means, mode, median, lowest mark, highest mark) statistics. After refining iteration

Mutanda, Gumede,
Mayisela, Ng'ambi

Using a design-based research approach for a supplementary instruction
programme: A pedagogical intervention during the COVID-19 pandemic

1, Cycle 1, further work will be done for iterations 2 and 3 to test the efficacy of the supplementary instruction intervention.

Table 3: Design guidelines reflected in SI practice

Draft Guidelines (DG)	Implementation in the SI programme learning environment
DG1. Flexibility and blended nature of the supplementary instruction programme.	A flexible synchronous and asynchronous SI learning environment was created to allow students to access the information and resources for learning.
DG2. Authentic supplementary instruction (SI) tasks reflect the usage of the knowledge in real life by the SI students.	Knowledge generated in the SI class was used in real life to improve student performance in-class tasks. The learning theory was tested in practice.
DG3. Promote collaboration and student interaction in the SI class.	Quantitative data reflected on own practice, implementation, and application of the theory. Each learner reflected on the usefulness of the SI programme.
DG4. Deep learning through the constructivist and socio-cultural learning via peer collaboration.	Students completed all the class tasks and assessments to be relevant to their experiences in SI learning in collaboration with peers.
DG5. Solving complex tasks over a period in class with the help of the SI leaders.	SI students explored different ways to execute quality testing and the SI leaders offered help to students in solving the complex Advanced Research Methodology problems. The SI students submitted a portfolio of evidence and a student satisfaction survey was undertaken.

RESEARCH FINDINGS AND DISCUSSION

The SI programme was subjected to the four phases of the DBR guided by the design principles. The number of students was determined, and the pass rates were calculated. Since face-to-face teaching was done in 2019, the data generated was regarded as secondary data. From the first cycle of DBR, the pass rates were calculated and found to be 95 per cent, 65 per cent, and 85 per cent for academic years 2019, 2020, and iteration 1 (2021) respectively (Table 4). Tactically, we argue that the SI intervention alone could not be attributed to the change in student performance, but rather it is acknowledged that there could have been other facts, including cheating due to online learning. Research is ongoing to account for other variables that could have contributed to this.

Table 4: The number of students and pass rates for the Advanced Research Methodology

	2019 Data	2020 Data	Iteration 1 (2021)
Online Students	0	48	52
On-campus Students	46	0	0
Total (N)	46	48	52
Pass Rate (%)	95	65	85

Mutanda, Gumede,
Mayisela, Ng'ambi

Using a design-based research approach for a supplementary instruction
programme: A pedagogical intervention during the COVID-19 pandemic

The quantitative data generated from one iteration indicated the success of the SI using the DBR approach which was implemented in this study since the pass rates improved from 65 per cent to 85 per cent in the one and final iteration. Notably, the pass rate dropped drastically to 65 per cent in 2020 which could be attributed to the COVID-19 pandemic shock as compared to 2019 (pre-COVID-19). However, the implementation of SI proved to be effective since the pass rate improved significantly by 85 per cent during iteration one (Hargreaves et al. 2021). These findings corroborate the peer-assisted learning study conducted at the University of York which found that, while students and staff are looking forward to in-person contact to provide them with interactions and easier methods of communication, the remote provision for peer support offered value in terms of accessibility and inclusivity (Hargreaves et al. 2022). They further argue that the main benefits of remote peer support centred on the convenience and accessibility of remote sessions compared to on-campus (Hargreaves et al. 2022). However, the improvement in pass rates after introducing the SI programme can also be attributed to other underlying factors i.e., students are now comfortable and competent in using the digital technologies as pedagogical tools in the 2021 iteration. In addition, recorded lectures allowed students to pause, rewind and re-play which students whose English is not their first language find useful. The collaboration and interaction that existed in the SI class immensely contributed to the professional development of all the practitioners and students participating in this project. Gamlath (2021) argues that involving trained current students in these activities has the potential to bring invaluable insights and is often a cost-effective approach to preparing outgoing students for work. To this end, as the academic who conceptualized this intervention, I developed proficiency and experience in the SI resource design and planning and acquired online learning skills as well as the application of recommended teaching and learning theories. Supplementary instruction has a pronounced effect on student persistence, and the effect increases continuously with increasing SI attendance (Malm, Bryngfors, and Fredriksson 2018). Therefore, the outcomes of the current research meet the minimum requirements of a typical DBR research project (Table 5). The limitation of the current study is that the first iteration used

Table 5: Quantitative and qualitative feedback from the original draft guidelines from the 1st iteration, i.e., feedback.

Draft Guideline (DG)	Quantitative and qualitative practical outcomes from the SI students
DG1. Flexibility and blended nature of supplementary instruction.	All students who attended the SI sessions concurred that the programme was flexible and blended. The students indicated that the programme was helpful to their studies.
DG2. Authentic supplementary instruction (SI) tasks reflect the usage of the knowledge in real	The students used the knowledge generated in the SI class in real life and there was an improvement in performance in-class tasks and eventually passing the module. All students performed well indicating that the learning

Mutanda, Gumede,
Mayisela, Ng'ambi

Using a design-based research approach for a supplementary instruction
programme: A pedagogical intervention during the COVID-19 pandemic

Draft Guideline (DG)	Quantitative and qualitative practical outcomes from the SI students
life by the SI students.	theory was adequate and successful after testing in practice.
DG3. Promote collaboration and student interaction in SI class.	Students positively confirmed that the SI implementation as an interventional tool was successful in fostering collaboration and interaction among peers. After reflecting on the usefulness of the SI programme, all students appraised the SI leaders in facilitating the SI programme.
DG4. Deep learning through the constructivist and sociocultural learning via peer collaboration.	All SI participating students agreed that they generated their knowledge from the empirical problems and tasks, from peers and SI leaders thereby confirming the validity and efficacy of the constructivist and sociocultural theories of learning in the SI programme.
DG5. Solving complex tasks over a period in class with the help of the SI leaders.	SI students confirmed that they were now equipped with advanced skills to solve the complex Advanced Research Methodology problems with the facilitation of the SI leaders.

secondary data since teaching was purely face-to-face. Furthermore, another limitation is that the process of the DBR approach is lengthy since the module is offered only once per year in Semester 1. Since secondary data were used for iteration 1, the refinement of the design and development of proof of concept will be undertaken in the second cycle.

CONCLUSION

In conclusion, the current study, DBR in conjunction with a SI programme interventional tool, solved a typical real-world problem of at-risk students failing the Advanced Research Methodology module. In a similar study, Anderson and Shattuck, (2012) concluded that the interest in the DBR is increasing and that the results offer limited evidence for guarded optimism that the methodology is meeting its promised benefits. Hence, a pragmatic intervention was designed and implemented using the supplementary instruction approach and subjected to the four phases of the DBR. The design principles were formulated to guide the DBR research and the refinement of the whole process. In this investigation, a flexible SI learning environment was designed and implemented for both practitioners and subjects of the study using the framework and theories by Van der Merwe, (2019) to come out with the desired design guidelines. Phase 3 of the DBR process created the design principles using the knowledge extracted from the previous iterations. In this investigation, a robust SI programme was created with a design-based research approach allowing students to build their knowledge and excel in the module. The SI students performed authentic activities with the help of the SI leaders facilitating the class assessments. Lastly, the design-based principles will be refined in the future to foster effective student collaboration and interaction in the SI class thereby increasing pass rates and throughput for the module. The students will be able to apply the gained knowledge after they complete their educational programme. Our findings are consistent

Mutanda, Gumede,
Mayisela, Ng'ambi

Using a design-based research approach for a supplementary instruction
programme: A pedagogical intervention during the COVID-19 pandemic

with the claims validated by the U.S. Department of Education that participation in SI is correlated with higher mean grades, lower failure and withdrawal rates, and higher retention and graduation rates (Dawson et al. 2014).

ACKNOWLEDGMENTS

REFERENCES

Armstrong, M., C. Dopp, and J. Welsh. 2020. "Design-Based Research." In *The Students' Guide to Learning Design and Research,* ed. R. Kimmons and S. Caskurlu, EdTech Books. https://edtechbooks.org/studentguide/design-based_research.

Anderson, T. and J. Shattuck. 2012. "Design-Based Research: A decade of progress in education research?" *Educational Researcher* 41(1): 16–25. DOI: 10.3102/0013189X11428813.

Collins, A., D. Joseph, and K. Bielaczyc. 2004. "Design research: Theoretical and methodological issues." *Journal of the Learning Sciences* 13(1): 15–42.

Dawson, P., J. van der Meer, J. Skalicky, and K. Cowley. 2014. "On the effectiveness of supplemental instruction: A systematic review of supplemental instruction and peer-assisted study sessions literature between 2001 and 2010." *Review of Educational Research* 84(4): 609–639. DOI: 10.3102/0034654314540007.

Dolmans, D. H. J. M. 2019. "How theory and design-based research can mature PBL practice and research." *Advances in Health Sciences Education* 24: 879–89. https://doi.org/10.1007/s10459-019-09940-2.

Ford, C., D. McNally, and K. Ford. 2017. "Using design-based research in higher education innovation." *Online Learning* 21(3): 50–67. DOI: 10.24059/olj.v%vi%i.1232.

Gamlath, S. 2021. "Peer Learning and the Undergraduate Journey: A Framework for Student Success." *Higher Education Research and Development* 41(1): 1–15. https://doi.org/10.1080/07294360.2021.1877625.

Hargreaves, J., C. Ketnor, E. Marshall, and S. Russell. 2022. "Peer-Assisted Learning in a Pandemic." *International Journal of Mathematical Education in Science and Technology* 1–9. https://doi.org/10.1080/0020739x.2021.2008036.

Herrington, J. A., S. McKenney, T. C. Reeves, and R. Oliver. 2007. "Design-based research and doctoral students: Guidelines for preparing a dissertation proposal." In "*Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2007*, ed. C. Montgomerie and J. Seale, 4089–4097. https://ro.uow.edu.au/edupapers/627.

Herrington, J. and T. C. Reeves. 2011. "Using design principles to improve pedagogical practice and promote student engagement." In *Changing Demands, Changing Directions, changing directions. Proceedings ascilite 2011,* ed. G. Williams, P. Statham, N. Brown and B. Cleland, 594–601. Hobart, Tasmania, Australia.

Jong M. S-Y., G. Chen, V. Tam, M-T. Hue, and M. Chen. 2022. "Design-based research on teacher facilitation in a pedagogic integration of flipped learning and social inquiry learning." *Sustainability* 14: 996. https://doi.org/10.3390/su14020996.

Mutanda, Gumede,
Mayisela, Ng'ambi

Using a design-based research approach for a supplementary instruction
programme: A pedagogical intervention during the COVID-19 pandemic

Malm, J., L. Bryngfors, and Johan Fredriksson. 2018. "Impact of Supplemental Instruction on Dropout and Graduation Rates: An Example from 5-Year Engineering Programs." *Journal of Peer Learning* 11(1): 76.

McKenney, S. and T. C. Reeves. 2012. *Conducting educational design research.* New York, NY: Routledge.

Meyers, G. L., M. Jacobsen, and E. Henderson. 2018. "Design-Based Research: Introducing an innovative research methodology to infection prevention and control." *Canadian Journal of Infection Control* 33: 158–164.

Mpungose, C. B. 2020. "The emergent transition from face-to-face to online learning in a South African University in the context of the Coronavirus pandemic." *Humanit Soc Sci Commun* **7:** 113. https://doi.org/10.1057/s41599-020-00603-x.

Nerantzi, C. 2020. "The use of peer instruction and flipped learning to support flexible blended learning during and after the COVID-19 Pandemic." *International Journal of Management and Applied Research* 7(2): 184–195. ISSN 2056-757X.

Papavlasopoulou, Sofia, Michail N. Giannakos, and Letizia Jaccheri. 2019. "Exploring children's learning experience in constructionism-based coding activities through design-based research." *Computers in Human Behavior* 99: 415–427.

Reeves, T. C. 2006. "Design research from a technology perspective." In *Educational design research,* ed. J. van den Akker, K. Gravemeijer, S. McKenney, and N. Nieveen, 52–66. London: Routledge.

Reeves, T. C. 2011. "Can educational research be both rigorous and relevant?" *Educational Designer* 1(4): 1–24. http://www.educationaldesigner.org/ed/volume1/issue4/article13/index.htm.

Reinholz, D. L. 2015. "Peer-assisted reflection: A design-based intervention for improving success in calculus." *International Journal of Research in Undergraduate Mathematics Education* 1(2): 234–267.

Shattuck, J. and T. Anderson. 2013. "Using a design-based research study to identify principles for training instructors to teach online." *The International Review of Research in Open and Distance Learning* 14(5): 186–210.

Scott, E. E., M. P. Wenderoth, and J. H. Doherty. 2020. "Design-Based Research: A methodology to extend and enrich biology education research." *CBE Life Sci Educ* 19: es1. DOI: 10.1187/cbe.19-11-0245.

Van der Merwe, B. 2019. "Design-based research for the development of a flexible learning environment." *Health SA Gesondheid* 24(0): a1050. https://doi.org/10.4102/hsag.v24i0.1050.

Wang, F. and M. F. Hannafin. 2005. "Design-based research and technology-enhanced learning environments." *Educational Technology Research and Development* 53(4): 5–23. DOI: 10.1007/BF02504682.

Zhao, L., W. He, and Y-S. Su. 2021. "Innovative pedagogy and design-based research on flipped learning in higher education." *Frontiers in Psychology* 12: 577002. DOI: 10.3389/fpsyg.2021.577002.

Zydney, J. M., Z. Warner, and L. Angelone. 2020. "Learning through experience: Using design-based research to redesign protocols for blended synchronous learning environments." *Computers & Education* 143: 103678.