Integrating ICT into organic chemistry teaching and learning using a flipped classroom:

The response of student-teachers in three colleges in Ghana

Benjamin Aidoo

Thesis for the degree of Doctor of Philosophy

June 2023

School of Education

UNIVERSITY OF ICELAND

Integrating ICT into organic chemistry teaching and learning using a flipped classroom:

The response of student-teachers in three colleges in Ghana

Benjamin Aidoo

Thesis towards the degree of Doctor of Philosophy

Supervisors

Dr Allyson Macdonald, University of Iceland, Reykjavík, Iceland

Dr Veli-Matti Vesterinen, University of Turku, Finland

Doctoral committee

Dr Svava Pétursdóttir, University of Iceland

Dr Berglind Gísladóttir, University of Iceland

Opponents at the defence

Dr Brian Lewthwaite, James Cook University, Townsville, Australia

Dr Stephen Day, University of the West of Scotland

June 2023

School of Education

UNIVERSITY OF ICELAND

Notkun upplýsingatæki í vendinámi í lífrænni efnafræði:

Upplifun kennara og kennaranema í þremur háskólum í Ghana

Benjamin Aidoo

Ritgerð til doktorsgráðu

Leiðbeinendur

Dr Allyson Macdonald, Háskóli Íslands

Dr Veli-Matti Vesterinen, Univerity of Turku, Finland

Doktorsnefnd

Dr Svava Pétursdóttir, Háskóli Íslands

Dr Berglind Gísladóttir, Háskóli Íslands

Andmælendur við vörnina

Dr Brian Lewthwaite, James Cook University, Townsville, Australia

Dr Stephen Day, University of the West of Scotland

Júní 2023

Menntavísindasvið

HÁSKÓLI ÍSLANDS

Thesis for a doctoral degree at the University of Iceland. All right reserved. No part of this publication may be reproduced in any form without the prior permission of the copyright holder.

© Benjamin Aidoo 2023

ISBN 978-9935-9727-0-5

ORCID: 0000-0003-0708-7746

Reykjavik, Iceland 2023

Ágrip

Kennsluhættir sem byggja á virku námi hafa vakið áhuga meðal kennara og nemenda. Á sama tíma leggja stefnumótunaraðilar áherslu á notkun upplýsingatækni í skólastarfi. Rannsóknir á virku námi og vendinámi jukust bæði að fjölda og gæðum í COVID-19 faraldrinum. Rannsóknaráætlun var unnin og aðlöguð til að bregðast við þessum aðstæðum sem mörkuðust af breyttri viðveru. Rannsóknin er framlag til þeirrar þekkingar sem faraldurinn varð kveikjan að. Kápa þessi er byggð á gögnum og greiningu úr fjórum birtum vísindagreinum.

Tilgangur þessarar rannsóknar var að framkvæma íhlutun í kennslu á lífrænni efnafræði með notkun upplýsingatækni og meta viðhorf og reynslu kennaranema sem og kennara þeirra. Gögnum var safnað í þremur kennaraháskólum í Ghana með þremur efnafræðikennurum. Spurningalistar voru lagðir fyrir breiðan hóp kennara og kennaranema, og teking vour viðtöl og rýnihópaviðtal á netinu. Kennarar og rannsakandi voru í reglulegum samskiptum fyrir og á meðan samgöngutakmarkanir vegna faraldursins áttu sér stað.

Meginmarkmiðið var að komast að því að hve miklu leyti háskólakennarar og kennaranemar gætu beitt upplýsingatækni við að tileinka sér vendinám- og kennslu við kennslu á lífrænni efnafræði. Skipulögð var kennsla í fjórar vikur þar sem hefðbundin kennsla byggð á fyrirlestrum í kennslustundum og skriflegri heimavinnu var skipt út fyrir kennsluhætti vendináms. Engar breytingar voru gerðar á innihaldi kennslunnar sem var samkvæmt námskrá fyrir háskólana. Þrjú viðfangsefni úr lífrænni efnafræði voru kennd með vendinámi, virku námi og með ríkri notkun á upplýsingatækni.

Kennurunum í teyminu fannst erfitt að breyta kennsluháttum sínum og taka upp kennslu á netinu. Hæfni þeirra í upplýsingatækni var ábótavant rétt eins og tækniinnviðir í skólunum. Þeir töldu það að nýta vendinám gæfi nemunum tækifæri til að efla færni sína og breyta kennsluháttum. Kennararnir höfðu nokkra þekkingu á sviði upplýsingatækni en það voru ýmsir veikleikar við notkun hennar í kennslu. Kennararnir gáfu einnig til kynna að þeir sem þó höfðu fengið þjálfun í notkun upplýsingatækni, fannst hún ekki nógu skipulögð eða nægjanleg til að geta fléttað notkun hennar í kennslu. Kennaranemarnir töldu að sveigjanleikinn sem felst í vendináminu hefði gert þeim kleift að vera virkari og að taka meiri ábyrgð á eigin námi. Þeim fannst að þeir gætu átt samskipti við kennara sína og unnið með samnemendum í vendináminu. Þeir álitu einnig að vendinámið yki hugtakaskilning þeirra, námsárangur og gagnrýna hugsun.

Stuðningurinn sem kennararnir sem leiddu verkefnið veittu hver öðrum dregur fram gildi þess að kennarar styðji hvern annan, þegar þeir eiga við sömu vandamál að stríða eins og gerðist í íhlutuninni. Þegar vendikennslu er beitt er mikilvægt að hafa í huga að þekking, leikni og hæfni kennara í upplýsingatækni geta aukið gæði náms og kennslu. Stöðug starfsþróun gerir háskólakennurum og nemendum kleift að nýta upplýsingatækni í skólastarfinu, til dæmis í lífrænni efnafræði.

Við lok rannsóknarinnar var gerð SVOT stefnumótandi greining á lykilþáttum íhlutunarinnar. Greindir voru innri styrkleikar og veikleikar í þeim þáttum sem áhrif höfðu á það hlutverk skólanna að mennta kennara samkvæmt námskrám. Einnig voru tækifæri og áskoranir úr ytra umhverfi varðandi virkt nám dregin fram. Lykilþættir fyrir það að upplýsingatækni sé fléttuð í skólastarfið með árangursríkum hætti eru nægjanleg þekking og færni, nothæfir tækniinnviðir og regluleg notkun upplýsingatækninnar.

Lykilorð:

Kennaramenntun, vendinám, leitarnám, upplýsingatækni, lifrinefnafræði.

Abstract

Student-centred models based on active learning have aroused interest among teachers and students. At the same time policymakers encourage the use of information and communication technologies in education. Research on active learning and flipped classrooms took an upward turn in quality and magnitude with the advent of COVID-19. The research proposal was developed just prior to the pandemic and was altered to deal with the new situation. This research has contributed to the research generated by the pandemic. This cover study incorporates the data and analysis from four published articles.

The purpose of this research was to develop a classroom intervention in organic chemistry using ICT and assess the perspectives of three classes of student-teachers and their chemistry teachers ("the threesome") on their experience. The data were gathered on-site in Ghana by the threesome and with online questionnaires for both educators and student-teachers, online interviews, and a focus group. The threesome and the researcher met regularly online before and during the COVID-19 period of restrictions on school attendance.

The main aim was to understand the extent to which teacher educators and student-teachers could use ICT to adopt flipped classrooms as a pedagogical approach while teaching organic chemistry. Four weeks of instruction in the traditional format of classroom lectures and written homework were replaced by a flipped mode of instruction in which students studied organic chemistry in school and in out-of-school settings. No changes were made regarding the content as prescribed in the national curriculum for tertiary education. The same topics from organic chemistry were introduced in all three colleges at the same time, using the flipped, active learning and incorporating extensive use of ICT.

The educators found it difficult to shift their pedagogical practice and adopt online teaching. ICT skills were weak as was the ICT infrastructure in the colleges. Some ICT resources in the form of data bundles were provided to all the student-teachers and the threesome and mobile Wi-Fi equipment to one educator. Some student-teachers who could not access the internet at home used these resources for their pre-class activities.

On reflection, the threesome believed that integrating flipped classrooms could provide opportunities for student-teachers to develop their skills and change their pedagogical practices. The threesome had some ICT knowledge, but there were weaknesses in the colleges in using and integrating it into the teaching. One of the reasons was that participants had not received professional ICT training that would enable them to be

competent in delivering or receiving technology-enhanced lessons. The threesome indicated further that even for those who had received some ICT training, it was not effectively organized or enough to enable teachers to put integration into practice. ICT-focused workshops were one-time only and too short and rushed to be beneficial.

The student-teachers perceived that the flipped classroom approach would enable them to take a more active role and responsibility for their learning because of the flexibility of the approach. Student-teachers felt they could interact with their teachers and collaborate with their peers through the flipped approach. Further, they believed that the flipped classroom activities enhanced conceptual understanding and increased academic achievement and critical thinking skills.

Both the threesome and student-teachers faced challenges implementing the national curriculum because of deficiencies in ICT infrastructure, and few opportunities to develop the relevant knowledge, skills, and competences for teaching and learning for the 21st century.

The support that the researcher provided highlighted the value of teachers supporting each other when they have the same issues. In this case the context of the intervention with flipped classrooms, it is important to consider that educators with knowledge, skills, and competence in ICT could produce quality teaching and the necessary learning processes. Ongoing professional development enables educators and teachers to integrate ICT sufficiently into their teaching, for example, in chemistry.

At the ed of the study, a so-called SWOT strategic analysis of innovation was carried out based on the data we had assembled before, during and after the intervention. Strengths and weaknesses of internal factors affecting the stated task of the institution, that is training teachers according to the national curriculum were identified as well as opportunities and threats to active learning found in the external environment. It is our conviction that the crucial factors for effective integration are adequate ICT knowledge and skills, functional ICT infrastructure, and regular use of ICT.

Keywords:

Teacher education, flipped classroom, inquiry-based learning, ICT, organic chemistry.

Acknowledgements

I want to thank all my friends, family, and teachers who contributed in one way or another to make this PhD journey a reality. To begin with, I am forever indebted to you, Allyson Macdonald (lead supervisor). You have supported me in many other ways or means that I cannot ask for more. I consider myself lucky to have a teacher and advisor like you. You have supported me throughout this journey by introducing me to meeting colleagues, teachers, and researchers and sorting out funding. Allyson has advised me on the choice of courses, seminars, conferences, and academic writing retreats to improve my writing. Despite naming my last daughter after you, I cannot thank you enough. To the other committee member, Svava Pétursdóttir, I want to express special thanks for the feedback, advise and corrections especially in the articles and the final stages of the write-up of this thesis. Thank you for your support, encouragement, and motivation in completing this work. In addition, special thanks go to Berglind Gísladóttir the constructive feedback and guidelines you provided on the articles and the write-up of this thesis. In addition, thanks to you Veli-Matti Vesterinen for supporting me despite my weaknesses in some respects. You took the time to explain and clarify during the interim evaluation, data cleaning, article writing, and the thesis. The countless discussions throughout the period, irrespective of the time of the day you were always available, have brought this research this far. I also appreciate your support and cooperation in the co-authorship of the articles. What I appreciate most is the Saturdays you spent with me to meet specific deadlines, which were enormous. Further, a very appreciative thanks to you, Kristján Ketill Stefánsson, for the enormous assistance with the quantitative data analysis. I also thank Peter Mtika (University of Aberdeen) for your comments and suggestions during my interim evaluation.

My sincere gratitude goes to Tumi Tomasson, who, on several occasions, provided comments and advice and proofread my articles along with final version of this thesis. However, I take responsibility of the final version of the contents. Also, what astonishes me the most is how you sometimes took my four kids for a walk and playgrounds so that me and Allyson can work on projects and other incidental tasks. Special thanks also go to Prof. Christian Anthony-Krueger of the University of Cape Coast, Ghana, who was crucial in supervising the project execution at all three research sites and co-authoring Article 4. Your effort and contribution to the success of this project are much appreciated. Also, to the three research team members, Francis Quansah, Johnson Tsyawo, and Alexander Gyampoh, who allowed me to share your classroom and students for the project. It was a pleasure collaborating and working with you. Your teamwork spirit made me get to know more and believe in the learning community, and

I hope to work with you in the future. Your commitment, suggestions, evaluation, and support in completing this project are highly appreciated.

Finally, thanks to my spouse, Florence, who sacrificed her working times, sleepless nights, and unending support throughout this Ph.D. journey. Also, I cannot forget my four lovely kids: Samuel, Prisca, Klara, and Allyson, who were been very supportive throughout this journey. I dedicate this thesis to you, Allyson Nyameye, and Klara Asor, who sometimes sat beside the desk to encourage me to write more meaningful pieces of text.

Contents

List of abbreviations

This section explains some key abbreviations and terms used in this thesis.

BL = Blended Learning

CoE = Colleges of Education

DBE = Diploma in Basic Education

FC = Flipped classroom

FL = Flipped learning

IBT = Inquiry-Based Teaching

MoE = Ministry of Education

MoESS = Ministry of Education and Sports

NaCCA = National Council for Curriculum and Assessment

SDG = Sustainable Development Goals

TPCK = Technological Pedagogical Content Knowledge

TIMSS = Trends in International Mathematics and Science Study

T-TEL = Transforming Teacher Education and Learning

List of figures

List of tables

List of original papers

This thesis is based on the following original publications, which are referred to in the text by their Roman numerals (I, II, III, IV):

I. Aidoo, B., Macdonald, A., Gyampoh, A. O., Baah, K. A., & Tsyawo, J. (2022). Factors influencing teachers' online teaching competence in higher education. *Social Education Research, 3*(1), 148-160. https://doi.org/10.37256/ser.3120221315

II. Aidoo, B., Macdonald, M.A., Vesterinen, V.M., Pétursdóttir, S., & Gísladóttir, B. (2022). Transforming teaching and learning with ICT using flipped classroom approach: Dealing with COVID-19 pandemic. *Educational Sciences,* 12(6), 4255. https://doi.org/103390/educsci12060421

III. Aidoo, B., Vesterinen, V. M., Macdonald, M. A., Gísladóttir, B., & Pétursdóttir, S. (2022). Perceptions of Ghanaian pre-service teachers on benefits and challenges of the flipped classroom: A Case Study. *Contemporary Educational Technology,* 14(4), ep37755. https://doi.org/10.30935/cedtech/12163

IV. Aidoo, B., Anthony-Krueger, C., Gyampoh, A. O. G., Tsyawo, J., & Quansah, F. (2022). A mixed-method approach to investigate the effect of flipped inquiry-based learning on chemistry students learning. *European Journal of Science and Mathematics Education*, 10(4), 507-518. https://doi.org/10.30935/scimath/12339

Declaration of contribution

In the project, I planned, designed, and prepared learning materials for the project with teacher educators. I designed the research instruments in collaboration with the supervisors, e.g., teacher-educator interview questions, student-teacher focus group questions, and teachers' questionnaires. I also designed the questionnaires for university teachers and the student-teachers' chemistry achievement tests. In Papers I-IV, I wrote the original drafts of each article. I led in writing the introduction, literature review, methodology, and discussions in Paper I. I wrote the introduction, literature review, results, discussions, and conclusions in Papers II and III. I wrote the introduction, literature review, and discussion in Paper IV.

1 Introduction

When I started my doctoral studies, I wanted to know more about inquiry-based learning and the use of ICT. I believed that student-centred approaches can make students become responsible for their learning, control it and construct knowledge based on their own learning experiences. Increasingly, ICT is being used to support pedagogical approaches that enhance students active learning. I have chosen the flipped classroom approach as my Trojan horse in my work and research. Through an intervention student-teachers will be exposed to and experience active teaching and learning in organic chemistry using ICT. Improving learning greatly concerns me and therefore I have chosen to address this issue in my thesis.

My plan had been to collect data myself in Ghana with regular visits to three colleges of education (CoE) but my project plan was altered when I realised that schools were being affected by the COVID-19 pandemic. I talked with some teacher educators in Ghana, and I discussed the challenges they were encountering with online teaching. I then considered whether it would be useful to carry out an intervention that would provide students with experience in using ICT in teaching and learning chemistry and us with data on their perceptions. I then re-designed the project as an intervention that would assist teacher educators and student-teachers in using ICT in the colleges. This approach corresponded to the vision of science for all, requiring a pragmatic approach to learning and building up knowledge which is of a technical nature.

In this first chapter, I identify and briefly discuss the rationale for the study, its purpose and aims, and several ideas which influenced how I constructed the study and how it was conducted. I describe the setting in which this thesis is situated, touching on educational policies as critical drivers of successful science education, and teaching innovation, teacher education, and the use of ICT in schools. As I discuss these settings, I narrow my interests to the point where I can formulate my research aims. I complete this introduction with a brief discussion of the value and scope of this thesis.

My intention in this doctoral study is to provide information for the purpose and practice of teacher education, especially science education, in which I have a particular interest because I am a trained and experienced chemistry teacher.

1.1 The need for change

Since colonial times and despite educational reforms since the late 1950s, educators and researchers have recognised the "difficulties of teaching students to learn, understand and retain knowledge" (Ritchhart et al., 2011). Education in many countries was designed to serve the elite and the colonial masters and their administrative needs (Pinto, 2019). Although Ghana was one of the first African countries to achieve independence from the British in 1957, the education system still carries many characteristics of the structure, content, and assessment of earlier times.

New curricula were developed in many parts of the Western world and then adopted by others with little adaptation to national needs and circumstances. They focus on the transformation of teachers' pedagogical practices from teacher-led instructions to student-centred strategies such as active learning activities (Bybee, 2014). Researchers have pointed out that students learn best by engaging in activities to create new knowledge and solve problems (Cervantes et al., 2015; Ismail & Elias, 2014). The knowledge and ideas form the foundation upon which further knowledge is developed. Unlike the traditional lecture approach, an active learning curriculum is designed as student-centred. Educators that engage students in active learning that enhances their retention, achievement, and critical thinking skills (Warfa, 2016). Active learning includes participating in learning activities such as discussions and problem-solving activities, involving analysing, synthesising, and drawing conclusions (Donohue et al., 2020). Therefore, it is important to understand how science teachers transition to develop and use active learning pedagogies.

In the next section, I will discuss some aspects of science education and how educators and researchers can contribute to its development, especially in chemistry education.

1.2 Improvements needed in chemistry education

In Ghana, school science aims to produce scientifically literate, creative, and confident citizens who are good at problem-solving and competent enough to contribute to and participate in remedying local and international issues of concern (NaCCA, 2019).

Scientific literacy has raised public debate and awareness of what and how scientific knowledge is perceived (Roberts, 2007). In reconciling the debates, attempts have been made to describe what constitutes scientific literacy (Coll & Taylor, 2009). Hodson (2009) argued that scientific literacy encompasses three elements: learning science and technology, doing science and technology, and learning about science and technology. Roberts (2011) categorised scientific literacy based on two visions: Vision I focuses on scientific content and process for the future, and Vision II deals with understanding the usefulness of scientific knowledge in our lives and society so that science can be learned in a meaningful context. The way in which science is taught to prepare future scientists (pipeline science) and teaching science for all has brought out tensions between the two visions. Hodson (2009) proposed a third vision to address this challenge. Vision III focuses on critical scientific literacy and relates to the connections between science and technology in society (Table 1).

The goal of science teaching is to increase student understanding of scientific concepts and improve student ability to construct knowledge that can improve scientific literacy and enhance positive attitudes toward science (Liu, 2013; Osborne, 2007; Taber, 2017).

Table 1 The three visions of scientific literacy in science education

Visions	Knowledge types	Aim of science	Focus on science education
I. Pipeline science	Theoretical, intellectual, and disciplines	Develop scientific understanding	Epistemological
II. Science for all	Pragmatic Technical	Support growth and wealth; sustainable development	Everyday life and usefulness
III. Science for transformation	Emancipatory Critical action	Democracy and justice; critical sustainability	Ethics and transformation

Despite the ambitions in the curriculum, Ghana has not done well in comparative assessments of integrated science in national or international tests (Anamuah-Mensah et al., 2005; Anamuah-Mensah et al., 2008). In 2003 and 2007 and 2011 Ghana ranked second last and last, in Trends in Mathematics and Science Study (TIMSS) assessments. Over the years, no 8th grade student reached the international average of 500 indicating Ghanaian students have difficulties in the three scientific domains of knowing, applying, and reasoning (Table 2). At the national level, over a nine-year period (2009-2017), students' performance in science in the West African Examination Council (WASSCE) has been poor. In 2009 and 2011, the percentage of students who passed integrated science was 34.5% and 42% respectively. Similarly, from 2013 to 2017, the highest pass rate has been 49.7% in 2013. This poor performance has been attributed to weak understanding of scientific concepts and application of basic principles (Fletcher, 2018).

Table 2 Ghana's 8th grade student performance in TIMSS

Year	Number of countries	Ghana's position	Average scores
2003	45	44	255
2007	48	47	303
2011	42	42	306

In order to foster scientific literacy in chemistry education, researchers have recommended connecting chemical concepts with learning experiences (Eilks et al., 2013; Mahaffy, 2006). Approaching chemistry teaching this way would help students to develop their abilities to test ideas and integrate their personal and societal views in making informed decisions. Metaphors of scientific phenomena can be used to develop an understanding of chemistry (Mahaffy, 2006) and facilitates the teaching and learning of science (Brown, 2003).

An example of a useful metaphor in chemistry teaching is the tetrahedral form that illustrates new dimensions in learning chemistry (Mahaffy, 2004) that guides students to encounter chemistry at different thinking levels to enrich their understanding of chemistry (Mahaffy, 2006). In enhancing metaphors and understanding, Johnstone (2000) suggested engaging students with content that shows the symbolic or representational, macroscopic, and molecular thinking levels. According to Mahaffy (2004), tetrahedral chemistry education connects chemistry knowledge to students and the public by grounding it as macroscopic, molecular, and symbolic dimensions of problem solving. Researchers have built curricula and pedagogies that focus on the connections among chemical concepts, chemical substances, symbolic representations, and the processes used to foster students understanding and address students' chemistry learning patterns (Mahaffy, 2006). Such connections can enable educators to deliver science concepts that give a genuine understanding of how scientists work (Mahaffy, 2004).

1.3 Developments in chemistry education

Worldwide curriculum development has focused on reforming teacher education to improve classroom practice and student learning (Bybee, 2014). Like other countries, a national curriculum for colleges of education (CoE) in Ghana depends on teachers becoming specialists in different school subjects. The Ministry of Education (MoE) has introduced reforms in the curriculum at both schools and colleges. Ghana's current education curriculum emphasises creativity, critical thinking, problem-solving, innovation, communication, and scientific literacy. Students need to be able to evaluate and disseminate scientific knowledge that could promote cultural identity and global citizenship based on scientific literacy (MoE, 2019).

Several studies have reported on the importance of chemistry learning. Learning and understanding chemistry concepts is believed to enable students to make informed decisions about their future (Vos & Bulte, 2002). Many students find chemistry concepts challenging (Childs & Sheehan, 2009), especially organic chemistry (Johnstone, 2010; O'Dwyer & Childs, 2017). Lack of understanding and low levels of achievement in chemistry has been linked to low self-concept and the inability of students to think critically (Anim-Addo & Adu-Gyamfi, 2022; Domin, 2008).

Several factors affect achievement in chemistry. These include under resourced schools, large classes, curricula mismatched to daily lives of students, unqualified teachers with weak content knowledge and ineffective pedagogical approaches (Fletcher, 2018). Some research indicates that teaching chemistry with a lecture-based approach could disconnect students from active learning that could allow them to engage in authentic chemical learning (Sevian & Talanquer, 2014). Conceptualisation approach in school chemistry teaching contrasts with the approach used in science education visions (Bybee, 2011; Osborne & Dillion, 2008), where students are expected to "engage in STEM learning concepts and apply crosscutting knowledge to deepen understanding of the core ideas" (NRC, 2011, p. 2).

Some teacher education programmes are used to train students in pedagogies that utilise various science processes to help students develop problem-solving skills (T-TEL, 2015). Teaching and learning science should enable students to "critically think, solve a problem and transfer ideas, knowledge, and skills in new situations" (Donohue et al., 2020). In recent years, teacher education reforms have focused on how teachers can provide students with meaningful learning experiences, making the teacher a critical factor in ensuring quality learning (Lange et al., 2011; Stronge et al., 2011). High-quality teachers must possess a deep mastery of pedagogy and subject matter to help students' achievement (Fletcher, 2018; Lange et al., 2011; Stronge et al., 2011). Effective pedagogies, teacher preparation, and professional teacher development are critical for effectively achieving student learning (Laurie et al., 2016).

Some chemistry educators have devised measures to transform chemistry education using context-based learning (Eilks et al., 2013). The teaching focuses on engaging students in learning the structure and characteristics of chemical substances and processes (van Berkel et al., 2000). Chemistry should be taught in contexts relevant to society and contribute to meeting global challenges (Eilks et al., 2013). Teaching from rich context provides students with a more profound and richer crosscutting learning concepts and experiences.

Current curricula present a rationale for shifting pedagogical practices that actively help to engage students in learning activities that make sense to them (MoE, 2015; NRC, 2011). These proposed pedagogical practices focus on contents and their applications to real-life contexts that form the basis of developing a better understanding of chemistry learning (King, 2012). Chemistry ideas taught superficially without building the core ideas, fail to foster students' deeper understanding which leads to poor performance.

1.4 Purpose and goals of the intervention

The goals of this study are two-fold:

1. Introducing and monitoring a flipped approach (FA) using active learning to understand teachers' and students' reversal of conventional roles.
2. Ascertaining whether and how ICT could be used coherently throughout the intervention by the student-teachers and their tutors.

It seems clear that young teachers, whether they be teacher educators or student-teachers, are in a situation in which they must bridge the gap from conventional/traditional teaching in teacher education to context-based "science for all" in community schools.

The focus of this study is to initiate change in teacher education by developing and testing teaching practices so that student-teachers will be capable of adopting these practices in their future classrooms.

1.4.1 Outline of the project

This project started by examining the views of teacher educators engaged in delivering online lessons. I examined their views on delivering online lessons and whether they felt competent in doing so. A questionnaire was used to collect data from the teacher educators. Three teacher educators from three CoE (the threesome) joined me in executing this project. Three units of organic-chemistry teaching content were selected from the syllabus and delivered to student-teachers weekly for four weeks. We designed new teaching sequences incorporating ICT. At the end of the teaching, the threesome and I discussed their views and experience of implementing the flipped approach. The student-teachers answered a questionnaire on their experience. A few took part in a focus group, and one class took an achievement test.

Through mapping the data from the survey, from the questionnaire from the student-teachers and from interviews and conversations with the threesome, I began to appreciate that I was getting a remarkable look into their experiences of integrating ICT into our developmental work.

This research had its roots in my experiences in teaching chemistry in Ghana, South Africa and Iceland. I assumed that by integrating ICT into university-level learning through flipped classrooms, a contribution could be made to:

- Enable educators to use and integrate ICT in their pedagogical practices.
- Help educators to engage students in out-of-class activities.
- Support students in developing interest in their learning.
- Facilitate independent homework and better preparation for class.
- Encourage students to collaborate with peers to learn.
- Enhance students' knowledge and understanding of concepts.
- Improve learning outcomes.

1.4.2 Aims of the project

Based on the goals and focus, my research aim was to investigate the impact of inquiry-based learning using ICT as an agent for integrating chemistry into a flipped classroom. I investigated how teacher educators had experienced using flipped classrooms in delivering instruction to student-teachers. I also wanted to examine how student-teachers experienced learning chemistry by examining their own experiences and their general perceptions of learning with flipped inquiry-based approaches. In developing the study further, I kept in mind the implications of COVID-19 on schools, as many classroom spaces were restricted. In general, the studies aimed to answer the following research questions:

- How do teacher educators use ICT in their teaching in Ghana?
- What are the views of flipped classrooms held by teacher educators in Ghana?
- How do student-teachers use ICT and adopt flipped learning?

Four academic papers were written to achieve these broad aims, each with a specific theme. The first paper generally focused on educators' experiences with online teaching. The second paper examined how teacher educators view the rationale of using flipped classroom teaching and how it impacted their work. In the third paper, I examined student-teacher perceptions and experiences with the flipped classroom approach. The fourth paper deals with the effects of flipped inquiry-based approaches on student-teachers' learning.

1.4.3 The research questions and publication of papers

In this research, I examine what teacher educators and learners experienced during the interventions. The synopsis focuses on the main findings from the four published papers and summarises my conclusions. The synopsis of the thesis is based on evaluating flipped learning and ICT integration and its effects on student-teachers' chemistry learning.

The research was to be design-based, but as things progressed, it changed because of complications arising from COVID-19 restrictions. A case-based approach was also considered, using each of the colleges as a case. This was however almost impossible to implement given the problems we had with ICT itself within the intervention.

The findings from the research papers are elaborated to highlight the important roles different participants and factors played in the research. Four papers were published in peer-reviewed journals, including *Contemporary Educational Technology*, *Educational Sciences*, *European Journal of Science* and *Mathematics Education, and Social Educational Research*. Some findings have been presented and discussed at seminars and conferences in Iceland and abroad, such as Ph.D. seminars and conferences at the School of Education, the University of Iceland, and a presentation at the Annual Conference of the Scottish Educational Research Association.

The four research studies were designed for a particular setting incorporating the use of ICT in active learning guided by my belief in learning with ICT (Figure 1).

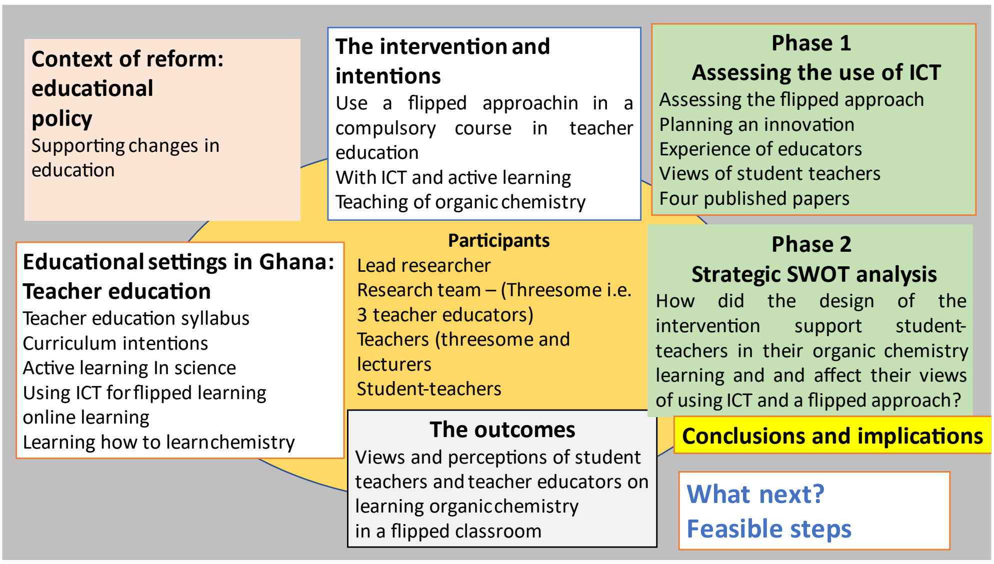


Figure 1 Components of the project

The four research papers were comprised of:

Paper I, Factors influencing teachers online teaching competence in higher education, was an investigation of tertiary education teachers' perceptions of using ICT to deliver online lessons. This quantitative research involved 77 university teachers (lecturers and teacher educators) who had delivered online lessons during the COVID-19 pandemic. A survey built on ICT knowledge and skills was used to evaluate the participants' assessments of ICT competence through a correlational design study.

Paper II, Transforming teaching and learning with ICT using flipped classroom approach: Dealing with the COVID-19 pandemic, was built on qualitative research in which views and experiences of teacher educators of integrating ICT to adopt flipped classrooms were examined. Three teacher educators were recruited focusing on phenomenology design to apply in an educational design-research approach.

Paper III, Perceptions of Ghanaian student-teachers on benefits and challenges of the flipped classroom: A case study. I examined student-teachers' perceptions and learning experiences in the flipped classroom approach. In this study, a descriptive case study was designed to investigate the perceptions of 143 participants in the project and provided responses through a survey and focus group.

Paper IV, A mixed-method approach to investigate the effect of flipped inquiry-based learning on chemistry students' learning. The study involved 100 student-teachers recruited to participate in the research. This study used mixed-methods design to examine the views and effects of a flipped inquiry-based learning approach on student-teachers' chemistry learning outcomes.

With the four research papers, I adopted a main research question: What are educators' and student-teachers' opinions and experiences of technology-enhanced teaching and learning approaches such as the flipped classroom? Further, three sub-questions adopted were:

- What is the rationale of the teacher educators for using ICT in teaching?
- What are the strengths and weaknesses of teaching and learning organic chemistry with ICT to adopt a flipped classroom?
- What are the opportunities and threats of using ICT to adopt flipped classrooms in schools and institutions?

1.4.4 Value and significance of the research activities

Flipped and inquiry-based learning approaches are recommended in teaching science since they can engage the learners in the learning activities to build knowledge and increase retention. The results from the four individual studies and this overview in the following chapter provide information on how science curricula can be designed to cater to students' affective and cognitive needs in learning science.

Ghana has made projections on increasing and sustaining student interest in science and technology to attain the Sustainable Development Goal 4 (SDG4) vision of 2030. Information from this study could encourage educators to change pedagogical practices to improve teacher quality and student performance in science. It could also enable teacher educators to motivate and sustain student-teachers' interests in learning and possibly improve science education.

A SWOT analysis was carried out on the outcomes of the four individual studies. This strategic analysis can help educational policymakers and other stakeholders make informed decisions on planning teaching and learning at all levels of education in the country, especially teacher development, curriculum development, and resource allocation such as ICT infrastructure.

1.4.5 Terms for clarification

Active learning is a self-initiated individual or collaborative, authentic learning task with limited direct instruction from an educator.

Collaborative learning is an instructional approach in which students are grouped to perform tasks for a common goal.

College of education is tertiary institution where students are trained to teach at the basic school level.

Cooperative learning is a structured form of group work where students work on a task with a common goal but are assessed individually.

Flipped classroom is a student-centred pedagogical approach used in achieving more active, meaningful, and effective learning through the reversal of traditional classroom activities with students reviewing content before a face-to-face class.

Flipped learning is the shifting of direct learning from a larger group learning environment to the use of ICT in an individualized smaller learning space.

Inquiry-based teaching is a pedagogical approach that facilitates learning from working to understand and solve a problem.

Lecturer is a person who teaches at the university.

Student-teachers are students learning at colleges of education or universities to become teachers.

Teacher educator is a person who teaches at the college of education.

Teaching sequence is a self-initiated individual or collaborative, authentic learning task with limited direct instruction from an educator.

2 The state of the art

The specific intervention of the study was to incorporate the use of ICT teaching in delivering modules on topics from organic chemistry in three teacher education colleges in Ghana using a flipped classroom approach. Revised teaching sequences were designed for this approach, and the content was based on Ghana's national curriculum for teacher education. I tried to find the best way for educators to find practical solutions to classroom challenges. First, I focused on finding frameworks for the way in which educators use ICT tools to deliver student instruction. I describe policies of teacher education in Ghana and expand on my rationale for conducting my research in Ghana. I also raise some questions regarding the effectiveness of teaching approaches and the need for innovative teaching practices.

There are several decisions to be made if a teacher is interested in using ICT. The actions needed are improving ICT skills, broadening one's knowledge and realizing that change is a process. Adapting the curriculum content to the affordances of ICT seems complicated to those working in schools.

2.1 ICT as a tool for classroom transformation

The use of ICT in education has called for innovative changes in teaching to meet 21st-century requirements to support student needs. Levy (2010) predicted that internet access and using tablets, smartphones, and laptop computers would soon come to dominate teaching and learning. Educators in colleges and universities have also discussed technology-mediated learning with the expansion of internet technology and learning management systems (Berrett, 2012; Silverman & Hoyos, 2018). Advances in technology have impacted teaching and learning call for a response to technological revolution in the education sector (Kruchoski, 2016). Educators are more likely to use new technology, corresponding to their teaching beliefs (Shelton, 2017). Kruchoski (2016) pointed out that future learning will focus on 'learning to learn' and that university educators should push students to use tools to learn and master learning materials outside the classroom. The way students learn is changing, with educators already implementing several pedagogical approaches with face-to-face and online instructions (Fadol et al., 2018). One such approach is blended learning, an 'ambiguous' term that describes an in- and outside-classroom student learning experience (Hrastinski, 2019).

Different definitions of blended learning have been adopted based on the design and implementation. Some scholars point out that any learning delivery method combining face-to-face and technology-mediated instruction can be called blended learning

(Alammary et al., 2014; Poon, 2014). Over the past few decades, most higher education institutions have adopted blended learning as a 'new normal' pedagogical approach to address student challenges. These issues include student active engagement and participation (Alammary et al., 2014), providing a personalised, timely, and flexible curriculum (Jonker et al., 2018), engaging in student interactions and collaborative learning (Poon, 2014), and communicating and assessing students learning progress (Boelens et al., 2018; Vanslambrouck et al., 2018).

Despite these benefits, due to criticisms and challenges, blended learning has not been fully utilised as an instructional approach. Poor access to ICT and the paucity of available resources such as laptops and Internet access have impeded educator readiness and acceptance of blended learning (Antwi-Boampong & Bokolo, 2021; Bokolo et al., 2020). Educator competence has also been identified as a critical factor for the effective use of blended learning (Sulaiman & Ismail, 2020). Improving and ensuring educator technical strength is vital for promoting subject and curriculum knowledge, pedagogic knowledge, and the use of ICT in teacher training programmes (MoE, 2017). Smith and Greene (2013) recommend that teacher educators "enrich technological use in their instruction to encourage student-teachers to use it" (p. 124).

Technology has accelerated the move toward new classroom practices, and educators are encouraged to support pedagogical change. In the next section, I will discuss how ICT has impacted teaching and learning in teacher education in Ghana and provide a rationale for doing the research in Ghana.

2.2 The state of ICT in Ghana's education

Ghana's journey for socioeconomic development with ICT is reflected in the adoption of the ICT policy (GoG, 2003) know as ICT for Accelerated Development (ICT4AD). The main goal of the policy was to:

> "...accelerate Ghana's socio-economic development process towards realising the vision to transform Ghana into a high-income economy and society predominately with information-rich and knowledge-based technology within the next two to three decades". (GoG, 2003).

The ICT in Education Policy (2015) and the Education Strategic Plan (2018 – 2030) were to promote ICT education by:

> "...integrating ICT and making ICT as a teaching and learning tool, to improve the quality of teaching and learning of science, technology, engineering, and mathematics (STEM) at all levels for students to acquire skills in learning and use in their daily lives and also choose ICT as a career option" (MoE, 2017).

In working towards these objectives, the government has provided a more relevant ICT curriculum with teaching and learning materials to improve teacher's student learning outcomes (MoE, 2015). The policy was aimed at improving ICT teaching in schools and adopt e-learning to transform teaching transformation in higher education (MoE, 2015; Yidana, 2018). There is a need to focus on ICT integration and sustainability in education, especially in teacher training (Buabeng-Andoh, 2012; OECD, 2017). The objectives of these policies have not been achieved due to a lack of institutional support (Buabeng-Andoh & Yidana, 2015), educators' low technical abilities to implement the policy (Gyampoh et al., 2020), and inadequate ICT infrastructure (Adarkwah, 2020).

In Ghana, student-teachers take ICT as a core subject in teacher training (Debrah et al., 2021). In Tanzania, ICT is integrated into all subjects (Kafyulilo, 2016). There are, however, reports of minimal use of ICT leading to low technological abilities and use among student-teachers (Debrah et al., 2021). Before the pandemic, studies had identified weaknesses in educators' ICT skills, competencies, and values (Atuahene, 2019; Buabeng-Andoh & Yidana, 2015). Also found was poor institutional support (Gyampoh et al., 2020) that affected educators use of technology in teaching. Successful ICT integration and implementation demand adequate support and training for educators (Gyampoh et al., 2020; Porter & Graham, 2016).

Ghana's ICT policies have called for schools to adopt technology-enhanced teaching and learning (MoE, 2015). Educators are expected to integrate technology into their daily classroom activities, including teaching to support student learning, including student-teachers (MoE, 2015; 2017). Student-teachers' use of technology depends on the kind of training they receive (Kafyulilio et al., 2015), and educators are expected to be competent in implementing ICT in their training (DeCoito & Richardson, 2018). Teacher training is, therefore, an important route for successful ICT integration and sustainable use in future teaching (Jimoyiannis et al., 2013).

Despite national policy for ICT, Ghanaian educators find integrating technology into their teaching and learning activities challenging (Adarkwah, 2020; Antwi-Boampong & Bokolo, 2021). Teachers need to understand student-teacher expectations and experiences with using ICT. These expectations depend on their experiences before college and the educator must understand the variety of expectations and beliefs the students hold about how and why they learn about and use ICT. Many studies have reported teacher educators' ability to integrate ICT could foster their technological skills development for their professional work (Agyei & Voogt, 2012), and help student-teachers to build up effective use of technological pedagogical content knowledge (TPACK) in their teacher training (Agyei & Voogt, 2012). Therefore, my case investigates the perspectives of teacher educators and student-teachers regarding integrating ICT for teaching and learning organic chemistry.

2.3 Teacher education at colleges of education

Ghana places value on teacher education and sets priorities to improve the quality of teacher education (Adegoke, 2003; OECD, 2019). As a result of that, the objectives of the teacher education programmes are to:

> "… prepare more reflective and proficient teachers with better knowledge and skills to provide quality teaching to learners in elementary and second cycle schools, through the creation of accessible, integrated teacher education and training including opportunities for continuous professional development in the teaching service". (MoESS, 2012).

Ghana has adopted the SDG4 which calls for increased supply of well qualified and effective teachers (Adu-Gyamfi & Otami, 2020) with several national policies been adopted to emphasise teacher training and development for professional growth by reviewing and restructuring teacher education. One such policy is to ensure teacher quality through the development of in-service training and other professional support for teachers (MoE, 2017).

2.3.1 History of teacher education in Ghana

Ghana's teacher education can be traced to early missionaries. The first teacher training college was established by the Basel Mission at Akropong-Akwapim in 1848 aimed to train teachers to teach in the traditional schools established by the missionaries. In pre-colonial times when Ghana (then Gold Coast) was ruled by European merchants, especially the Dutch and English (1919-1927), comprehensive elementary education for all children was instituted (Williams, 1964). In 1951, the demand for education led to a massive expansion of the education system, including teacher education. A policy adopted in 1951 called the accelerated development plan (ADP) which was to provide free, universal six-year compulsory primary education for all children was adopted. This led to a rapid increase in the number of schools, from 1,081 to 3,372 over the next five years, which resulted in a doubling of enrolment (Foster, 1966; Scadding, 1989).

Pre-independence schooling was meant to train and recruit teachers to meet the high demand for primary schools. In contrast, the training of post-independent cohorts was designed to train teachers to become generalists with specialisations in some subjects. In 1961, an Education Act highlighting the importance of teacher education led to the expansion of existing teacher-training colleges and the establishment of new ones. Also, there was a provision for short-term in-service training programmes for teachers and training of unqualified teachers in the field. Despite these efforts, there were still many untrained teachers who could not teach the content of the curriculum. The independence era from 1962 saw major policy initiatives by successive governments, but most have been unsuccessful due to political instability. Frequent changes in educational policies affected teaching and learning in compulsory schools. For instance, in 1981, many trained teachers left the country due to harsh revolutionary conditions from military governments (Akurang-Parry, 2007).

In Ghana, teacher training takes two routes: either through the main university system or through the colleges of education. Teacher candidates at universities and colleges are trained in courses that leads to teacher qualification status for upper secondary and elementary school respectively (MoESS, 2012). Currently, teacher training programmes

are all run for candidates at universities and colleges of education to obtain a 4-year Bachelor of Education degree (MoE, 2017).

2.3.2 Reforms of teacher education in Ghana

Since 2005, teacher education reforms have been aimed at training students to become teachers, and in-service teachers provided with additional training to improve the quality of teachers (Adu-Gyamfi & Otami, 2020; Buabeng et al., 2020; Quashigah et al., 2014). The constant need for change in primary education requires that teachers undergo institutional training at each level to upgrade to the new policy standards. As part of the reform process, a major commitment was the provision of pre-service and in-service training for teachers at the colleges of education (MoESS, 2012). Newer reforms were instituted in since 2005 to include teaching practice aimed to improve teaching and learning in schools, but there is still weaker professional classroom practice exhibited by the mentors of student-teachers (Institute of Education, 2005). Previous teacher education curricula has not provided student-teachers enough opportunities to learn in real classroom context which has impacted on their classroom practice (Lauwerier & Akkari, 2015). In addressing the problem, there was inclusion of teaching practice to maximize student-teachers real classroom practice and profesional learning (Akyeampong, 2017).

The continuous change in teacher education policies has resulted in the transition from Teacher Certificate "A" to a Diploma in Basic Education (DBE) and now a Bachelor of Education programme. These changes were meant to inculcate innovative approaches that could be used to prepare student-teachers for the use of active learning (Asare & Nti, 2014). For example, the earlier DBE programme consisted of a basic 3-year course and a subsequent 2-year top-up training meant to train and upgrade teachers to teach all subjects or specialised subjects at elementary schools (Asare & Nti, 2014). Unfortunately, upon completing the program, some teachers were reluctant to take the 2-year upgrade course but still had to teach critical subjects like mathematics and science. It came to light that the objective of producing quality teachers from CoE was far from being achieved as most graduates could not effectively teach the critical subjects for which they should have been trained (Aboagye & Yawson, 2020; Akyeampong, 2017; T-TEL, 2015). This, in turn, affected learner performance in basic schools (MoESS, 2012). Poor performance was linked to the type of training student-teachers were getting (Eshun & Ashun, 2013). As a result, issues identified in the 2005 and 2008 curricula included teachers' lack of pedagogical content knowledge, lack of commitment, few opportunities for professional development, and little discussion of 21st-century teaching values, such as innovation and creativity (Adu-Gyamfi & Otami, 2020; T-TEL, 2015).

Again, despite the teacher education reforms, the student-centred approaches have been underutilised by both student teachers and in-service teachers in their classrooms (Adu-Yeboah et al., 2014).

Since the 1960s and 1970s the roles of teachers and learners have begun to change as learners are increasingly become active part in their own learning. An important part of change is the willingness and ability of teachers to work towards change. Another key aspect is the approach to learning favoured by teachers and the ways in which learners respond to different learning theories.

In 2015, a new curriculum called Transforming Teaching Education and Learning was introduced to train teachers to deliver high-quality teaching and learning (T-TEL, 2015). The intent was to strengthen student-teacher education and Bachelor of Education degree implementation in Ghana colleges of education. The program is expected to incorporate student-centred instructional methods and integrating technology since research has shown that these methods have improved learning outcomes. Adopting a new curriculum has helped educators embrace change, an essential component of modern teaching. Integrating technology into the classrooms is intended to support effective teaching and learning by allowing for new teaching strategies and testing techniques (T-TEL, 2015).

Over time, Ghana has undergone several curriculum modifications through various teaching corps to improve teacher quality (Table 3). In the next chapter, I will discuss teaching strategies stipulated in the various curricula and their impacts on student learning.

Table 3 Teacher training programs in Ghana

Period	Award	Year	Duration (years)	Rationale for the training
Pre-independence	Certificate 'A'	1930	4	Train teachers to meet the demand for primary schools
	Certificate 'B'	1937	2	
	Post-secondary certificate 'A'	1951	2	
	Post-secondary Certificate 'B'.	1956	2	
Post-independence	Diploma	1962	2 or 3	Train teachers in specialist subjects, e.g., science, English, and mathematics, and improve their professional competence.
	Certificate A and Post Diploma	1993		
	Diploma in Basic Education	2005/ 2008	2	Train teachers in general and specialist subjects
	Post-diploma			
	Bachelor of Education	2019	4	

2.4 Active learning

The decades since 1950 have seen schools change in line with educational reforms, calling for changes in curriculum content, pedagogy and assessment. In the traditional teacher-led classroom, teachers talk, and learners listen. The constructivist classroom promotes active learning, enhancing content understanding for knowledge construction (Murillo-Zamorano et al., 2019). Teacher-centred approaches are less engaging for students, contributing to a poor understanding of concepts (Addae & Quan-Baffour, 2018). Teachers have come to realise that students become active and learn best when they take responsibility for their own learning (Sigurðardóttir & Heijstra, 2017). Active learning is student-centred, where the responsibility for learning is assigned to the learner (Prince, 2004; Sigurðardóttir & Heijstra, 2017). The use of constructivism in teaching and learning makes educators facilitate learning while students become active learners as they explore and construct knowledge (Prince, 2004).

Active learning is at the heart of instructional pedagogies that focus on students' active engagement and thinking about the learning process (Prince, 2004). There have been philosophical debates for many years on active learning and how it promotes intellectual development. Empirical studies on active learning have led to findings on how educators can increase students' interest and engagement in lessons. Among the active learning strategies there have been the inclusion of multimedia learning materials to improve students' attention (Berk, 2009), collaboration (Poon, 2014), and facilitating teacher-student communication (Boelens et al., 2018; Vanslambrouck et al., 2018). These changes have affected teaching in higher education, especially where lecturing is the norm (Berrett, 2012; Kruchoski, 2016). Despite the highlights of active learning in schools, one question remains: which instructional approaches can effectively promote active student learning. Various approaches used to engage students in active learning and collaboration include flipped classrooms and inquiry-based learning.

Improvements in classroom instruction have resulted in the development of several contemporary active learning methods, covering a multitude of learning options, such as collaborative learning, problem-based learning, and experiential learning (Prince, 2004; Slavich & Zimbardo, 2012). Instructional approaches that engage students in learning through collaboration and discussion promote active learning strategies by students, instead of them depending on teacher information (Lee et al., 2018).

Under the active learning umbrella, four broad instructional strategies are identified: individual activities, paired activities, small, informal groups, and collaborative learning, which require students to utilise higher-order thinking skills such as analysis, synthesis, and evaluation (Zayapragassarazan & Kumar, 2012), leading to increased academic achievement (Prince, 2004; Freeman et al., 2014).

In the next section, I will narrow the discussion to review the literature on inquiry-based teaching in education.

2.4.1 Inquiry-based teaching

In this section, I will elaborate on inquiry-based teaching as a general example of an active learning approach. Inquiry-based teaching in education is recognised as a fundamental approach that supports active learning roles by students in the learning process. It is rooted in ideas from earlier philosophers such as Homer Lane (1875-1925) and John Dewey (1870-1952), who advocated for children's inquiry, curiosity, and imagination for learning. According to the pioneers, inquiry-based teaching is a pedagogical approach that facilitates "learning resulting from working to understand

and solve a problem" (Barrows & Tamblyn, 1980). Other researchers define the inquiry-based approach as a constructivist pedagogical approach where educators focus on well-structured active, collaborative learning with hands-on activities to guide students to solve real-life problems (Cervantes et al., 2015; Ismail & Elias, 2014). It involves instructors guiding groups of students to formulate, brainstorm and structure ideas on challenging issues and problems (Trinidad et al., 2020).

Inquiry-based teaching has gained in popularity in K-12 and higher education because it helps improve technical developments with the support of technology learning environments (de Dieu Kwitonda et al., 2021; Pedaste et al., 2015). Inquiry-based learning has been studied widely, but it is unclear how the approach has been applied in chemistry teacher education in Ghana.

In the next section, I will narrow the discussion on inquiry-based teaching in chemistry and teacher education.

2.4.2 Inquiry-based chemistry teaching and teacher education

Several studies have reported on inquiry-based approaches improving student academic performance in chemistry. Uzezi and Zainab (2017) investigated the effects of guided-inquiry laboratory instructions on students' thinking and process skill performance. Students exposed to guided inquiry performed significantly better than those in a traditional lecture course. Similar findings have been reported in other studies (Aidoo et al., 2016; Leonard & Nwanekezi, 2018), which investigated the effectiveness of guided inquiry on the academic performance of chemistry students and found an increase in mean post-test scores in the experimental group compared with the control group taught with the lecture method. It was concluded that inquiry learning activities could be more effective than lecturing depending on planning and preparation.

Inquiry-based learning has been shown to positively impact student attitudes toward chemistry learning. For instance, Ural (2016) investigated the effects of guided inquiry on student-teacher attitudes, anxiety, and achievement in a chemistry laboratory applications course. A significant increase in positive attitude toward academic achievement and decreased student anxiety toward chemistry learning was revealed. These studies indicate that the approach help to improve students' learning attitudes leading to a more profound acquisition and understanding of knowledge, and application of chemistry findings have been reported in other studies indicating that inquiry-based learning activities. Similar concepts can improve students' attitudes and understandings of chemistry concepts (Ascar et al., 2013).

Several studies have shown that inquiry-based learning activities enhance student-teachers' critical thinking skills and ability to apply their knowledge and understanding to actual practice (Arsal, 2017; Saputro et al., 2019). Arsal (2017) designed inquiry-based learning activities to examine how these activities can enhance student-teachers' critical thinking skills. He found that learning activities through the inquiry-based model were appropriate and enhanced student-teachers' critical thinking skills to apply the content to real practice. Inquiry-based learning activities and discussions therefore enable students to develop positive attitudes, understand concepts, and develop skills to relate what they have learned to real-world problems.

Inquiry-based learning has been shown to positively impact the student-teachers acquisition of theoretical concepts related to practice, helping them develop knowledge for future teaching and improving their attitudes (Boye, 2019; Laursen et al., 2016). Learning activities through the inquiry-based model enhance student-teachers' critical thinking skills and abilities to apply their knowledge and understanding to actual practice (Saputro et al., 2019).

Science teachers with social constructivist perspectives have incorporated pedagogical practices that support conceptual change in curriculum to promote student interactions and scaffolding towards deep learning (Barak, 2017). Educators are encouraged to support pedagogical change toward new classroom practices inculcating ICT integration. As Barak (2017) indicated, predominant pedagogical technologies and approaches could enhance the development of 21st-century skills.

One popular example of a blended learning model incorporating technological tools is the flipped classroom approach, where online and offline learning activities are used concurrently (Jeong & Seo, 2015). In the next section, I will discuss flipped classrooms and their applications in education.

2.5 The flipped classroom

Flipped classrooms are spaces that teachers and schools have created for active learning. They have also been viewed as a change in the mode of instructional processes from the traditional lecture style toward encouraging more student involvement in the learning process. A flipped classroom is

> "a pedagogical approach where direct instruction is moved from the group learning space into an individualised learning space, with the resulting group space changed into a dynamic and interactive learning environment between the teacher and students in a creatively engaged subject matter which leads to the application of concepts" (FLN, 2014).

The flipped classroom thus involves individual students engaged in out-of-class direct instruction via video lectures or other learning materials, enabling educators to use regular class time to organise individualised or group tasks (Bergman & Sams, 2012). Within the flipped classroom environment, active learning activities comprise discussion, investigation, and problem-solving, enabling students to acquire high order thinking skills through analysis and decision-making (Lai & Hwang, 2016).

2.5.1 Characteristics of a flipped classroom

Flipping a class often leads to a situation where educators can implement one or more methodologies in their classrooms (FLN, 2014). It has been suggested that to achieve flipped learning, it should include four key pillars that enhance student learning, namely,

- flexible environment
- learning culture
- intentional content
- professional educator

Flipped classrooms must be a *flexible learning environment* that allows students to select the time and place to learn to accommodate diverse learning styles to support either group or individual work in a lesson. The instructor should make the timeline for the activities flexible as the students work at their own learning pace. Assessment should have a meaningful, flexible timeline for the students.

In flipped pedagogy, instructions are shifted purposely to a student-centred method. During in-class time, the instructor *provides opportunities for the students to construct meaningful knowledge independently*. In-class time is used for exploring in-depth knowledge-learning opportunities. As a result, students become active learners because of their active involvement in the learning process. Learning becomes more meaningful to them.

The *intentional content* in a flipped classroom is used to maximise implementation of the student-centred method during in-class time and active learning plans according to student level and subject matter. Educators using this method of instruction constantly plan to identify materials students could use to enhance their conceptual understanding.

The role of the educator in the flipped classroom is at least as important as in traditional teaching. Educators observe and assess their students' work and provide relevant feedback in class. Educators using this method often *reflect on their practice, accept positive criticism, and employ effective classroom-controlled* mechanisms to reflect on their practice.

Flipped classrooms have gained much general recognition in both K-12 and higher education due to the numerous benefits of the approach to educators and students. The popularity and continuous research on flipped classrooms have expanded to learning approaches in other disciplines. In the next section, I will discuss how flipped classrooms have been utilised in chemistry and teacher education.

2.5.2 Flipped classroom chemistry learning and teacher education

Several studies have reported on the importance of how chemistry and chemical industries play an essential role in the transition toward sustainable development (Blum et al., 2017). Figueiró and Raufflet (2015) have argued that in teaching students to foster education for sustainable development, educators need to review and revise their didactic approach and adopt innovative ways of teaching. Unfortunately, despite the importance of chemistry education and different efforts by teachers, student academic performance has not been encouraging, although adopting the flipped classroom has been found to improve student learning outcomes in chemistry.

The flipped classroom approach can improve student chemistry learning outcomes and academic performance (Fautch, 2015; Paristiowati et al., 2017). Schultz et al. (2014) investigated what effects a flipped classroom could have on high school students' understanding of chemical concepts and academic performance. Those exposed to flipped classroom approaches obtained higher scores in all assessments than those taught traditionally. They liked the approach since they could pause the video, rewind, and review the lectures to understand the material better.

Students in a flipped chemistry classroom have been found to develop positive attitudes toward their learning (Petillion & McNeil, 2020). Mooring et al. (2016) implemented flipped learning to combat poor student attitudes and high failure rates in an organic chemistry course. There was a significant improvement in the students' grades compared with previous years and a decrease in the failure rate. Students' attitudes toward chemistry learning improved due to increased emotional satisfaction compared to students in the traditional lecture classroom. The flipped classroom gave students access to the course material, which helped their in-class discussions and group learning. Olakanmi (2017) examined how flipped learning activities could affect high school students' chemistry learning. Students liked the approach because the learning materials were helpful, and they could learn at their convenience and communicate with peers and the instructor. Students in the experimental group achieved higher post-test scores than the control-group students.

Several studies on flipped classrooms involving student-teachers have found that it promotes active student learning and collaborative peer learning (Vaughan, 2014). Flipped classrooms provide student-teachers with opportunities to learn both in and out of the classroom. There are still gaps in developing flipped classrooms as evidenced by mixed results in teacher education programmes.

The flipped classroom approach promotes positive learning attitudes in students (Fraga & Harmon, 2014; Dove & Dove, 2017). Tomas et al. (2019) reported that student-teachers found flipped learning beneficial because they could learn at their own pace and time by reviewing the video lectures repeatedly, which enhanced their understanding. Similar findings are reported in a study by Wyk (2018), who found that flipped instructions create positive learning experiences for student-teachers since the approach enables them to take responsibility for their own learning.

Other studies have reported that flipped classrooms help to improve academic performance (Jeong et al., 2018; Maycock et al., 2018). Ozudogru and Aksu (2020) found that students in a flipped learning group obtained significantly higher scores than those in a traditional lecture class. Students found the use of educational technology valuable in controlling their learning activities which tended to arouse their interest and decrease the difficulty level of the tasks. Students faced technological challenges with the internet and the quality of the videos, which affected their satisfaction.

Several studies have examined the effect of the flipped classroom approach on student-teachers' creativity and thinking skills. For instance, Al-Zahrani (2015) investigated the impact of the flipped classroom on student-teachers' creative thinking skills. Students perceived that the flipped classroom facilitated their creativity skills regarding fluency, flexibility, and novelty. But student-teachers faced difficulties with limited preparation during out-of-class activities due to inadequate e-learning tools. Similar findings have been reported in other studies that have found that student-teachers in a flipped learning environment developed thinking skills to apply knowledge in real-life situations (Vaughan, 2014).

This short literature review indicates that flipped learning makes students take ownership of their learning, become confident, and better prepared to practice enhancing their thinking skills for curiosity and creativity to apply knowledge learned than in traditional classrooms. Despite the popularity of flipped classrooms, limited research has been done in Ghana, especially in chemistry teacher education.

2.5.3 Challenges to flipped classroom implementation

Studies have reported negative views about the approach due to barriers and challenges associated with its implementation. One of the essential components of flipped classrooms is independent learning during pre-class sessions. Concerns have been raised regarding the lack of independent learning in the flipped classroom compared to face-to-face instruction. Strayer (2012) explained that students exposed to flipped learning are not fully engaged in the subject matter but can complete the course without showing interest in learning. It is, therefore, essential for the educator to provide engaging content for flipped classroom teaching.

In the flipped classroom, the role of the instructor or more knowledgeable peer is to provide scaffolding to students (Vygotsky & Cole, 2018). However, some studies have indicated that the roles of educators in the flipped classroom are identified as one factor that has caused resistance. Some educators feel that there needs to be more time to adequately prepare flipped learning materials and deliver instructions simultaneously, increasing their workload. Technological competence among educators may hinder setting up and regulating student learning activities in flipped instructions. Some researchers have found educators to have inadequate skills in preparing flipped learning materials hindering the effective use of the approach (Nielsen, 2012; Pilgrim et al., 2018; Rasheed et al., 2020). Nielsen (2012) pointed out that the quality of a video to be presented to students may determine the effectiveness of the learning. Making quality videos requires committed educators and extra time to prepare. Some studies have reported that the lack of student ICT competence results in difficulty concentrating and focusing on the learning (Burke & Fedorek, 2017). Students may not be skilled enough to direct and control their learning (Zheng et al., 2020), making them prefer traditional face-to-face lectures with homework activities (Davenport, 2018). Such incompetence suggest adequate training or experience is needed when implementing flipped classroom classrooms.

Some studies have acknowledged the difficulty of students' preparation due to inadequate ICT infrastructure and school resources. Lack of internet access and online learning resources may negatively affect the smooth implementation of flipped learning (Adedoja, 2016), which only works in high-income and urban schools (van Niekerk & Delport, 2022). It has been argued that the high cost associated with learning technologies and internet facilities discourages educators and students from adopting flipped classrooms (Sinha & Bagarukayo, 2019), especially those with low-income status (Scherer & Siddiq, 2019). Most research studies provide supporting evidence that the future of flipped classrooms seems promising despite the challenges when using the approach.

Despite the popularity of flipped classrooms, limited research has been done in Ghana, especially in chemistry teacher education. There is a need to examine how ICT could be used in teacher education in Ghana to make flipped classrooms a reality.

3 Conceptual and theoretical framework

On this project's journey, I sought a pragmatic solution to an identified problem by searching the literature on research frameworks and trying different approaches and designs. Through extensive reading, searches, discussions with experts, and reflections, I modified the framework that enabled me to structure this thesis.

The study sought to investigate how educators would implement a blended flipped inquiry-based learning approach and its impact on student-teacher chemistry learning. In searching the literature, I aimed at the best ways of finding practical solutions to classroom challenges. Given that, I wanted to find how research frameworks and tools could be combined to benefit educators and students. Since educational theories play an important role in research design, I considered theories interconnected to teacher professional development and student learning (Cobb et al., 2003). More specifically, theories related to how educators can integrate ICT into their classroom chemistry practices.

This chapter introduces how educators could use technological pedagogical content knowledge (TPACK) to use instructional technologies to support students' collaborative learning with social constructivism. Based on the principles and assumptions of TPACK and constructivism, this study intends to discuss how educators have utilised educational and technological tools to transform students' inquiry and collaborative learning.

The theoretical framework for this study was thus based on a combination of the features of TPACK and social constructivism. The TPACK deals with how teachers can integrate ICT into their classroom practices. The social constructivist approach shows how students become active learners in constructing their knowledge from prior knowledge or experience that enables them to develop learning skills such as critical thinking for problem-solving. The social constructivist learning theories are used by educators to support students in using ICT to learn. These theories provide an enabling environment to support educators' use of ICT and students' learning in a computer-supported collaborative learning environment.

3.1 Technological pedagogical content knowledge (TPACK)

The use of ICT in education has mixed benefits. On the one hand, it can improve student learning in class and beyond the classroom. Using ICT has helped students to understand difficult concepts and has enabled students to work and collaborate with peers and communicate with educators (OECD, 2017). On the other hand, using ICT in classrooms and in schools, is hindered by weak commitment and a lack of knowledge and skills (Antwi-Boampong & Bokolo, 2021). Some teachers have inadequate or inappropriate teacher training or experience using ICT. Koehler et al. (2013) argued that many teachers earn degrees devoid of instruction on technology, leading them to be insufficiently prepared to use technology in their studies and work. Further, even when such new knowledge is acquired, it is unlikely to be used unless it is consistent with the individual's pedagogical beliefs (Ertmer, 2005). Most often, professional development in technology is not much more than a one-size-fits-all approach and is limited to infrequent short courses. In technology-mediated teaching, three components - content, pedagogy, and technology - are linked by interaction. My search for a practical framework for the study led me to TPACK (Koehler et al., 2013).

The TPACK framework focuses on technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK).

- The content knowledge (CK) deals with the teacher's knowledge of the subject matter.
- Pedagogic knowledge (PK) addresses the teachers' deeper understanding of teaching and learning strategies.
- Technological knowledge (TK) deals with the teachers' deeper understanding and mastery of ICT for communicating, information processing and problem-solving.
- The technological pedagogical knowledge (TPK) deals with the teachers' understanding of how technological tools can be used to change a teaching and learning experience and adopt a new pedagogical approach.
- The PCK deals with teachers understanding of how technology can influence a pedagogical approach to deliver content.
- The technological content knowledge (TCK) shows teachers understanding how technology and content influence each other in the classroom (Fig. 1).

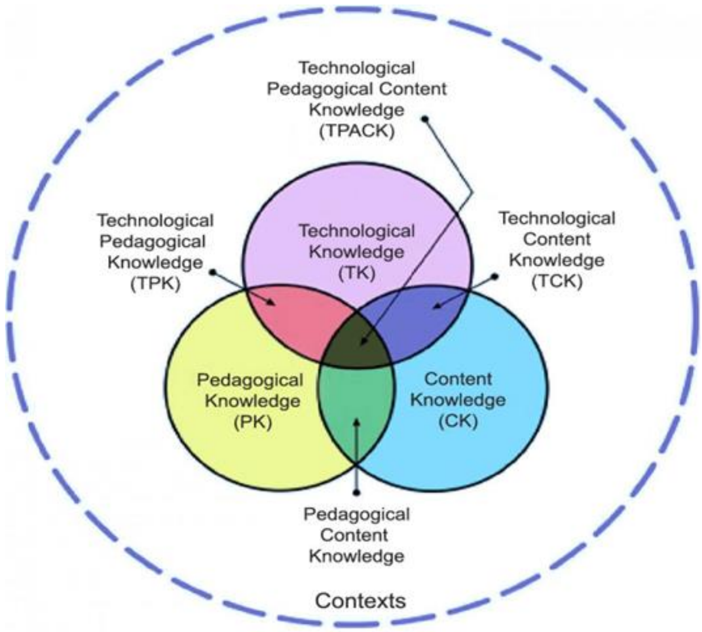


Figure 2 TPACK framework (Koehler et al., 2013)

The framework is appropriate as it helps teachers to plan their use of technology when delivering content. Koehler et al. (2013) pointed out that the TPACK has proven to be an effective framework as it helps teachers integrate various types of knowledge to make use of educational technology feasible in the classroom. The TPACK framework helps teachers evaluate their own knowledge in teacher training and during professional development (Engida, 2014).

3.2 Supporting active learning activities with theories

Constructivists believe learners construct knowledge bit by bit in a logical way with their environment. In constructing knowledge, an individual must understand their world by adapting new information to prior knowledge (assimilation) and altering existing ideas to fit new knowledge (accommodation). According to Phillips (1995), students construct new knowledge as individuals or within social communities. Students' knowledge construction arises from three distinct roles: active, creative, and social. Learners should take active roles and assume responsibility for their learning. Leach and Scott (2000) suggested that educators should plan lessons that make sense to learners by exploring the differences between everyday occurrences and scientific explanations of scientific phenomena.

Social aspects of constructivism championed by Vygotsky (1896-1934) also shows how learning is constructed with the support of other people. Vygotsky believed that learning is restricted to an individual´s prior knowledge unless there is an interaction with others. Knowledge construction is, therefore, not purely an internal process nor a passive behaviour but involves a social setting, culture, environment, and context. Linking social constructivist ideas in the classroom context, Vygotsky argued that students learn with the help of an instructor or peers in a socially situated environment.

Vygotsky's ideas of learning focus on the development of metacognition that relies on social interaction. Learning occurs in two sequential order levels: interacting with people and incorporating the ideas from the discussion into the mental faculty (Moll et al., 2015). Flipped learning requires more forms of learning as students move through the various tasks each with their own environment. For example, internalisation and the zone of proximal development (ZPD) are determining factors in the development of higher mental functions in an individual. Vygotsky believed that mediation tools support the transformation of mental function since knowledge is internalised using these tools. The ZPD is "the distance between an individual's actual development level, independent of the potential development through adult guidance or collaboration with peers in problem-solving activities" (Vygotsky, 1978, p.86). Vygotsky and Cole (2018) used ideas of learning through the ZPD to assess the individual potential level of understanding of knowledge through what people can accomplish on their own and what they can achieve with the help of others and in the classroom that can help educators to effectively assist learners in acquiring new understanding at the level of their ZPD.

3.3 Learning theories in flipped classroom practice

Educators can use the flipped classroom with different learning theories involving active learning that is situated in the constructivism perspectives and direct instruction (Bishop & Verleger, 2013). Students can review the learning materials many times taking notes to enhance their understanding (Bergman & Sams, 2012), and interact with peers in class discussions and group work to foster collaborative learning (Vaughan, 2014). This indicates that the out-of-class activities are undertaken before class as students use prior knowledge and experiences to build an understanding of the new material. Constructivism provides one of several pathways in active student learning. The flipped classroom relates well to Bloom's ideas of mastery learning, where knowledge is constructed and developed in stages. Students are provided with flexible learning environments to learn at their convenience, and according to their abilities making their learning more differentiated. A flipped classroom is an approach that educators use to provide students with differentiated learning according to the needs of individual students and provide feedback for remediation and learning progress (Bergman & Sams, 2012; Zainuddin & Attaran, 2016).

The constructivist and social constructivist perspectives are linked in the flipped classroom as instructors guide students to construct knowledge through collaborative and cooperative learning (Chen & Chen, 2015). Active learning draws on Piaget's theory that individuals learn by acting and applying new ideas and concepts (Piaget, 1970). Students construct and acquire new knowledge through experience, which enables them to create mental models that change through accommodation and assimilation. Students' ability to reach higher levels of learning requires interaction with peers that enable them to develop a 'cognitive conflict' for knowledge accommodation. Educators focus on two essential principles: active learning and prior experiences which must be embedded in flipped learning.

Bloom's taxonomy of mastery learning, and thinking can guide educators in planning learning activities that help students develop cognitive learning skills (Bloom et al., 1956). In most flipped learning models, students engage in learning activities such as reading texts, watching videos and lectures, and engaging in face-to-face or online discussions with peers and instructors (Galway et al., 2014; Davies et al., 2013).

While there is no specific model, the standard practice of flipped classrooms involves moving homework to class and classroom lectures out of the class or at home (Bergman & Sams, 2012). Inquiry-based learning and flipped classroom are two instructional approaches that provide learning environments for students active learning. In both approaches student role and engagement are essential as students should interact and communicate with peers and educators. In supporting student's inquiry learning activities, Trowbridge et al. (2004) have developed a 5E learning cycle that nurtures students active skills and expectations through five stages: engage, explore, explain, elaborate, and evaluate.

Researchers have incorporated several active learning activities by integrating flipped classrooms with other science teaching approaches, such as inquiry-based learning (Paristiowati et al., 2017; Aşıksoy & Ozdamli, 2017), mathematics (Capaldi, 2015; Love et al., 2015) and computer science (Chis, 2018) programs and found the approach to be promising in developing students learning flexibilities, interest, motivation that enhances their knowledge construction and improvement in academic performance and thinking skills. For instance, Aşıksoy and Ozdamli (2012) developed a flipped learning model that involved a 5E (5ELFA) in promoting and supporting students' active learning with inquiry and discovery learning activities in physics. The model comprised engagement, exploration, explanation, elaboration, and online or offline evaluation. Students were engaged in experiential activities and demonstrations that facilitated knowledge acquisition throughout the learning cycle, where learning occurs from lower-order to higher-order skills. The findings showed students in the experimental group (5ELFA) achieved higher post-test scores and positive opinions than the control-group students who received the lecture instructions. Chis (2018) investigated the effectiveness of combined flipped-inquiry based classroom approach instructional strategy for a computer programming course. Students were required to build their own knowledge from watched video lectures and performed open-ended problems tasks. They reported that they were satisfied with the combined FC and IBL since their satisfaction for motivation and engagement were higher compared to the traditional approach. Love et al. (2015) implemented a mathematics course through the flipped inquiry-based learning approach. Most student found the approach useful as they learn at their convenience, become active learners and collaborating with peers enhanced their retention of content materials.

To date, almost all emerging studies on flipped inquiry-based learning have reported positive results. Collectively, these studies provide empirical support for using the flipped classroom to provide opportunities that enable students to take responsibility for their learning, collaborate with peers to share ideas, and construct personal knowledge that enhances their thinking skills leading to higher achievement than in traditional classrooms. Inquiry-based learning activities and discussions enable students to develop positive attitudes, understand and develop conceptual knowledge, and skills to relate what they have learned to real-world problems, especially chemistry content. However, there is a need to examine and understand how ICT can be used to adopt flipped classrooms, including inquiry-based teaching in teacher education, to make flipped classrooms a reality. Adopting the flipped-inquiry model could help educators to use both approaches to support students learning, especially student-teachers. Therefore, my research aim is to investigate the impact of inquiry-based learning in a flipped classroom model on student-teachers' chemistry learning. To achieve this aim, I intended to find the answer to opinions and experiences that teacher educators and student-teachers have on technology-enhanced teaching and learning approaches such as the flipped classroom.

In the next chapter, I introduce the design approaches in each paper (I – IV). I further describe the methods, including the population and sample, development of research instruments, sampling techniques, data collection procedures, and analysis aspects. Ethical issues of this research will also be considered.

4 Materials and methods

In this research I investigated the impact of inquiry-based learning in a flipped classroom model on student-teachers' chemistry learning. Before implementing the model, I was interested in examining the teacher educator's competence in the delivery of online lessons. I conducted a quantitative research study to examine factors that influence teachers' online teaching competence. At this stage, I had an idea of how educators could use ICT to implement the flipped classroom lessons.

A flipped approach was then introduced to three teacher education classrooms in Ghana, and I explored how the approach could be implemented to teach chemistry courses. Three teacher educators and I developed an organic chemistry unit for flipped learning. I aimed to investigate, on the one hand, the perceptions of flipped learning held by the student-teachers after completing a unit on organic chemistry. On the other hand, I examined the effects of a flipped classroom model incorporating inquiry-based learning on student-teachers learning.

4.1 The epistemology behind the research

Pragmatism was chosen as a research paradigm for this study. Pragmatism focuses on the interplay between the problems we recognize and the actions we take to solve them. Based on John Dewey's (1933-1986) idea of how we think, we make decisions on how to act by reflecting and interpreting our beliefs and at the same time reflect on our actions to generate beliefs. According to Dewey, when confronted with a challenge, pragmatists approach the challenge by looking at the likely consequences of using a different approach and then deciding on the most appropriate way to resolve the uncertainties. From this point of view, scientific research is simply more self-conscious about problem solving and reflection. Dewey describes research as one form of systematic inquiry moving from problem identification to suggesting solutions and eventually to taking action. Throughout this process meaning is created by reflecting on beliefs to make decisions and reflecting on the imagined or realised consequences of actions to generate beliefs (Morgan, 2013). Thus, Dewey's concept of inquiry links our beliefs and actions in a decision-making process through a *"paradigm of choices"* (Patton, 1980).

My goal was to understand how educators ICT competence in delivering chemistry content could affect student-teachers learning outcomes. From that point of view, I searched the literature on how professional development support could help educators improve their teaching and student-teachers learning. I intended to investigate the impacts of educators ICT competence on supporting student-teachers' chemistry learning. Most of the studies in the literature on ICT integration to adopt flipped classrooms are based on qualitative approaches. I felt that a need for an approach that could provide both qualitative and quantitative results directed me to the value of the mixed methods (Johnson & Onwuegbuzie, 2004). Through reflections, the next action was to choose a design that could be used to collect data from both educators and student-teachers.

The next section describes the methods, including the participants and sample, development of research instruments, sampling techniques, data collection procedures, and analysis aspects.

4.2 Methods and approaches

Design-based research framework was utilized (McKenney & Reeves, 2008). I focused on finding solutions to challenges in classroom practice through partnerships (Coburn & Penuel, 2016; Juuti et al., 2021). In this project, I adopted a researcher-teacher partnership to investigate and explore solutions for educational practice in teacher education.

In paper I, I wanted to determine how teachers use ICT in teaching in Ghana and examine factors that influence teachers' online teaching competence. A quantitative method with a correlational design to test and determine how ICT knowledge of teacher educators, use of ICT, ICT-related training, and online learning experience correlate with online teaching competence.

Paper II adopted a qualitative method with a phenomenology design to understand how participants interpret their experiences (Merriam & Tisdell, 2015). The aim was to understand the views of flipped classrooms held by teacher educators in Ghana. The approach was appropriate to identify the situations to conduct the other research processes. This approach gave me a broader view of educators' preparedness and experiences in ICT integration. I collaborated with three teacher educators and co-designed and enacted the flipped inquiry-based learning principles on organic chemistry. The project included co-planning the teaching and learning activities with the teacher educators from each college. It also involved data collection during the implementation of the teaching units.

In paper III, the purpose was to understand how student-teachers could use ICT and adopt flipped learning. I used a descriptive qualitative case design to examine student-teachers' lived experiences (Stake, 1995). The design approach was appropriate to helped develop an in-depth understanding of student-teachers experiences in flipped classroom. I was concerned about using a quantitative method to provide holistic and in-depth explanations of the phenomenon in context. Therefore, by choosing the descriptive case design, I could go beyond the quantitative statistical results and try to understand the behavioural conditions of the student teachers' perspectives. Utilising quantitative and qualitative data, the descriptive case design helped explain the phenomenon process and outcome by observing, reconstructing, and analysing the cases under investigation (Tellis, 1997).

In paper IV, I wanted to examine the effects of flipped learning of student-teachers chemistry learning. I utilised a mixed-method approach involving quantitative and qualitative approaches to provide a complete understanding of the intervention (Creswell & Clark, 2017). Most mixed methods research favours pragmatism as a paradigm of action to meet goals framed around research questions (Johnson & Onwuegbuzie, 2004; Teddlie & Tashakkori, 2009). Dewey's inquiry approach was useful and appropriate for this study as it provided me with a direct link to the research design issues. In a mixed methods approach, complex decisions require evaluating the strengths of qualitative and quantitative methods together (Morgan, 2013). According to Teddlie and Tashakkori (2009), mixed methods design provides a more complete understanding of the phenomena of interest and gives evidence for more robust inference. A non-equivalent quasi-experiment design with pre-test/post-test with non-equivalent control group design comparison groups was utilised in the quantitative aspect. The design was appropriate and useful due to the practicality and ethical issues involved in the study.

4.3 Participant selection and sampling procedures

The target populations were educators and student-teachers from three colleges of education in Ghana. The participants involved teacher educators and their student-teachers taking chemistry courses. The selection of participants for the project took place in four phases. In phase I, I adopted convenient sampling procedures to identify 77 teacher educators and university teachers from eastern, central, and southern parts of Ghana in the 2019/2020 academic year. These identified participants could enable me to understand in-depth information on ICT integration in Ghanaian schools. An online survey was sent to the teachers through the contacts in the respective universities and CoEs.

In phase II, a critical case sampling technique was used to identify three chemistry teacher educators identified from the three colleges of colleges in the 2019/2020 academic year. These selected participants could enable me to understand the phenomenon being studied and get rich and in-depth information on ICT integration in Ghanaian schools and how they can adopt flipped classrooms. These three educators had at least 10 years of experience teaching chemistry at the College of Education. It was important to select such teacher educators with the idea of having adequate content knowledge in chemistry. Also, identified teacher educators had some form of relationship with the researcher, were available, committed to participate in the study, and had varied resources in their institutions.

In phase III, a purposeful sampling technique was used to select 143 student-teachers from the three teacher educators classes. Since the CoEs had a well-structured course, I did not have control of the treatment, so the pre-existing classes from the three teacher educators were used. These students were already placed in classes based on their combination of programs and courses. These participants were second-year students with different major subjects but took chemistry as a compulsory course in the 2019/2020 academic year. The ages of these student-teachers ranged from 20 to 30. These participants were selected to establish how they could use ICT and adopt flipped learning.

In phase IV, in the 2021/2022 academic year, two classes totalling 100 student-teachers selected from one college were assigned as a control group (n= 48) and experimental groups (n = 52) through convenience sampling. I wanted to understand the how flipped-inquiry based learning can improve student-teachers chemistry learning.

4.4 Design approach and procedures

Since I was interested in helping teacher educators integrate technology into their classroom practices to transform their teaching and learning, we designed the research into four phases: The aims of each research in the phases are indicated in table 9 and a corresponding data taken from mapping up and preparation, implementation, and evaluation, as shown in table 4.

Table 4 Timelines for the research and milestones

Mapping up and preparation (Jul-Aug. 2020)	Implementation (Oct.-Nov. 2020)	Implementation and evaluation (Oct. -Nov. 2020)	Review Implementation and evaluation (Feb. -April. 2021)
Discussions with teachers *Data set 1* (Surveyed teachers)	Development of learning materials Teaching sequences *Data set 2* Surveyed student-teachers and interviewed teacher educators	Teaching sequences *Data set 3* Interviewed teacher educators. Student-teachers answered questionnaires and focus group discussions	Teaching sequences *Data set 4* Student-teachers took a test and participated in focus group discussions.

4.4.1 Planning and preparation of the design

Before the intervention, I wanted to know how teacher educators used ICT to deliver their lessons (Paper II). I also intended to examine the nature of their experiences during the pandemic (Paper I). ICT integration became even more urgent during the pandemic, so the design was amended to explore those circumstances. My main aim was to examine the participants' competencies in using ICT and what factors influence their competencies. Data were collected from teacher educators and university teachers, and the preliminary findings provided a comprehensive understanding of educators' use of ICT. I interviewed the three teacher educators to ascertain their knowledge and experiences in using ICT (paper II). Through the discussions, the teacher educators shared their experiences using different instructional approaches and ICT integration.

4.4.2 Designing the learning materials

In collaboration with the educators, we chose to use the organic chemistry unit as it is one of the challenging topics for the students. Concepts associated with hydrocarbons were used to determine the effectiveness of an interventional model for teaching the concepts. The concepts of hydrocarbons (classification, naming, structures, properties, preparation, and uses) were administered to the student-teachers over four weeks. The assessment was administered at the end of the four weeks (See Appendix G). The same content was chosen and provided to the same classes in the various colleges by the same teachers. The design was suitable since most related studies involve students exposed to the traditional teaching method with either the flipped classroom or inquiry-based learning. The researcher and the teacher educators developed learning materials from videos, PowerPoint slides, and learning tasks based on the content in the syllabus (See Appendix G). A web-based Google classroom model was created where all the instructional materials, test items, classroom activities, and videos were stored. The link to the web-based classroom model is shared with student-teachers via the WhatsApp platform. Zoom was used for online teacher-student and student-student discussions and face-to-face activities.

The topics were taken from the national syllabus for teacher education and, by default, would prepare the student-teachers for teaching organic chemistry when taking positions in the future. Using ICT in schools is promoted as a significant necessity at the levels of policymaking and curriculum goals in Ghana. The country has ambitious goals for the development of science and industry. Still, it needs help to obtain the financial and technical resources to provide enough trained teachers to implement the policies in schools, colleges, universities, and various industrial start-ups.

4.4.3 Implementation and course delivery

The same teacher educator delivered the instruction in the classes at each research site. At the beginning of each week, the teacher educator reflects on the objectives of the learning content, students learning activities, schedule of learning expectations, and other tasks and assessments that student-teachers had to complete during each phase of the learning process. Information on tasks and what is expected from student-teachers within the week are shared so they can familiarise themselves beforehand (See appendices H and I). The student-teachers were supposed to watch lecture videos, review other tasks such as readings, and complete short quizzes on concepts in the learning materials during the in-class and out-of-class sessions in their own time as shown in Table 5.

Table 5 Topics and learning focus over the four-week period

Weeks	Topic of focus	Indicators for learning activities
1	Classification and naming of organic compounds	· Group given organic compounds into alkanes, alkenes, alkynes, alkanols and alkanoic acids · Write the names of given organic compounds
2	The structure of different organic compounds.	· Tell the difference in structure of different organic compounds. · Draw the structure of given organic compounds · Describe the structural (chain, position, and functional group) and geometric isomerism
3	Physical and chemical properties of organic compounds	· Describe the physical and chemical properties of some organic compounds · Compare the chemical and physical properties of organic compounds
4	Preparation and uses of organic compounds.	· Explain the laboratory preparation and test of three named organic compounds · Describe the uses of three named organic compounds

4.4.4 Students' learning activities in the flipped classroom

In the flipped classroom, there was the delivery of basic knowledge concepts (reading, watching videos, and answering questions) at home and engaged in learning activities that involved the application and practice of knowledge learned from the out-of-class learning with the educator face-to-face in the classroom as shown in table 6.

The learning process for the out-of-class activities (homework) including the reviewing the pre-recorded lectures, videos, and PowerPoint slides materials focused on the knowledge level of remembering and understanding (Mason et al., 2013). Student-teachers reviewed the assigned homework on their mobile phones or in the college ICT laboratory or classroom before coming to the next class. The 10-15 minutes videos with short quizzes were used not only as students' preparatory activities but also to monitor whether students watched the videos and other preparatory activities.

Table 6 Teaching and learning processes for the study

Out-of-class	· Students watch lecture videos · Review other learning materials e.g, PowerPoint slides · Answer questions based on content of the video lectures
In-class activities	· Educators go over materials with learners · Educator recall facts and principles of the content of the home activities · Educator direct and guide students to seek knowledge · Students do collaborative work, peer learning, problem solving activities in face-to-face and Google classroom · Educator and student-teachers' interactions on Zoom, WhatsApp on specific content · Educators reflect on concepts, learning assessment tasks with students face-to-face · Groups presentations · Assessment (e.g. tests, quiz individually)

Student-teachers are then engaged in discussions with the teacher educator during the classroom session and different activities based on their video, either face-to-face, via Google Classroom, or Zoom. During the face-to-face session, the educator introduces the learning concept (e.g., classification and nomenclature of aliphatic compounds) by reviewing the pre-recorded lesson and videos using questions and answering. Through class discussion, the educator explains the fundamental concepts of the content to the student-teachers with examples shown in table 6. Educators discuss with student-teachers and provide further illustrations and examples of the concepts (e.g., naming and drawing structures of aliphatic hydrocarbons). Educators then give tasks to students to work on individually to practice while moving around to monitor students learning progress. More exercises are given to students to practice as homework. Further additional tasks are assigned to students in groups to work on and present results. At the end of the week, a quiz on the week's content learned is assigned to test students understanding. Google Classroom and Zoom were used to track student-teachers' participation in the course's teaching and learning activities.

4.4.5 Evaluation and assessments

At the end of the four-week intervention, student-teachers took a test, answered a questionnaire, and took part in focus group discussions, to assess the effectiveness of the intervention.

Table 7 Sample concepts, learning outcomes, and practice questions.

Learning Outcome:	**Practice questions**
Classify organic compounds into their correct functional groups.	· What are organic compounds? · What is a hydrocarbon? · List the three types of groups into which hydrocarbons are classified. · Group the following into their various functional groups: Propane, Butyne, ethanoic acid, propane, ethanol, hexane
Write the correct chemical formulae and IUPAC names of alkanes, alkenes, and alkynes.	· Write down the chemical formulae of the following compounds: Propane, Butyne, 2-chrolo-3-pentane, 4-bromo-2-hexene, 3-chloro-2,4-dimethylhexane, 2-methylbut-5-yne · Write the IUPAC name for the following compounds: a. $CH_3CH_2CH_2CH_3$ b. $CH_3CH_2CH{=}CHCH_3$ c. $CH_3CH(CH_3)CH(Cl)CH(CH_3)CH_2CH_3$ d. $CH_3CH{\equiv}CH(CH_3)CH_3$
State some physical and chemical properties of alkanes, alkenes, and alkynes	· Use chemical reactivity with hydrogen, oxygen and water and boiling point to explain
Write and explain simple reactions to differentiate between alkanes and alkenes.	· How would you differentiate between alkane and alkene in the laboratory? · Two samples of hydrocarbons are suspected to be alkane and alkene. Use bromine in CCl4 to differentiate between the two samples
Balance simple chemical equations with the state of the substances attached to them.	· Balance the following reactions. a. $CH_4(g) + 2O_2 \rightarrow CO_2(g) + H_2O$ b. $CH_3CH{=}CHCH_3 + \quad \rightarrow CH_3CH_2CH_2CH_3$ c. $CH{\equiv}CH + O_2 \rightarrow \quad + 2H_2O$ d. $CH_3CH_2CH{=}CH_3 + 2H_2O$ e. $CH_4(g) + Cl_2 \rightarrow$

4.5 Data sets collected

Since the research involves several steps involving three groups of participants, three sets of data were collected (Refer to table 9). All collected data were stored on Google Forms, Zoom, and WhatsApp. The data collection took place in three phases, each with a respective sample.

4.5.1 Teachers' survey

A questionnaire was used to collect educators' views on online teaching experiences (paper I). The questionnaire contained items that measured the educators' knowledge, skills, and integration of ICT in teaching. Also, other questions such as demographics, available resources, ICT-related training, and online teaching experiences were included in the questionnaire to assess the factors that influence their competencies in teaching online (ERT).

4.5.2 Interviews with the threesome

The threesome was interviewed before and after the project to examine their views and the nature of their experiences of using ICT (paper II). The interviews lasted 45—60 minutes each and were video-taped or audio-taped with Zoom and WhatsApp, respectively. Each teacher educator was asked about their views of methods of teaching, teaching and learning activities in the classroom, and experiences of ICT in teaching.

4.5.3 Student-teachers' surveys, focus groups, and tests

A questionnaire was used to collect information from student teachers on views of teaching and learning approaches, teaching, learning activities in and out of the classroom, and experiences in using ICT to learn. After the intervention, a questionnaire on experiences of learning chemistry in a flipped classroom environment was administered to the student-teachers for written descriptions of experiences was administered as well as focus group discussions. The questions included views on ICT resources, teaching and learning activities, and the impacts of the approach on learning outcomes (paper III). In addition, test items adopted from the National Diploma in Basic Education database were used to assess student-teachers' knowledge, understanding, and thinking skills in hydrocarbons. The questions were categorised into multiple-choice, one-word, and written answers requiring knowledge application. Further, 16 (6 from papers III and 10 in IV) participants from the experimental class (flipped class) were engaged in a focus group discussion to describe their nature of experiences in flipped classrooms. The focus group discussions lasted for 60 mins and were videotaped on Zoom.

4.5.4 Class observations

During the teaching and learning sequences, I observed each class once via Zoom and watched the teaching and learning activities, including teacher-led classroom and student group discussions. Each observation took 60mins in each class. During the observations, I could not communicate with students or educators as I aimed to assess the kind of classroom relationship between the educators and student-teachers and among the student-teachers themselves.

4.5.5 Selection of SWOT data

Students focus groups, questionnaires and teacher interviews were used to analyse the SWOT analysis data.

Table 8 Data for SWOT analysis

Strengths (Internal factors)	**Weaknesses** (Internal factors)
Inside the institution, i.e., classroom	Inside the institution, i.e., classroom
Opportunities (External factors)	**Threats** (External factors)
Usefulness to the environment, e.g., students' teachers can add value to the schools.	Factors from policymakers

4.6 Data analysis

In paper I, I categorized and analysed the data in the papers with descriptive statistics, including per centages, means, and standard deviations. Statistical tests, including Pearson´s correlations and multiple regression analysis used to examine the educators' competence in using ICT to teach online lessons. SPSS version-27 statistical software was used for the data analysis. In paper II, the interviews were transferred to Google stream to be transcribed. The themes from the transcriptions were identified and categorized through thematic analysis. The themes were then sorted and coded through a series of initial coding, open coding, and cross-case analysis to show the associations of the themes (Saldaña, 2009). In Paper III, the student-teachers' responses to the questionnaire and focus group discussions were transcribed verbatim in Google stream and sorted into themes and subthemes. The data was analysed using content analysis (Mayring, 2000). The themes and subthemes were then revised so any overlaps that may have arisen could be removed. In paper IV, the items were selected using facility index, practical significance tested with Cohen's d effect size, differences between groups in achievement measured with a t-test, and focus group with qualitative content analysis (Mayring, 2000).

Further, the advantages and challenges of using ICT for flipped classrooms in chemistry teaching were analysed using a SWOT analysis. SWOT is an analytical framework focused on examining the internal strengths and weaknesses and external opportunities and threats outside an organization or system. The SWOT analysis is used strategically to plan projects by mapping the advantages (strengths and opportunities) and challenges (weaknesses and threats) of doing the project or intervention (Leigh, 2009).

Table 9 Overview of the data sets

Aims	Data sets in the research papers	Participants	Period
Examining educators' expectations, experiences, and use of ICT	Perceived beliefs in ICT knowledge, skills, and ICT competence collected by surveying teacher educators. See 4.5.1	77 teachers (lecturers and teacher educators)	Jul-Aug. 2020
Explore the views of teacher educators towards using flipped classrooms in chemistry teaching	Use of ICT in teaching collected with interviews with teacher educators. See 4.5.2.	Three teacher educators	Oct-Nov 2020
Explore student-teachers' views about using ICT and adopting the flipped classroom approach	The students teachers' focus groups and questionnaires collected views on opportunities and threats of the flipped classroom approach. See 4.5.3	143 student teachers	Oct-Nov 2020
Examine the effects flipped classroom approach on student-teachers' chemistry learning	Academic performance and opinions on flipped-inquiry learning collected by students' chemistry achievement diagnostic test. See 4.5.3.	100 student teachers	Feb-Apr 2020
To evaluate the intervention through SWOT	Perceived beliefs in the role of ICT in the classroom, knowledge, skills, and ICT competence collected by educators' surveys, interviews, and student focus groups. See 4.5.1, 4.5.2. and 4.5.3	Teachers, teacher educators and student teachers	Jul 2020 – Apr 2021

4.7 Credibility and trustworthiness of the data

During the data collection, the issue of credibility and trustworthiness was an essential factor to consider. In ensuring the credibility and trustworthiness of the qualitative data, member checking was done with teacher educators to check the interpretations before analysing the data. It was essential to use member checking to ensure I accurately described the lived experiences as reported by the teacher educators (van Manen, 1990). I used the exact words of the teacher educators as they described their experiences implementing and adopting the flipped classroom. I also continuously corresponded with the participants, sharing the summary extracts from the interviews to ensure they reflected their actual experiences. Again, as Yin (1994) pointed out, to ensure the credibility of research, researchers should incorporate "correct operational measures for the topic under study." In this research, I considered the central construct investigated and how the flipped classroom approach could be used to obtain qualitative and quantitative data about these constructs. A triangulation matrix and member checking were used to validate data results from all the sources, as indicated in Table 10. The data triangulation provided comprehension, increased validity, and enhanced understanding of the data on participants learning experiences (Denzin, 2012; Flick, 2018). The benefits of using multiple methods through triangulation, on the one hand, were to use both qualitative and quantitative methods to decrease the weaknesses in one method and, on the other hand, the multiple approaches also help provide valid results and strengthen the findings of the study (Scandura & Williams, 2000).

4.7.1 Content validity

To ensure the content validity of the items used in the questionnaire, a wide range of issues related to the literature was read to understand the themes highlighted in the prior studies. The questionnaire was developed and shared with four university teachers, including chemistry, science, and teacher educators, who gave advice, and their inputs were considered. Some modifications and new items were added to make the content clear for participants to provide a valid response to the questions. The revision focused on content (organic chemistry), distinctions between flipped classrooms and face-to-teaching, and inquiry-based learning (pedagogy).

Table 10 Triangulation of data sets

Quantitative data (Paper I)		
Data sets	Questionnaire	Numerical data from the questionnaire
Data analysis	Descriptive statistics, Pearson correlation, multiple regression	Significance correlations
Qualitative data (Paper II)		
Data sets	Pre- and post-teacher interviews	Interview transcripts
	Classroom observations	Field notes
	Teacher reflections	
Data analysis	Thematic analysis	Emergent themes
	Focused coding	Narratives
	Line-by-line coding	
Qualitative data (Paper III)		
Data sets	Questionnaire	Field notes
	Focus group	Interview transcripts
	Classroom observations	
Data analysis	Content analysis	Emergent themes
	Focused coding	Narratives
Quantitative data (Paper IV)		
Data sets	Pre- and post-tests	Numerical data from the questionnaire.
Data analysis	Descriptive statistics, t-test, Cohen-d	Significance differences
	Data interconnection	
Integration of all data	Data triangulation	Result interpretation, discussions, reflections, and implications

4.7.2 Construct validity and reliability

To ensure the validation of the data, it was essential to consider that the research instruments measure what is expected and intended to measure. In ensuring the construct validity, Cronbach alpha reliability was measured and used to measure the constructs ranging from 0.7 to 0.9, indicating that the resultant coefficient was reliable. A discrimination index, facility index, and instrument reliability were computed on the test items. The facility index ranged from 0.4 – 0.7, indicating the test items were neither complicated nor straightforward, and the discrimination index was ≥ 0.4 (Büyüköztürk et al., 2013). Therefore, the test items were considered very good for the research.

4.8 Ethical considerations and informed consent

The data was collected during the 2020-2022 academic year. A link to the online survey was sent to the course teachers. Teachers, educators, and student-teachers received an email containing the survey link and assessed it through the class WhatsApp platform. A consent form (Appendix A) to participate in the study was part of the participants connection. The participants (student-teachers) acknowledged their understanding and agreed to participate in the project. In this research, permission was sought from the colleges heads of department to use their colleges as research sites. The respondents signed an informed consent form, which explained that participation in the study was voluntary and that participants should not be forced to participate (de Vos et al., 2011). The consent form also explained that participants could withdraw from the study at any time if they no longer wanted to participate, and their personal information was treated as anonymous to ensure subjects privacy. This implies that the names of the participants remained anonymous in the thesis or publications in academic papers and thesis.

4.9 Limitations of the research

This project had some limitations which can inform future studies on flipped classrooms. Although the study was limited to three colleges of education, the findings open further research to involve a larger sample to ascertain student-teachers views on using blended learning. This would give broader information and perspective on future preparedness for a possible pandemic causing considerable disruptions in teaching and learning activities. Since many aspects of the research were conducted during the COVID-19 pandemic, students learned under duress which might have affected participants views, experiences, and academic performance. However, access to the internet, learning technologies, and effective use of the learning platforms that are easily compatible with smartphones should be considered to improve flipped classroom adoption.

5 Results and discussions

The research questions developed and integrated into papers I – IV are as stated:

- What are the teachers (lecturers and teacher educators) rationale for using ICT in teaching?
- What are the strengths and weaknesses of teaching and learning chemistry with ICT to adopt flipped classroom?
- What are the opportunities and threats of using ICT to adopt flipped classrooms in schools and institutions?

In this chapter, I will discuss the findings and issues that arise from the findings for further development of the effective use of ICT for pedagogy. The results will be discussed using SWOT analysis.

5.1 Teachers' rationale for using ICT in teaching

All the teacher educators in this study believed that integrating ICT could enable them to develop their skills and change their pedagogical practices to adopt and implement 21st-century approaches such as active learning. The teacher educators believed that implementing active learning pedagogies could enable students to learn independently and with instructor's support enhance their academic performance.

5.1.1 Becoming competent in using ICT

According to Ghana's current national teaching framework, educators must use ICT to transform their pedagogical approaches to support student learning (MoE, 2015; 2017). The educators in this study believed the time had come to revisit the ICT policy in the national curriculum and implement what is recommended and expected of them. It is expected that educators who intend to use ICT to adopt flipped classrooms possess skills in preparing learning materials, engaging, interacting, and monitoring students' progress during online lessons. One of the teacher educators however, lacked the skills and competence to develop learning materials for online instruction (Paper II). All the teacher educators believed their knowledge and regular use of ICT would enable them to become competent in using technological tools in their classrooms. The teachers' perceptions on online teaching competence correlated strongly with their knowledge of ICT ($r = 0.80$, $p < 0.01$) and regular use of ICT in teaching ($r = 0.87$, $p < 0.01$) (Paper 1).

Educators also felt that using ICT could help student-teachers develop skills in using learning technologies to use in their studies and future professional teaching work. Smith and Greene (2013) have also argued that teacher educators who use technology in teaching regularly can enrich their skills, which would encourage student-teachers to use it as well. Researchers have adopted inquiry learning to address problems in their courses. For instance, Dailey and Robinson (2017) identified barriers science teachers faced with implementing technology-mediated inquiry-based teaching and developed a professional program for teachers to improve their science teaching. An instructional professional development intervention focusing on active student roles helped improve the teachers' science teaching skills and inquiry classroom practices. Some teacher educators had difficulty delivering chemistry courses (Paper II). This suggests a lack of professional development training when transitioning to online teaching during the pandemic. The significance of professional development for improving science teaching is noteworthy since it gives educators more confidence in trying new strategies in their classrooms. Dailey and Robinson (2017) pointed out that professional development enables teachers to work when they are provided with extensive support, such as professional learning communities and coaching.

5.1.2 Adoption of active learning pedagogies

Educators believed that implementing student-centred learning approaches would enable them to shift their teaching focus toward active learning practices to support student learning, such as group work, think-pair-share, and peer-assisted learning. From the threesome perspectives, using ICT to integrate flipped classrooms was meant to shift their traditional classroom practices using educational technology (Paper II). They believed that using ICT could enable them to shift from teacher-centred approaches and adopt learner-centred approaches. Educators felt acquiring ICT skills could support independent learning approaches such as flipped classrooms. Implementing student-centred learning approaches could allow students to take responsibility for their own learning and actively participate in the learning process.

Many studies have indicated that educators integrate ICT into their classrooms to enable them to change pedagogical practices and purposely adopt new strategies that are more student centred. The pandemic disrupted classroom activities, especially those that demand face-to-face meetings. Teacher educators felt they could use ICT to engage their students outside the classroom. The increase and improved access to educational technologies has supported educators in changing their traditional teaching approaches to adopt emerging pedagogical approaches (Seery, 2015). My findings were in line with previous studies that provide evidence that technological advances have enabled educators to engage students in and out of the classroom. With the ICT revolution, learning propositions have already started with educators implementing blended pedagogical practices (Fadol et al., 2018). It would be worthwhile to go back and see what hindered the uptake of ICT.

5.1.3 Provision of flexible learning

Student-teachers felt that the flipped classroom approach offered them flexibility in their studies (Papers III and IV). Flexible learning opportunities allowed them to choose learning activities and when to do them. Access to learning materials enhances flexible learning opportunities as students learn at their own pace at convenient times. Most student-teachers felt they could review the learning materials independently at their convenience and pace. Students were introduced to new concepts by watching videos before joining the class to participate in active learning. Watching instructional videos before class helped them prepare for in-class activities as they could review the videos by pausing and rewinding. One participant said *students could repeatedly review the videos when it suits them*. Student-teachers were able to reflect and make notes to enhance their understanding. In the focus group, student-teachers claimed their chosen activities were based on time, convenience, and place, especially when working on pre-class tasks. For example, one student-teacher indicated that *there are flexible learning opportunities as students learn at their own pace at convenient times*.

The student-teachers agreed that they could moderate their own learning according to their own abilities. Flexibility in reviewing the learning materials, e.g., video lectures, enhanced students' knowledge construction and conceptual understanding. This finding broadly supports the work of other studies on flipped classrooms linked with flexible learning opportunities, allowing students to take control of their learning and take notes (Fraga & Harmon, 2014; Schultz et al., 2014). In this set of studies (Papers II, III, and IV), most student-teachers had access to Android phones that they used to perform pre-class and in-class tasks. Access to these mobile learning technologies made it easier for them to learn at their convenience. Bergman and Sums (2012) reported that the availability of video lectures made it possible for absentee students to cover lost lessons. The colleges in this study suffered difficulties with access to the internet and power outages which made it difficult to use the flexible affordances of ICT.

5.1.4 Academic achievement

Both teacher educators and student-teachers perceived the flipped approach enhanced their conceptual understanding and knowledge construction (Papers II and III). Teacher educators believe students' active participation in the learning processes is linked to their ability to self-regulate their learning styles to suit the assigned tasks. Being able to do the learning activities, such as pre-class learning and in-class discussions with peers, made students become active learners. The teacher educators felt this made student-teachers understand the concepts better and able to construct their knowledge. These findings reflect what Paristiowati et al. (2017) found that implementing flipped inquiry-based learning helps students better understand chemistry content and apply the knowledge gained in teaching their peers.

Student-teachers perceived that active participation in the learning activities and tasks enabled them to grasp the concepts and use the ideas to construct their knowledge. They often worked on independent or group tasks without relying much on educators. Some student-teachers stated in the focus group that *active learning in activities enable them to understand the concept better*. The flipped classroom approach enhanced student-teachers understanding of organic chemistry concepts, which increased their academic performance and critical thinking skills (Papers II, III, and IV). Teacher educators and student-teachers believed the flipped instructions contributed to improving learning skills. For instance, teacher educators thought *the in-class activities involved more cognitive abilities, enabling student-teachers to perform challenging tasks. Once the students are able to progress through the learning processes, they develop deep thinking to enhance their conceptual understanding*. These thinking skills enable student-teachers to think critically and construct their knowledge. One educator pointed out that *the kind of questions students ask and how they respond to them indicates higher-order thinking skills development*.

The students' actual performance reflects their beliefs in the value of flipped learning. The flipped classroom enhanced student-teacher academic performance in the chemistry achievement test. A higher average score of participants in the experimental group (M=15.65, SD=1.44) was found compared to the control group (M=12.13, SD=2.19). An independent samples t-test showed a significant mean score difference between the groups ($t=-9.544$, $p<0.05$) and an effect size of 0.84. Similar findings are reported in other studies where authors have found positive perceptions to lead to improved learning outcomes (Paristiowati et al., 2017; Olakanmi, 2017). In the focus group discussions, the student-teachers narrated their learning experiences and reflected on the flipped-inquiry-based approach after being introduced to it. They indicated they could connect the content learned to the outside world and apply it to solve everyday problems. Students gained process skills that foster a greater understanding of the subject matter, enhancing their learning performance. A higher average score of participants' critical thinking skills in the experimental group (M=15.22, SD=1.77) was found compared to the control group (M=13.60, SD=2.18) and an effect size of 0.81. An independent samples t-test showed a significant mean score difference between the groups ($t=-4.008$, $p<0.05$). Other studies have also linked academic achievement and critical thinking skills with flipped classroom approach (Aşıksoy & Ozdamli, 2017).

5.2 SWOT analysis of the results

During the interviews, focus group discussions and questionnaires, participants responded to open-ended questions to explain and write their views and perceptions of the advantages and challenges or barriers of using ICT to adopt flipped classrooms.

The data from the survey and interviews transcripts were used for the SWOT analysis relating to the internal and external factors for their adoption of flipped classroom. The analysis provided a good understanding of the strengths and weaknesses (internal factors) and opportunities, and threats (external factors) with respect to adopting flipped classroom as shown in table 11.

5.2.1 Strengths and weaknesses of ICT in flipped classrooms

The threesome and student-teachers believed that teaching sequences and learning activities in flipped classroom were beneficial to them. These strengths are effective use of working time, increase ICT skills and competence, students assured of learning responsibilities, effective classroom interactions and collaborative learning among students.

5.2.1.1 Strengths

The threesome believed access to ICT and learning technologies enhance *efficient use of time for their work*. Implementing flipped classrooms with ICT required time to prepare the instructional materials. Teacher educators, however, believed they could do many learning activities with ICT within a relatively short period of time (Paper II). For instance, two of the threesome indicated that using videos meant less time writing lecture notes and dictating to students before explaining the main ideas. An educator noted that *students watching the videos, taking short quizzes and other preparatory activities at home created time for more in-class activities such as discussions and group tasks*. They claimed the videos were self-explanatory, and with the support of PowerPoint slides, students got some understanding of the concepts during pre-class preparation. To them, integrating flipped classrooms with ICT has reduced and changed the nature of their workload. One educator indicated that *ICT in flipped classrooms reduced the workload because I did not need to write notes and explain to students using videos and PowerPoint slides*. Previous studies have also found that the effective use of learning technologies helps decrease the time for preparation (Rotella & Cain, 2016). In addition, educators felt that with ICT, they could encourage students to share information, communicate, engage, and interact regardless of time and place. Rotella and Cain (2016) indicated that flipped classroom approach facilitates teacher educators' effective utilisation of contact time in and out of the classroom. These findings are, however, not undisputed and contradict what Graziano (2017) reported, that instructors resist flipped classrooms because they feel the approach takes time from other activities, such as meeting with parents and preparation of lesson plans.

Teacher educators and student-teachers believed that teaching sequences and learning activities in flipped classrooms resulted in *improved ICT skills and competence*. Results from the first paper revealed a strong positive correlation between online teaching competence and ICT knowledge ($r = 0.80$, $p < 0.01$) and ICT usage ($r = 0.87$, $p < 0.01$). In addition, teacher educators felt that implementation of ICT could help to increase the student-teachers desire to learn and develop their potentials in using ICT to create opportunities for development of employable skills. Participants believed such developments would bring an opportunity for students to take STEM programs at the universities to develop their skills further that could enhance their suitability for the job market. For instance, students are required to do final projects that could enable them to use their skills to develop materials or learning platforms with ICT. In addition, in each of the colleges of education, there are few ICT teachers, usually one that works as a specialist, which limits the knowledge base for developing ideas. One teacher educator reiterated that, *ICT experts are scarce and therefore integration and use of ICT could promote student-teachers job opportunities in any ICT fields such as telecommunications or ICT teaching*. This finding is also reported in a report by OECD that shortages in ICT related fields and it is the duty of universities to train more desirable ICT specialists (OECD, 2015). It is required for people to attain a high-end skill to be able to invent and apply ICT and thus new efforts are needed to bridge the gaps between education and practice. Aničić et al. (2017) pointed out that successful ICT students should develop discipline-specific knowledge and skills for communication and problem solving. This could be achieved through the integration of such content in the curriculum and focus on how educators could use teaching methods to deliver such skills. This suggests that training could enable students to get jobs in either local communities or even in the CoEs.

Participants believed that using ICT to adopt flipped classrooms *promotes the culture of learning responsibilities*. Results from the interviews, questionnaire, and focus group revealed that teacher educators and student-teachers acknowledged that the flipped classroom approach makes students more active learners (Papers II, III and IV). Teacher educators focused much attention on building on student knowledge from pre-class activities, which implied that students' responsibility was essential. They indicated that their role was to facilitate the learning process by guiding students on how to learn and construct knowledge by themselves. One teacher educator stated during the interviews that *students are given opportunities to work on pre-class tasks independently, which gives them control of their learning*. In addition, a student-teacher indicated in the survey that *flipped learning activities make students become more responsible for their own learning*. These findings support earlier observations that educators adopt flipped classrooms to create flexible opportunities to engage students in inquiry-based learning activities so that students would construct knowledge by themselves (Dove & Dove, 2017; Hajhashemi et al., 2016). According to Dove and Dove (2017), student independent learning processes enable them to assume responsibility for learning by managing their own learning materials and tasks to achieve deeper understanding. From a constructivist perspective, knowledge construction through student-centred learning is based on learners creating and interpreting experiences independently through active engagement and not through transmission (Alammary et al., 2014). Flores et al. (2016) pointed out that flipped learning is based on the principle that teaching and learning should be focused on students, and the role of the instructor is to direct the learning content and focus on students' abilities and interests.

Both the threesome and student-teachers indicated that the flipped instructions created an *opportunity for effective interaction among students and with the teacher* (Papers II, III, and IV). The threesome felt that the flipped classroom approach increased student interaction through regular discussions and feedback. They felt replacing some of the regular classroom activities with homework created time to engage in teacher-led discussions which can be used to identify struggling students and provide appropriate support and assistance. For example, one teacher educator mentioned during the interviews that *there is an opportunity to discuss challenging problems with students for remediation*. The student-teachers also believed that constant interactions with educators enabled them to correct misconceptions and enhance their learning. They believed the regular discussions and interactions with educators made them understand the concepts better, especially when they encountered difficult concepts that educators could explain. A student-teacher indicated that *there is an opportunity for educators to lead a question-and-answer session where they constantly receive clarifications and feedback on their learning tasks.* Consistent with the literature, educators could use flipped classrooms to create an avenue for effective classroom discussions and other communications with students (Almodaires et al., 2019; Zainuddin & Attaran, 2016). Almodaires et al. (2019) indicated that flipped classrooms allow educators to clarify difficult concepts to students through classroom interactions. Through such discussions, there are avenues for active engagement in exploration, discovery, and active learning. Further, Zainuddin and Attaran (2016) have pointed out that using some of the regular class time for active learning activities creates time for meaningful classroom discussions and content reflections and help educators connect and provide timely instructions to students who face difficulties or need clarifications of learning concepts (Bergman & Sams, 2012).

Furthermore, the flipped classroom provides an *opportunity to promote collaborative student learning* (Papers II, III, and IV). According to the teacher educators, most in-class activities were group work and class discussions, giving them much time to monitor the students. Student learning activities were mostly inquiry-based and think-pair-share, which enhanced their scaffolding abilities. The flipped classroom allows student-teachers to fully engage in collaborative work and discussions reflecting on out-of-class learning. One teacher educator stated that *various activities with group work are used in the in-class time, which helps students to understand the concepts and construct knowledge*. Teacher educators also believed that group discussions enabled the student-teachers to collaborate, share ideas, and support each other to construct their knowledge. One teacher educator mentioned that *students could collaborate with peers to share ideas, work together and practice tasks that construct personal knowledge*. The student-teachers also perceived that the flipped classroom approach allowed them to engage with their peers in collaborative learning activities to build a learning community. They also felt that collaborating with their peers on the assigned tasks enhanced their understanding of the concept and knowledge construction. One participant wrote in the survey that *working in group tasks with peers helped them* to *develop to their interest as they received assistance from their peers and enhanced concept understanding*. Zainuddin and Attaran (2016) pointed out that in the flipped classroom, students interact with classmates during group work and engage in discussions and other collaborative learning activities reduced their learning difficulties to improve their learning.

5.2.1.2 Weaknesses

Despite the benefits of using ICT in teaching, integrating ICT also have associated weaknesses to both teachers and students. During the intervention, educators and student-teachers expressed certain weaknesses. These weaknesses are related to low competences in using ICT, overload curriculum and high learning content demand, lack of time and unequal distribution of resources in the learning environment.

The threesome and student-teachers believed that teaching sequences and learning activities in flipped classrooms resulted in improved ICT skills and competence. However, this was not the case as less than half (43 %) of teachers believed they had sufficient knowledge of ICT that could enable them to deliver technology-mediated instructions (Paper I). Only 10 % indicated that they always used ICT in their lessons. Regular usage of ICT, however, could enhance educators' ICT competence in delivering online lessons. When interviewed teacher educators reported a *low ability to use ICT to create their videos, provide feedback, and use ICT*, confirming the challenges the weaknesses in their use of ICT were confirmed in the interviews (Paper II). One of the threesome mentioned he could not use digital tools to make videos but instead relied on already-made ones and charts. For instance, one educator indicated that *it was difficult to create and draw some organic structures using the computer*. Similar findings are reported by Hajhashemi et al. (2016) that one concern that lecturers had about blended learning was finding suitable videos for teaching concepts. In addition, they found it challenging to monitor students' pre-class and in-class online activities and provide timely feedback, especially during group work online. Similar shortcomings are in Chao et al. (2015), study that instructors found it difficult to monitor student out-of-class activities to ensure they genuinely watch videos and provide support. The student-teachers also stated they lacked the knowledge and skills to use learning technologies and platforms such as Zoom and Google Classroom. Some student-teachers unfamiliar with learning technologies and platforms became frustrated when they encountered a technical challenge and had no knowledge how to fix it (Paper III). For example, one student teacher stated that they *find it challenging to navigate on the learning platforms, post assignments, join class discussions, and mute/unmute themselves during class discussions*. The lack of technical know-how resulted in poor interaction and communication among students and educators. These deficiencies demotivated some participants as they found the lessons complicated and uninteresting. The lack of technical skills mainly contributed to students' inability to participate, leading to negative views of the flipped classroom (Yılmaz & Malone, 2020). This suggests that for educators and students to adopt technology learning environments, they must gain new knowledge and skills regularly (Buabeng-Andoh, 2012; Erdemir & Eksi, 2019). Lack of adequate ICT literacy and technology competence thus hinder educators' implementation of flipped classrooms.

The study showed that teachers did not receive the training needed to gain adequate online teaching competence. The threesome agreed on the benefits of integrating ICT as stipulated in the curriculum. Teachers believed that adequate training in ICT could enhance their experiences and competences in developing and improving their pedagogical practices, however, due to the lack of professional development training they could not do so. One of the threesome indicated that, *there was not adequate training during the pandemic and the only thing the administrators did was to organize a one-day workshop for us*. Whalen (2020) mentioned that professional development workshops, sharing experiences and evaluation, and instructional support can promote instructors' knowledge and skills to design online lessons effectively. The study results confirm previous findings of lack of training for instructors as among the reasons online instructors lowly embraced online teaching (Asomah et al., 2022). Instructors need adequate training to be familiar with online education to effectively implement it and provide sufficient guidance for students. Effective integration of ICT into online teaching requires good training by institutions and the government but professional development workshops offered one-time with little follow-up activities is less effective. Kramer et al. (2012) advised an all-one-time workshop in "one-size-fits-all" does not produce mastery of the required skills for effective online teaching, but it helps to some extent.

The study findings showed student-teachers could not effectively use the ICT in learning due to the *workload in the curriculum*. In the syllabus, the student-teachers are required to take at least eight courses including teaching practice. In all these courses, it is a requirement to do all tasks and pass examinations before progressions to the next level. In flipped classrooms, students must be independent and responsible for their learning. Because of the student-teachers' prior experiences in lecture-based classrooms, some students complained about their increased workload and claimed the learning activities were too much compared to the traditional lecture classroom. The student-teachers claimed the flipped approach was too demanding for many learning activities and that the series of learning activities, especially preparing before class, and engaging in other learning activities not done in the traditional classroom, brings an extra workload. For instance, a student indicated that *the pre-class activities, presentations, and online discussions seem to be a lot of work for them compared to the traditional classroom activities*. Another participant indicated, *chemistry as a subject was challenging to us and adding a new skill which they are less familiar with could increase their learning frustrations*. Student teachers also exhibited weaker content knowledge in the organic chemistry. Most of them have weaker foundations from their high school chemistry learning experiences, they claimed the content was *challenging, complicated, and difficult*. Already student teachers struggle with mastering the content and integrating ICT made them felt the flipped classroom approach is more *"cumbersome"* due to the various learning activities. This observation was also reported by Findlay-Thompson and

Mombourquette (2014) and Wilson (2020) that students negative experiences in the flipped classroom are related to increased workload as compared to the lecture approach. Students' complaints about workload were mainly also attributed to inadequate preparation due to the lack of resources and low technical abilities, which the students did not encounter in the traditional face-to-face classes. These findings reflect earlier observations by Fletcher (2018), who found that, students perform poorly in chemistry because of inadequate resources in schools and weaker content knowledge.

Participants found *inadequate resources in their institutions* to be a critical weakness to using ICT to adopt flipped classroom. The learning environment is a factor that influences students' learning both in and outside the classroom. For effective and efficient use of ICT to adopt flipped teaching, access and availability of learning infrastructures is important. For instance, some student-teachers found flipped learning challenging and uninteresting because they needed more essential ICT resources. Due to the lack of internet access, most student-teachers could not participate in the pre-class and online discussions. They could not watch the videos nor participate in online discussions making them always lag in their preparations. The flipped classrooms favour students in urban areas where internet services are better than rural areas. During the focus group, student-teachers indicated *disparities in internet access from different colleges and homes.* In addition, during the interviews, one teacher educator indicated that, *because not only did the internet access impact the project but so did the quality of the internet as well.* He indicated that the location of the college and especially that of the town affected the quality of internet connectivity. Some of the lessons observed were conducted as early as 5 am because the network was to slow during the day. The same problem was identified by van Niekerk & Delport (2022), who argued that using flipped classrooms in rural settings can be difficult for student engagement.

Some teacher educators found ICT integration *time consuming* and stated that it is time-wasting and unsuitable as the time spent on preparation could have been used for other tasks. To reduce the time wasted on pre-class activities, teacher educators sometimes opened ICT labs for students without regular access to the internet. In addition, teacher educators also expressed dissatisfaction with the quality of the network connectivity. One teacher educator indicated that, *integrating ICT is not new but usually calls for much consultation and time as much time could be spent on preparation that are meant for other tasks.* Similar challenges have been encountered by other researchers in developing countries (Adejoja, 2016; Aidoo et al., 2022). These findings suggest that if the project had occurred in all urban centres with quality networks and internet services, students learning experiences may have been different from what I observed.

5.2.2 Opportunities and threats to using ICT in schools

Participants believed adoption of flipped classroom with ICT could create opportunities for training for professional development and employable skills and expansion of courses for students.

5.2.2.1 Opportunities

The threesome felt the integration of ICT could provide training opportunities for professional development. They believed that in most Ghanaian communities, access to the internet is a challenge and, as such, doing such projects is difficult. Successful use of the approach could change if communities could attract the attention of government, NGOs, and companies to invest in the internet. One educator stated that, *successful integration of ICT-related projects can result companies providing cooperative social responsibility roles to promote such local communities such as resource centres for training purposes*. In Ghana, there is a Pre-tertiary Teacher Professional Development and Management (PTPDM) policy that designs career progressions for teachers focusing on continuous professional development at school, cluster, or district levels. With such opportunities, distance learning opportunities could be developed for teachers to enable them to develop their ICT skills that could enhance their professional competencies in their subjects (Atta & Mensah, 2015).

The institution could have a wider reach to students across the country with the introduction of online courses or distance learning e.g MOOCS. Teacher educators believed with the efficient adoption of ICT, instructors could disseminate academic learning materials to students without them travelling far to campuses. One teacher educator indicated *effective integration could lead to the adoption and implementation of online learning programs to serve the students, teachers, and other workers. Because of working conditions many people cannot go for further studies in the main university campuses and adoption of satellite campus could be a headway*. This in a way will save cost and relief some financial burdens on students. Similar findings are reported in a study by Asomah et al. (2022) that university academic staff believes adoption of e-learning has the potential of reaching most students in different areas. Also, academic materials could be disseminated through learning management systems as an innovation in their teaching practices.

5.2.2.2 Threats

Despite the benefits of using ICT, there are associated challenges to both teachers and students. During the intervention, educators and student-teachers encountered certain constraints. These challenges are related to the working environment of schools and the quality and access to resources.

The threesome believed the integration of ICT would bring a change in the way things are done. But due to the inflexible and rigid timetables, they felt executing ICT-related projects would be time-consuming because it demands much planning and preparation. According to the threesome, the syllabus is planned such that there is limited flexibility to integrate new things that demand more time and would also disrupt the school timetable. School leaders are uncooperative when they have no knowledge about the innovation themselves. Teacher educators believed commitment of school leaders play an essential role in bringing about change as most decision making comes from them. One of the threesome hinted, *integrating ICT is ideal for change but much depends on the institutional leader as in our part of the world they are the final authority*. Research indicates that although teachers are motivated and willing to adopt innovations to learn new skills, constraints in the working environment does not allow them to use the skills (Blume et al., 2010) due to lack of time and a rigid school timetable. The threesome pointed out that since ICT integration for flipped teaching is a new method, they needed much time to adopt the approach but the time for their periods and other activities in the CoE are not enough. Similar findings have been reported by other studies that have reported the lack of time and heavy workloads hinder the application of new knowledge (Abonyi et al., 2020). School leaders will have to modify teachers' workloads to enable them to practice new knowledge they have learnt. Kafyulilo et al. (2016) reported that, due to lack of time, teachers who have gained knowledge and skills through professional development programs, only few continued to use the knowledge. Therefore, encouragement from the school management is a critical factor for teachers' continuous use of technology.

In addition, the quality of the internet for learning is also a challenge for the students, according to the teacher educators. Some student-teachers believe the cost of learning technologies and internet services threatens the effective use of flipped classrooms. The amount of data bundles used per class session was around 1GB which was too expensive for them to afford. The cost of the flipped classroom made most students prefer the traditional face-to-face approach. Some students indicated *the internet is very expensive and they have to work before they can afford the data bundles, which affected their attitudes and learning*. Several researchers have found that start-up costs limit implementation of the flipped classroom approach (Aidoo et al., 2022; Sinha & Bagarukayo, 2019). Aidoo (2022) pointed out that many sub-urban Ghanaian students are underprivileged in e-learning programs because of the lack of access to the internet, computers, and smartphones as they are under-resourced compared to peers in urban centres. The disparities in the students background always leads to negative attitudes towards e-learning. Therefore, the cost of internet use made the students dislike the flipped classroom approach. The present study concludes that the student-teachers' economic background contributed to their ability to access and own ICT infrastructure. Further, organisational support and resources are strongly correlated with ICT competence (Paper I). ICT infrastructure positively predicts teacher educators' use of technology to adopt pedagogical approaches such as flipped classrooms. Therefore, it is unsurprising that teacher educators mentioned ICT infrastructure as challenges and barriers to flipped classrooms (Paper II).

5.2.3 Summary of the SWOT analysis

Overall, the results of the SWOT analysis (Table 11) indicate that when educators are given adequate support and resources such as computers, the internet, from their institution, they can develop sufficient knowledge and skills to become competent to use ICT efficiently and effectively. Therefore, teacher educators believe that using flipped classrooms could improve their skills and competencies to use learning technologies given time to practice what they have learned.

Table 11 Strategic analysis of adopting flipped classrooms using ICT.

STRENGTHS	WEAKNESSES
• Access to ICT enhance efficient use of working time • Improved ICT knowledge, skills, and competence • Students are given more learning responsibilities • More teacher-student and more student-student interactions • Students can collaborate and learn with peers	• Low ICT skills and competences • Overloaded curriculum and the content difficult for most students • Unequal distribution of resources • Time restraints limiting the use of ICT
OPPORTUNITIES	**THREATS**
• Opportunities for training for professional development in the communities • Adopt online learning programs e.g. MOOCS	• Rigid school working environment • Lack of resources and training results in educators and student-teachers leads to low ICT competences to use ICT

6 Summary and conclusions

In this chapter, I provide answers to the research questions that arose from the combination of the four research papers and the synopsis of the thesis. The findings from the educators' knowledge, skills, and competencies in ICT show how important these factors are when integrating ICT into the classroom. Also, adequate ICT resources and professional development training are among the key factors highlighted in the curriculum.

6.1 Overview of the findings

Both the integration of ICT and the introduction of flipped classrooms require the acquisition of new knowledge and relevant skills to be used in chemistry teaching. The three teacher educators cooperating with the researcher believed that teachers in colleges and universities need support when introducing ICT into their pedagogical practices, like student-centred approaches. Teacher educators believe that implementing flipped classrooms would create opportunities for students' academic achievement. The student-teachers perceived that the flipped classroom approach would enable them to take a more active role and responsibility for their own learning because of the flexible nature of the approach. The student-teachers felt they could interact with their educators and collaborate with their peers through the flipped approach.

This study shows that the flipped classroom enhances student conceptual understanding and improves their academic performance and critical thinking skills. However, teacher educators face challenges related to weaknesses in ICT infrastructure s and lack of opportunities to develop their knowledge, skills, and competencies for 21st-century teaching. The student-teachers faced inadequate ICT infrastructure and a lack of technical competence to use ICT. Teacher educators had some ICT knowledge but using and integrating it into their teaching was insufficient. One of the reasons was that they had not received professional ICT training that would sufficiently enable them to be competent in delivering technology-enhanced lessons. The threesome indicated further that even for those who had received some ICT training, it was not effectively organized or enough to enable them to put it into practice. ICT-focused workshops were one-time and rushed through, so they did not benefit much.

The student-teachers perceived the flipped classroom approach as being positive and believed it enhanced their conceptual understanding and learning outcomes. The prevailing home conditions influenced their opinions, as did educator support, learning materials, motivation, and strategies. Most student-teachers owned and relied on their smartphones to prepare for class. Homes with limited access to technological devices, poor internet connection, and technological skills contributed to some students' lack of communication with teachers and problems with navigating the learning platforms. Aidoo et al. (2022) pointed out that implementing flipped classrooms requires adequate facilities for students, especially those from poorer homes.

Educators intending to implement flipped classrooms must consider the location of the learning environment. As van Niekerk & Delport (2022) pointed out, flipped classrooms are effective in urban areas with good internet facilities and network connectivity. In my study, I found that, despite the clear inclusion of ICT in policy, the institutions are not adequately resourced to live up to their task, although some have more resources than others. As Adarkwah (2020) indicated, as part of corporate social responsibilities, institutions should get support from telecommunications companies and non-governmental agencies with learning technologies and data bundles for educators and students to use. In adopting flipped classrooms, educators can use CDs to make videos accessible to students in areas with poor network connectivity.

6.2 Effective use of ICT to adopt flipped classrooms

Throughout my teaching, I have learned that the teacher assumes the role of a facilitator in the flipped classroom by creating space for students to explore. Educators in the flipped learning environment acknowledge students' learning needs and make provision for appropriate learning support, such as explanations, setting up homework, and leading class discussions. Therefore, a paradigm shift toward student-centred approaches is vital since students are the final receivers of knowledge. Individual students need support crucial in the teaching and learning environment. During in-class activities, students do activities and interact with other students in small groups and are engaged in collaborative learning. Active learning enhances student development of social skills as they collaborate with peers (Rotellar & Cain, 2016).

As Bergmann & Sams (2012) indicated, although lecture videos can deliver instruction directly, it does not mean the teacher's role as a facilitator should be replaced. The flipped classroom instructor must create an inquiry-based learning environment where face-to-face teaching is shifted toward a student-centred approach. Through the flipped classroom, the students gain the opportunity to learn independently outside the classroom space, which is essential for achievement as they experience their learning (Fraga & Harmon, 2014; Tomas et al., 2019). Implementing the flipped classroom as an instructional approach helps students retain knowledge since, they take more responsibility for their learning than in a teacher-centred approach (Sigurðardóttir & Heijstra, 2017). Olakanmi (2017) explained that students focus on learning in the flipped classroom approach outside the classroom anytime and anywhere within a conducive learning space. Since they learn at their own pace and time, students' participation, and activeness in flipped learning matters. Thus, students are engaged in several active learning activities, which help them to move from passive listeners to active learners.

In the student-centred classroom, instructors engage students in active learning activities that foster interactive discussion and problem-solving activities that help them to correct misconceptions. The educators seek to engage the students in discussions that enhance their understanding of the concepts and learning outcomes instead of validating correct answers to questions. According to socio-constructivism, it is the role of educators to provide collaborative learning opportunities that create avenues for students to learn with their peers. In this research, the Zoom and Google classroom platforms provided audio and interactive space, allowing teachers and student-teachers to interact. Google classroom allows educators to monitor student work and learning progress so that they can provide constructive feedback. The Zoom and WhatsApp applications have chat features enabling participants to ask questions during collaborative learning. These features provided an enabling communication environment for the teacher educators and student-teachers to interact to promote student-learning collaboration.

Integrating ICT was a critical factor in allowing students to learn irrespective of time and place. However, the lack of training opportunities for teacher educators and student-teachers must be considered by higher institutions to teach and foster knowledge acquisition through the integration of ICT. The teacher educator's failure to integrate ICT affected the skills and competencies of his students (Agyei & Voogt, 2011). ICT is taught as a core subject in the teacher training curriculum, which does not produce any valuable results, so change is needed (Debrah et al., 2021). Policymakers, heads of institutions, and curriculum developers should consider new professional development programmes as part of teacher training and in-service training in the future. It is recommended that ICT be made a requisite tool to be integrated into all subjects as stipulated in the curriculum.

Educators' acceptance of ICT integration as stipulated in the curriculum is informed by their characteristics such as knowledge, skills, competence, and institutional and government commitments like the provision of resources. However, the policies are there to guide educators to do their work as expected, but the needed support is inadequate. For example, educators willing to change their pedagogical practices to adopt ICT in their classroom practices are discouraged due to the lack of support from both institutions and the government, threatening the adoption of ICT for flipped classrooms. Disparities in infrastructural support between the urban and rural settings may lead to the goals of government policies not being attained.

From this research, I conclude that the flipped classroom approach can be seen as a promising pedagogical approach to transform future teaching and learning. Adopting and using the flipped classroom approach requires adequate technology infrastructure, and training for educators and students needs attention from educators and policymakers. However, we expected the institutions to be more resourced in ICT infrastructure after years of ICT policy existence.

Based on the findings, discussions, and conclusion of these studies, I recommend the following:

- online learning for effective implementation at the colleges of education and universities to adequately prepare students and teachers to be up-to-date with the skills and competencies in using ICT to teach and work.
- Internet infrastructure and network connectivity in Ghana need to be upgraded to improve access and quality since they constitute a major challenge that hinders the effective implementation of online learning.
- The universities should begin offering online programs for teachers to upgrade their ICT skills to become technologically inclined.
- ICT and e-learning centres should be provided in each district to serve as satellite learning resource centres for teachers and students to upgrade their skills and knowledge in ICT in all disciplines.
- The government and institutions should provide training and technical support for teachers as an incentive to increase instructors' willingness to design and implement online courses.

6.3 Contribution to the research aims

In my research, I aimed to understand how teacher educators use ICT to adopt flipped classrooms as a pedagogical approach. I identified that most educators found it challenging to shift their pedagogical practice and adopt online teaching during and after the pandemic. Some challenges identified were educators' technology skills and the lack of ICT infrastructure in the colleges. At the onset of the project, we provided some ICT resources in the form of data bundles to all the participants and mobile Wi-fi equipment to one educator. Some student-teachers who could not access the internet at home used these resources for their pre-class activities. Throughout this study, I discussed the crucial factors for educators to use ICT for teaching with teachers and policy makers in Ghana. The findings revealed that sufficient ICT knowledge and skills, ICT infrastructure, and regular use of ICT are required before educators can effectively integrate ICT into their teaching (Paper I). In alleviating the problem, I had discussions with the three teacher educators and some policymakers developing teacher professional development programmes. As a way of preparation to achieve that goal, I initiated the idea of using the flipped classroom with a group of three teacher educators and worked with them throughout the project. I built on my reading from the literature, training, and experience as a chemistry teacher to design some teaching and learning materials. I established online learning platforms, such as Google classroom and zoom.

Moving forward, one important thing I considered was working with other teachers in a collaborative project in the colleges to build support groups. As Romeu et al. (2016) pointed out, collaborating with colleagues with similar ideas helps build a community of practice as they regularly interact. Therefore, educators should be aware of the importance of supporting each other when they all have the same issues that must be addressed and developed. In a way, I expected this support would enhance educator skills in using and integrating ICT to adopt student-centred learning approaches for chemistry teaching and learning. With our collaborative work with the three teacher educators, we were building a mini professional development learning community that could be expanded to include other educators. I have learned that most educators have some ICT knowledge in teaching, but what is lacking is professional development training that can enable them to integrate it sufficiently into their teaching, especially in chemistry. This situation can enable educators to deliver science concepts in a manner that gives students an accurate understanding of how scientists work (Schmidt, 2021).

The findings of this research showed most of the student-teachers benefited from the ICT integration into the teaching and learning of chemistry. Through the model, teacher educators could use the TPACK to design a lesson that can provide opportunities for student-teachers to discuss and reflect on skills and knowledge required to integrate technology in science classroom. Teacher educators acknowledged that flipped learning provided them with an opportunity to utilize different pedagogical approaches and acquainted to the challenges ICT integration in their classroom and become conversant with content, pedagogy, and technology. Through such development teacher educators were able to use their technological knowledge to implement some form of chemistry content with an effective pedagogy as stipulated in the TPACK model (Koehler et al., 2013). Since the teacher educators are professional chemistry teachers with long teaching experience, the issue of the teacher educators organic chemistry content knowledge (CK) and pedagogic content knowledge (PCK) were sufficient. However, some teacher educators technological content knowledge (TCK) was challenging they were not conversant with the technological applications for delivery specific chemistry contents. In summary, I found the intervention as an effective professional development research for the educators and student-teachers for ICT integration and competencies as they developed confidence as they reflect on their use of ICT.

Since the ultimate aim of teacher education is to prepare student-teachers for working in schools, it is encouraging that educators (activists) have an interest in working with ICT. Teacher educators are key players as the nation takes on issues of human rights and sustainable development on their shoulders in the school curriculum, it is important that they are prepared at the colleges of education.

6.4 Reflections and personal learning

Since teaching chemistry in Ghana, South Africa, and Iceland and engaging in online studies with Concordia University, blended learning fascinates me. When I began my research interest in 2018, I started by taking compulsory courses in education, keeping myself up to date on these areas of research interest, and planning my project. In

March 2020, when I presented my project proposal, the COVID-19 virus was making itself felt worldwide. I could not return to Ghana in October for the planned fieldwork. I revamped my approach and turned it into an online research study, an intervention in which students-teachers as participants would undertake online work for one month of flipped learning chemistry as part of their education.

My experiences teaching chemistry using inquiry-based learning and flipped classrooms made me see the potential this research might have on teacher educators, student-teachers, and policymakers in Ghana. I intend to use the knowledge from this research to motivate teachers and students to learn chemistry and change the views teacher educators, policymakers, and other stakeholders in teacher education in Ghana hold on teaching and learning chemistry. I believe flipped inquiry-based classroom teaching could enable educators to shift their classroom teaching from the traditional didactic approach to address students' chemistry learning patterns, for which educators need to adopt pedagogical practices such as active learning that help students to focus on the connections between chemical concepts, chemical substances, and symbolic representations to foster students understanding (Mahaffy, 2006). Further, this approach would enable students to connect learning experiences to real-life situations.

As the project began to take shape, I realized I had taken the project as a simple task. I would need to know something about teaching and learning interventions as experienced by student-teachers in teacher education settings and directed by teacher educators in chemistry education requiring reliable ICT in teacher education. My experience tells me now that educational research in real settings can be cumbersome and expensive. When I changed this project, my experience did not tell me how complicated my project tasks would become when conducted from a distance. Also, my graduate education in teaching and research did not reveal a straightforward theoretical approach or framework for understanding the multidisciplinary knowledge involved in this research that I would need to pull into the assessment and evaluation of my attempt to introduce change.

My online learning searches helped me find ways to transform teaching through the flipped classroom. I was overwhelmed by the number and nature of research studies regarding the use of ICT and flipped learning went from only a few in 2018 to many in 2020 during the pandemic. But, with encouragement from others, I began to look at my work as a real-time evaluation of a system of my own making. As I neared the end of this work, I realized that I did have good data, it was just about innovative systems being tested in three schools and the skills and competencies needed to drive the innovation. I had become engaged in assessment and evaluation; an important step would be completing my current work by conducting a SWOT analysis.

Based on the findings from the project, it will be interesting to expand the project to many students and compare the findings before making conclusions. For instance, the selection of schools that have similar characteristics, e.g., colleges that are all urban or all sub-urban and maybe mixed since they may have almost the same ICT resources. Also, I look forward to selecting colleges that train only science teachers to compare student-teachers' abilities. I propose that future studies consider the flipped classrooms impact on student academic achievement in any subject or educational level.

In the current study, the participants comprised science and home economics students with different science backgrounds. For the last 30-40 years, student centred methods based on a variety of active learning models have aroused interest among students and teachers in many parts of the world. Policy makers and the private sector encourage the use of ICT in education. However, the promise of ICT is not yet fully used as many have not fully realised what ICT can do. What students and teachers can do without ICT and with ICT depends on the affordances of the technology used in training teachers (Conole & Dyke, 2004). Clear affordances are necessary for effective usability in the proposed setting.

.

References

Aboagye, E., & Yawson, J. A. (2020). Teachers' perception of the new educational curriculum in Ghana. *African Educational Research Journal*, *8*(1), 6-12. https://files.eric.ed.gov/fulltext/EJ1242678.pdf

Abonyi, U. K., Yeboah, R., & Luguterah, A. W. (2020). Exploring work environment factors influencing the application of teacher professional development in Ghanaian basic schools. *Cogent Social Sciences*, *6*(1), https://doi:10.1080/23311886.2020.1778915.

Adarkwah, M. A. (2020). "I'm not against online teaching, but what about us?": ICT in Ghana post Covid-19. *Education and Information Technologies*, *26*(2), 1665-1685. https://doi.org/10.1007/s10639-020-10331-z.

Addae, D., & Quan-Baffour, K. (2018). The pedagogical value of the lecture method: The case of a non-formal education program in Ghana. *Africa Education Review*, *15*(1), 123-137. https://doi.org/10.1080/18146627.2016.1256748.

Adedoja, G. (2016). Pre-service teachers challenges and attitude toward the flipped classroom. *African Educational Research Journal*, *4*(1), 13-18. https://files.eric.ed.gov/fulltext/EJ1216177.pdf

Adegoke, K. A. (2003). Capacity building of lead teacher training institutions in sub-Saharan Africa: Ghana. UNESCO digital library. https://unesdoc.unesco.org/ark:/48223/pf0000143483.

Adu-Gyamfi, K., & Otami, D. C. (2020). In search of an effective teacher: Ghana's move towards achieving sustainable education through teacher education reforms. *International Journal of Higher Education*, *9*(4), 216-232. https://doi.org/10.5430/ijhe.v9n4p216.

Adu-Yeboah, C., Kwaah, C., Abreh, M., & Amuah, E. (2014). An investigation of the practical component of the Initial Teacher Education Programme. *Cape Coast, Ghana: University of Cape Coast Publication*.

Agarwal, Y. P. (1986). *Statistical methods, concepts, applications and computations*, Sterling publishers (pvt) ltd. New Delhi.

Agyei, D. D., & Voogt, J. (2011). ICT use in the teaching of mathematics: Implications for professional development of pre-service teachers in Ghana. *Education and Information Technologies*, *16*(4), 423-439. https://doi:10.1007/s10639-010-9141-9.

Agyei, D. D., & Voogt, J. (2012). Developing technological pedagogical content knowledge in pre-service mathematics teachers through collaborative design. *Australasian Journal of Educational Technology*, *28*(4), 547-564. https://doi.org/10.14742/ajet.827

Aidoo, B., Boateng, S. K., Kissi, P. S., & Ofori, I. (2016). Effect of problem-based learning on students' achievement in chemistry. *Journal of Education and Practice*, *7*(33), 103-108. https://files.eric.ed.gov/fulltext/EJ1122651.pdf

Aidoo, B., Tsyawo, J., Quansah, F., & Boateng, S. K. (2022). Students learning experiences in a flipped classroom: A case study in Ghana. *International Journal of Education and Development using Information and Communication Technology*, *18*(1), 67-85. https://files.eric.ed.gov/fulltext/EJ1345826.pdf

Akyeampong, K. (2017). Teacher educators practice and vision of good teaching in teacher education reform context in Ghana. *Educational Researcher*, *46*(4), 194-203. https://psycnet.apa.org/record/2017-24457-004.

Akurang-Parry, K. O. (2007). Problems of seeding and harvesting higher education in postcolonial Ghana: Historical antecedents and contemporary trends. In Afoláyan, M. O. (editor) *Higher Education in Postcolonial Africa: Paradigms of Development, Decline, and Dilemmas*, pp. 39-55. Africa Research and Publications.

Almodaires, A. A., Alayyar, G. M., Almsaud, T. O., & Almutairi, F. M. (2019). The effectiveness of flipped learning: A quasi-experimental study of the perceptions of Kuwaiti pre-service teachers. *International Education Studies*, *12*(1), 10-23. https://eric.ed.gov/?id=EJ1201519.

Al-Zahrani, A. M. (2015). From passive to active: The impact of the flipped classroom through social learning platforms on higher education students creative thinking. *British Journal of Educational Technology*, *46*(6), 1133-1148. https://doi.org/10.1111/bjet.12353.

Anamuah-Mensah, J., & Mereku, D. K. (2005). Ghanaian JSS2 students´ abysmal mathematics achievement in TIMSS 2003: A consequence of the basic school mathematics curriculum. *Mathematics Connection*, *5*(1), 1-13. https://doi.org/10.4314/mc.v5i1.21489.

Anamuah-Mensah, J., Mereku, D. K., & Ghartey-Ampiah, J. (2008). TIMSS 2007 Ghana Report: Findings from IEA's trends in international mathematics and science study at the eighth grade. *Accra: Ministry of Education*. https://www.academia.edu/33123728/TIMSS_2007_Ghana_Report_Findings_from_IEAs_Trends_in_International_Mathematics_and_Science_Study_at_the_Eighth_Grade

Aničić, K. P., Divjak, B., & Arbanas, K. (2016). Preparing ICT graduates for real-world challenges: Results of a meta-analysis. *IEEE Transactions on Education*, *60*(3), 191-197. https://doi:10.1109/TE.2016.2633959.

Anim-Eduful, B., & Adu-Gyamfi, K. (2022). Chemistry students' conceptual understanding of organic qualitative analysis. *Pedagogical Research*, *7*(4). https://doi.org/10.29333/pr/12307.

Antwi-Boampong, A., & Bokolo, A. J. (2021). Towards an institutional blended learning adoption model for higher education institutions. *Technology, Knowledge and Learning*, 27, 765-784 (2022). https://doi.org/10.1007/s10758-021-09507-4.

Arsal, Z. (2017). The impact of inquiry-based learning on the critical thinking dispositions of pre-service science teachers. *International Journal of Science Education*, *39*(10), 1326-1338.

Asare, K. B., & Nti, S. K. (2014). Teacher education in Ghana: A contemporary synopsis and matters arising. *Sage Open*, *4*(2), htpps://doi.org/10.1177/2158244014529781.

Ascar Sesen, B., & Tarhan, L. (2013). Inquiry-based laboratory activities in electrochemistry: High school students' achievements and attitudes. *Research in Science Education*, *43*, 413-435.http://doi.org/10.1007/s11165-011-9275-9.

Aşıksoy, G., & Ozdamli, F. (2017). The flipped classroom approach based on the 5E learning cycle model-5ELFA. *Croatian Journal of Education: Hrvatski časopis za odgoj i obrazovanje*, *19*(4), 1131-1166. https://doi.org/10.15516/cje.v19i4.2564.

Asomah, R. K., Agyei, D. D., & Assamah, G. (2022). A SWOT analysis of e-learning integration in University of Cape Coast. *European Journal of Education and Pedagogy*, *3*(4), 1-8. https://doi.org/10.24018/ejedu.2022.3.4.373.

Atta, G., & Mensah, E. (2015). Exploring teachers' perspectives on the availability of professional development programs: A case of one district in Ghana. *International Journal of Humanities and Social Science*, *5*(7), 48-59. https://doi.org/10.1080/25783858.2022.2065923.

Atuahene, E. (2019). Integrating technology (ICT tools) in teaching and learning: A case study of Offinso college of education, Offinso, Ghana. *European Journal of Education Studies*.5(11), https://doi.org:10.5281/zenodo.2392717.

Barak, M. (2017). Cloud pedagogy: Utilizing web-based technologies for the promotion of social constructivist learning in science teacher preparation courses. *Journal of Science Education and Technology*, *26*, 459-469. https://doi.org:10.1007/s10956-017-9691-3.

Barrows, H. S., & Tamblyn, R. M. (1980). *Problem-based learning: An approach to medical education*. Springer Publishing Company.

Bergmann, J., & Sams, A. (2012). *Flip your classroom: Reach every student in every class every day*. International Society for Technology in Education.

Berk, R. A. (2009). Multimedia teaching with video clips: TV, movies, YouTube, and mtvU in the college classroom. *International Journal of Technology in Teaching & Learning*, *5*(1), 1-21. https://www.scirp.org/(S(lz5mqp453ed%20snp55rrgjct55))/reference/referencespapers.aspx?referenceid=1241236.

Berrett, D. (2012). How flipping the classroom can improve the traditional lecture. *The Chronicle of Higher Education*, *12*(19), 1-3. http://commons.marymount.edu/instructingonline/wp-content/uploads/sites/135/2013/07/Flipping-The-Chronicle.pdf

Bishop, J., & Verleger, M. A. (2013). The flipped classroom: A survey of the research. 120th *ASEE Annual Conference & Exposition*, 30, 1-18. https://doi.org:10.18260/1-2–22585.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Handbook I: Cognitive domain*. New York: David McKay.

Blum, C., Bunke, D., Hungsberg, M., Roelofs, E., Joas, A., Joas, R., ... & Stolzenberg, H. C. (2017). The concept of sustainable chemistry: Key drivers for the transition towards sustainable development. *Sustainable Chemistry and Pharmacy*, *5*, 94-104. https://doi.org:10.1016/j.scp.2017.01.001.

Blume, B. D., Ford, J. K., Baldwin, T. T., & Huang, J. L. (2010). Transfer of training: A meta-analytic review. *Journal of Management*, *36*(4), 1065-1105. https://doi.org/10.1177/0149206309352880.

Boelens, R., Voet, M., & De Wever, B. (2018). The design of blended learning in response to student diversity in higher education: Instructors' views and use of differentiated instruction in blended learning. *Computers & Education*, *120*, 197-212. https://doi.org/10.1016/j.compedu.2018.02.009

Boye, E. S. (2019). Problem-based learning in the teaching and learning of mathematics for pre-service teachers in Ghana: A literature review. *Texila International Journal of Academic Research*. https://doi.org:10.21522/TIJAR.2014.SE.19.02.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How people learn*. Washington, DC: National Academy Press.

Brown, T. L. (2003). *Making truth: Metaphor in science*. University of Illinois Press.

Buabeng, I., Ntow, F. D., & Otami, C. D. (2020). Teacher education in Ghana: Policies and practices. *Journal of Curriculum and Teaching*, *9*(1), 86-95. https://doi.org:10.5430/jct.v9n86.

Buabeng-Andoh, C. (2012). An exploration of teachers' skills, perceptions and practices of ICT in teaching and learning in Ghanaian second-cycle schools. *Contemporary Educational Technology*, *3*(1), 36-49. https://doi.org/10.30935/cedtech/6066.

Buabeng-Andoh, C., & Yidana, I. (2015). Teachers' ICT usage in second-cycle institutions in Ghana: A qualitative study. *International Journal of Education and Development using ICT*, *11*(2), 104-112. https://eric.ed.gov/?id=EJ1074160.

Burke, A. S., & Fedorek, B. (2017). Does "flipping" promote engagement?: A comparison of a traditional, online, and flipped class. *Active Learning in Higher Education*, *18*(1), 11-24. https://doi.org/10.1177/1469787417693487

Büyüköztürk, Ş., Çokluk, Ö., & Köklü, N. (2013). *Statistics in Social Sciences* (13th Edition). Ankara: Pegem Academy Press.

Bybee, R. W. (2011). Scientific and engineering practices in K-12 classrooms. *Science Teacher*, *78*(9), 34-40. http://edcipr.com/wp-content/uploads/2017/02/Science-Engineering_Practices.pdf

Bybee, R. W. (2014). NGSS and the next generation of science teachers. *Journal of Science Teacher Education*, *25*(2), 211-221. htpps://doi.org:10.1007/s10972-014-9381-4.

Cervantes, B., Hemmer, L., & Kouzekanani, K. (2015). The impact of project-based learning on minority student achievement: Implications for school redesign. *Education Leadership Review of Doctoral Research*, *2*(2), 50-66. https://eric.ed.gov/?id=EJ1105713.

Chao, C. Y., Chen, Y. T., & Chuang, K. Y. (2015). Exploring students learning attitude and achievement in flipped learning supported computer-aided design curriculum: A study in high school engineering education. *Computer Applications in Engineering Education*, *23*(4), 514-526. https://doi.org/10.1002/cae.21622.

Chen, L., Chen, T. L., & Chen, N. S. (2015). Students' perspectives of using cooperative learning in a flipped statistics classroom. *Australasian Journal of Educational Technology*, *31*(6), 621-640. https://doi.org/10.14742/ajet.1876.

Childs, P. E., & Sheehan, M. (2009). What's difficult about chemistry? An Irish perspective. *Chemistry Education Research and Practice*, *10*(3), 204-218. https://doi.org/10.1039/b914499b.

Chis, A. E., Moldovan, A. N., Murphy, L., Pathak, P., & Muntean, C. H. (2018). Investigating flipped classroom and problem-based learning in a programming module for computing conversion course. *Journal of Educational Technology & Society*, *21*(4), 232-247. https://www.jstor.org/stable/26511551.

Cobb, P., Confrey, J., DiSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher*, *32*(1), 9-13. https://doi.org/10.3102/0013189X032001009.

Coburn, C. E., & Penuel, W. R. (2016). Research—practice partnerships in education: Outcomes, dynamics, and open questions. *Educational Researcher*, *45*(1), 48-54. https://doi.org/10.3102/0013189X16631750.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Second edition. New York, Lawrence Earlbaum Associates.

Coll, R. K., & Taylor, N. (2009). Special issue on scientific literacy. *International Journal of Environmental and Science Education*, 4, 197—349.

Conole, G., & Dyke, M. (2004). What are the affordances of information and communication technologies. *ALT-J, Research in Learning Technology, 12*(2), 113-124. https://doi.org/10.1080/0968776042000216183.

Dailey, D., & Robinson, A. (2017). Improving and sustaining elementary teachers' science teaching perceptions and process skills: A postintervention study. *Journal of Science Teacher Education*, *28*(2), 169-185. https://doi.org/10.1080/1046560X.2016.1277601.

Davenport, C. E. (2018). Evolution in student perceptions of a flipped classroom in a computer pProgramming course. *Journal of College Science Teaching*, *47*(4). https://doi.org/10.2505/4/JCST18_047_04_30.

Davies, R. S., Dean, D. L., & Ball, N. (2013). Flipping the classroom and instructional technology integration in a college-level information systems spreadsheet course. *Educational Technology Research and Development*, *61*(4), 563-580. http://dx.doi.org/10.1007/s11423-013-9305-6.

de Dieu Kwitonda, J., Sibomana, A., Gakuba, E., & Karegeya, C. (2021). Inquiry-based experimental design for enhancement of teaching and learning of chemistry concepts. *African Journal of Educational Studies in Mathematics and Sciences*, *17*(2), 13-25. https://www.ajol.info/index.php/ajesms/article/view/220946.

de Vos, A. S., Delport, C. S. L., Fouche, C., & Strydom, H. (2011). *Research at grass roots: A primer for the social science and human professions*. Van Schaik Publishers.

de Vos, W., Bulte, A. M. W., & Pilot, A. (2002). Chemistry curricula for general education: Analysis and elements of a design. Gilbert, J. K., De Jong, R. Justi, O., Treagustand, D. F., & Van Driel, J. H. (Eds.), *Chemical education: Towards Research-based Practice* (101—124).

Debrah, A., Yeyie, P., Gyimah, E., Halm, G. G., Sarfo, F. O., Mensah, T., ... & Vlachopoulos, D. (2021). Online instructional experiences in an unchartered field. The challenges of student-teachers of a Ghanaian College of Education. *Journal of Digital Learning in Teacher Education*, *37*(2), 99-110. https://doi.org/10.1080/21532974.2021.1892553.

DeCoito, I., & Richardson, T. (2018). Teachers and technology: Present practice and future directions. *Contemporary Issues in Technology and Teacher Education*, *18*(2), 362-378. https://eric.ed.gov/?id=EJ1181412.

Denzin, N. K. (2012). Triangulation 2.0. *Journal of Mixed Methods Research*, *6*(2), 80-88. https://doi.org/10.1177/1558689812437186.

Dewey, J. (1986). Experience and education. *The Educational Forum*, *50*(3), 241-252. https://doi.org/10.1080/00131728609335764.

Domin, D. S., Al-Masum, M., & Mensah, J. (2008). Students' categorizations of organic compounds. *Chemistry Education Research and Practice*, *9*(2), 114-121. https://doi.org/10.1039/B806226A.

Donohue, K., Buck, G. A., & Akerson, V. (2020). Where's the science? Exploring new science teacher educator's theoretical and practical understandings of scientific inquiry. *International Journal of Research in Education and Science*, *6*(1), 1-13. https://doi.org/10.46328/ijres.v6i1.571.

Dove, A., & Dove, E. (2017). Flipping preservice elementary teachers' mathematics anxieties. *Contemporary Issues in Technology and Teacher Education*, *17*(3), 312-335. https://www.learntechlib.org/primary/p/171621/.

Eilks, I., Rauch, F., Ralle, B., & Hofstein, A. (2013). How to allocate the chemistry curriculum between science and society. Eilks, I., & Hofstein, A. (Eds.) *Teaching chemistry-A study book* (pp. 1-36). Rotterdam, Sense.

Engida, T. (2014). Chemistry teacher professional development using the technological pedagogical content knowledge (TPACK) framework. *African Journal of Chemical Education*, *4*(3), 2-21. https://www.ajol.info/index.php/ajce/article/view/104084

Ertmer, P. A. (2005). Teacher pedagogical beliefs: The final frontier in our quest for technology integration? *Educational technology research and development*, *53*(4), 25-39. https://doi.org/10.1007/BF02504683.

Eshun, I., & Ashun, E. A. (2013). Teacher preparation: The case of the two years "in" and one year "out" policy of the in-in-out programme of colleges of education in Ghana. *Development Country Studies*, *3*(6), 77-88. https://core.ac.uk/download/pdf/234634504.pdf

Fadol, Y., Aldamen, H., & Saadullah, S. (2018). A comparative analysis of flipped, online and traditional teaching: A case of female Middle Eastern management students. *The International Journal of Management Education*, *16*(2), 266-280. https://doi.org/10.1016/j.ijme.2018.04.003.

Fautch, J. M. (2015). The flipped classroom for teaching organic chemistry in small classes: is it effective? *Chemistry Education Research and Practice*, *16*(1), 179-186. https://doi.org/10.1039/C4RP00230J.

Figueiró, P. S., & Raufflet, E. (2015). Sustainability in higher education: A systematic review with a focus on management education. *Journal of Cleaner Production*, *106*, 22-33. https://doi.org/10.1016/j.jclepro.2015.04.118 .

Findlay-Thompson, S., & Mombourquette, P. (2014). Evaluation of a flipped classroom in an undergraduate business course. *Business Education & Accreditation*, *6*(1), 63-71. https://ssrn.com/abstract=2331035.

Flick, U. (2018). Triangulation in data collection. In *The SAGE handbook of qualitative data collection*, pp. 527-544. https://doi.org/10.4135/9781526416070.

Fletcher, J. (2018). Performance in Mathematics and Science in basic schools in Ghana. *Academic Discourse: An International Journal*, *10*(1), 1-18.

FLN, (2014). What is flipped learning? The four pillars of FLIP. *Flipped Learning Network*, *501*(2). Summary of research, reports, and studies. Retrieved from http://www.flippedlearning.org/domain/41

Flores, O., Del-Arco, I., & Silva, P. (2016). The flipped classroom model at the university: Analysis based on professors' and students' assessment in the educational field. *International Journal of Educational Technology in Higher Education*, *13*(1), 1-12. https://doi.org/10.1186/s41239-016-0022-1.

Foster, P. J. (1966). *Education and social change in Ghana*. London, Routledge.

Fraga, L. M., & Harmon, J. (2014). The flipped classroom model of learning in higher education: An investigation of preservice teachers' perspectives and achievement. *Journal of Digital Learning in Teacher Education*, *31*(1), 18-27. https://doi.org/10.1080/21532974.2014.967420.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23), 8410-8415. https://doi.org/10.1073/pnas.1319030111

Galway, L. P., Corbett, K. K., Takaro, T. K., Tairyan, K., & Frank, E. (2014). A novel integration of online and flipped classroom instructional models in public health higher education. *BMC Medical Education*, *14*(1), 1-9. htpp://dx.doi.org/10.1186/1472-6920-14-181

GoG. (2003). *The Ghana ICT for accelerated development (ICT4AD) policy*. Government of Ghana. https://nita.gov.gh/theevooc/2017/12/Ghana-ICT4AD-Policy.pdf

Graziano, K. J. (2017). Peer teaching in a flipped teacher education classroom. *TechTrends*, *61*(2), 121-129. https://doi.org/10.1007/s11528-016-0077-9

Gyampoh, A. O., Ayitey, H. K., Fosu-Ayarkwah, C., Ntow, S. A., Akossah, J., Gavor, M., & Vlachopoulos, D. (2020). Tutor perception on personal and institutional preparedness for online teaching-learning during the COVID-19 crisis: The case of Ghanaian colleges of education. *African Educational Research Journal*, *8*(3), 511-518. https://doi.org/10.30918/aerj.83.20.088.

Hajhashemi, K., Caltabiano, N., & Anderson, N. (2016). Integrating digital technologies in the classroom: Lecturers' views on the flipped classroom approach. *Australian and International Journal of Rural Education*, *26*(3), 18-29. https://doi.org/10.47381/aijre.v26i3.74

Hodson, D. (2009). *Teaching and learning about science: Language, theories, methods, history, traditions, and values*. Rotterdam, Sense

Hrastinski, S. (2019). What do we mean by blended learning? *TechTrends*, *63*(5), 564-569. https://doi.org/10.1007/s11528-019-00375-5

Institute of Education. (2005). Three-year diploma in basic education: Course structure (revised syllabus). Cape Coast, Ghana: University of Cape Coast.

Ismail, N., & Elias, S. (2014). Inquiry-based learning: An innovative teaching method inquiry-based learning: A new approach to classroom learning. *English Language Journal,* 1(2), 13—24.

Jeong, J. S., Cañada-Cañada, F., & González-Gómez, D. (2018). The study of flipped classroom for pre-service science teachers. *Education Sciences*, *8*(4), 163. https://doi.org/10.3390/educsci8040163

Jeong, Y., & Seo, J. (2015). Development of the flipped classroom teaching and learning model for the smart classroom. *Journal of the Korean Association of Information Education*, *19*(2), 175-186. https://doi.org/10.14742/ajet.157

Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher*, *33*(7), 14-26. https://doi.org/10.3102/0013189X033007014.

Johnstone, A. H. (2000). Teaching of chemistry-logical or psychological? *Chemistry Education Research and Practice*, *1*(1), 9-15. https://doi.org/10.1039/A9RP90001B

Johnstone, A. H. (2010). You can't get there from here. *Journal of Chemical Education*, *87*(1), 22-29. https://doi.org/10.1021/ed800026d.

Jonker, H., März, V., & Voogt, J. (2018). Teacher educators' professional identity under construction: The transition from teaching face-to-face to a blended curriculum. *Teaching and Teacher Education*, *71*, 120-133. https://doi.org/10.1016/j.tate.2017.12.016

Juuti, K., Lavonen, J., Salonen, V., Salmela-Aro, K., Schneider, B., & Krajcik, J. (2021). A teacher-researcher partnership for professional learning: Co-designing project-based learning units to increase student engagement in science classes. *Journal of Science Teacher Education*, *32*(6), 625-641. https://doi.org/10.1080/1046560X.2021.1872207

Kafyulilo, A., Fisser, P., Pieters, J., & Voogt, J. (2015). ICT use in science and mathematics teacher education in Tanzania: Developing technological pedagogical content knowledge. *Australasian Journal of Educational Technology*, *31*(4).

Kafyulilo, A., Fisser, P., & Voogt, J. (2016). Factors affecting teachers' continuation of technology use in teaching. *Education and Information Technologies*, *21*, 1535-1554. https://doi.org/10.1007/s0639-015-9398-0.

King, D. (2012). New perspectives on context-based chemistry education: Using a dialectical sociocultural approach to view teaching and learning. *Studies in Science Education*, *48*(1), 51-87. https://doi.org/10.1080/03057267.2012.655037.

Knowles, M. S., Holton III, E. F., & Swanson, R. A. (2014). *The adult learner: The definitive classic in adult education and human resource development*. Routledge.

Koehler, M. J., Mishra, P., & Cain, W. (2013). What is technological pedagogical content knowledge (TPACK)? *Journal of Education*, *193*(3), 13-19. https://doi.org/10.1177/002205741319300303.

Kramer, R. M. De, Masters, J., Dwyer, L. M. O., Russell, M., Magidin, R., Masters, J., & Dwyer, L. M. O. (2012). Relationship of online teacher professional development to seventh-grade teachers' and students' knowledge and practices in English language arts. *The Teacher Educator 47*(3):236-259. https://doi.org/10.1080/08878730.2012.685795.

Kruchoski, P. (2016). Skills you need to thrive tomorrow—and the universities that will help you get them. https://www.weforum.org/agenda/2016/08/10-skills-you-need-to-thrive-tomorrow-and-the-universities-that-will-help-you-get-them/

Lai, C. L., & Hwang, G. J. (2016). A self-regulated flipped classroom approach to improving students learning performance in a mathematics course. *Computers & Education*, *100*, 126-140. https://doi.org/10.1016/j.compedu.2016.05.006

Lange, K., Kleickmann, T., & Möller, K. (2011). Elementary teachers' pedagogical content knowledge and student achievement in science education. In C. Bruguiere, A. Tiberghien & P. Clément (Eds.), *Science Learning and Citizenship*. Proceedings of the Ninth ESERA-Conference 2011. Lyon. https://www.uni-muenster.de/imperia/md/content/didaktik_des_sachunterrichts/dokumente/literaturmoeller/elementary_teachers_pedagogical_content_knowledge....pdf

Laurie, R., Nonoyama-Tarumi, Y., Mckeown, R., & Hopkins, C. (2016). Contributions of education for sustainable development (ESD) to quality education: A synthesis of research. *Journal of Education for Sustainable Development*, *10*(2), 226-242. https://doi.org/10.1177/0973408216661442.

Laursen, S. L., Hassi, M. L., & Hough, S. (2016). Implementation and outcomes of inquiry-based learning in mathematics content courses for pre-service teachers. *International Journal of Mathematical Education in Science and Technology*, *47*(2), 256-275. https://doi.org/10.1080/0020739X.2015.1068390.

Leach, J., & Scott, P. (2000). The concept of learning demands as a tool for designing teaching sequences. Paper prepared for the meeting Research-based teaching sequences, Université Paris VII, France, November 2000. http://natturutorg.is/wp-content/uploads/2016/10/LeachScottSequences2000.pdf

Lee, D., Morrone, A. S., & Siering, G. (2018). From swimming pool to collaborative learning studio: Pedagogy, space, and technology in a large active learning classroom. *Educational Technology Research and Development*, *66*, 95-127. https://doi.org/10.1007/s11423-017-9550-1.

Leigh, D. (2009). SWOT analysis. In Silber, K. H., Foshay, W. R., Watkins, R., Leigh, D., Moseley, J. L., & Dessinger, J.C. (Eds.) *Handbook of Improving Performance in the Workplace*. https://doi.org/10.1002/9780470592663.ch24

Lauwerier, T., & Akkari, A. (2015). Teachers and the quality of basic education in sub-saharan Africa. *Education Research and Foresight*: Working Papers Series, (11). http://archive-ouverte.unige.ch

Leonard, N. C., & Nwanekezi, A. U. (2018). Effects of guided inquiry and task hierarchy analysis model in cooperative learning strategy on chemistry students' performance in Imo State. *European Scientific Journal, 14*(25), 54-62. https://doi.org/10.19044/esj.2018.v14n25p54.

Levy, F. (2010). How technology changes demands for human skills. OECD Education Working Papers, No. 45, OECD Publishing. http://dx.doi.org/10.1787/5kmhds6czqzq-en.

Liu, X. (2013). Expanding notions of scientific literacy: A reconceptualization of aims of science education in the knowledge society. In *Science education for diversity: Theory and Practice*, pp. 23-39. https://doi.org/10.1007/978-94-007-4563-6_2.

Long, T., Cummins, J., & Waugh, M. (2017). Use of the flipped classroom instructional model in higher education: Instructors' perspectives. *Journal of Computing in Higher Education*, *29*(2), 179-200. https://doi.org/10.1007/s12528-016-9119-8.

Love, B., Hodge, A., Corritore, C., & Ernst, D. C. (2015). Inquiry-based learning and the flipped classroom model. *Primus*, *25*(8), 745-762. https://doi.org/10.1080/10511970.2015.1046005.

Mahaffy, P. (2004). The future shape of chemistry education. *Chemistry Education Research and Practice*, *5*(3), 229-245. https://doi.org/10.1039/B4RP90026J.

Mahaffy, P. (2006). Moving chemistry education into 3D: A tetrahedral metaphor for understanding chemistry. Union Carbide Award for Chemical Education. *Journal of Chemical Education*, *83*(1), 49. https://doi.org/10.1021/ed083p49.

Mason, G. S., Shuman, T. R., & Cook, K. E. (2013). Comparing the effectiveness of an inverted classroom to a traditional classroom in an upper-division engineering course. *IEEE Transactions on Education*, *56*(4), 430-435. https://doi.org/10.1109/TE.2013.2249066

Matlin, S. A., Mehta, G., Hopf, H., & Krief, A. (2016). One-world chemistry and systems thinking. *Nature Chemistry*, *8*(5), 393-398. https://doi.org/10.1038/nchem.2498.

Maycock, K. W., Lambert, J., & Bane, D. (2018). Flipping learning not just content: A 4-year action research study investigating the appropriate level of flipped learning. *Journal of Computer Assisted Learning*, *34*(6), 661-672. https://doi.org/10.1111/jcal.12274

Mayer, R. E. (2004). Should there be a three-strikes rule against pure discovery learning? *American Psychologist*, *59*(1), 14—19. https://doi.org/10.1037/0003-066X.59.1.14

Mayring, P. (2000). *Qualitative inhaltsanalyse: Grundlagen und techniken* [Qualitative content analysis: Basics and techniques]. Deutscher Studien Verlag

McKenney, S., & Reeves, T. C. (2018). *Conducting educational design research*. Routledge.

Merriam, S. B., & Bierema, L. L. (2013). *Adult learning: Linking theory and practice*. John Wiley & Sons.

Merriam, S. B., & Tisdell, E. J. (2015). *Qualitative research: A guide to design and implementation*. John Wiley & Sons.

MoE. (2015). *ICT in Education Policy*. Ministry of Education, Accra, Ghana. https://planipolis.iiep.unesco.org/sites/default/files/ressources/ghana_ict_in_education_policy_august_2015.pdf

MoE. (2017). *The National Teacher Education Curriculum Framework: The Essential Elements of Initial Teacher Education*. Ministry of Education, Accra, Ghana. https://uew.edu.gh/sites/default/files/Announcement%20Files/National%20Teacher%20Education%20Curriculum%20Framework%20.pdf

MoE. (2019). *Science curriculum for primary schools*. Ministry of Education, Accra, Ghana t, https://nacca.gov.gh/wp-content/uploads/2019/04/SCIENCE-UPPER-PRIMARY-B4-B6.pdf

MoESS. (2012). Teaching syllabus for Colleges of Education. Ministry of Education Science and Sports Accra-Ghana.

Moll, R., Pieschl, S., & Bromme, R. (2015). Blessed oblivion? Knowledge and metacognitive accuracy in online social networks. *International Journal of Developmental Science*, *9*(2), 57-60. https://eric.ed.gov/?id=EJ1144154

Mooring, S. R., Mitchell, C. E., & Burrows, N. L. (2016). Evaluation of a flipped, large-enrolment organic chemistry course on student attitude and achievement. *Journal of Chemical Education*, *93*(12), 1972-1983. https://doi.org/10.1021/acs.jchemed.6b00367

Morgan, D. L. (2013). *Integrating qualitative and quantitative methods: A pragmatic approach*. Sage publications.

Murillo-Zamorano, L. R., Sánchez, J. Á. L., & Godoy-Caballero, A. L. (2019). How the flipped classroom affects knowledge, skills, and engagement in higher education: Effects on students' satisfaction. *Computers & Education*, https://doi.org/10.1016/j.compedu.2019.103608.

NaCCA. (2019). Ministry of Education English syllabus for primary 4-6. National Council for Curriculum Assessment. https://nacca.gov.gh/wp-content/uploads/2019/06/englishb4-B6.pdf

National Research Council. (2011). *Successful K-12 STEM education: Identifying effective approaches in science, technology, engineering, and mathematics*. National Academies Press.

Nielsen, L. (2012). Five reasons I'm not flipping over the flipped classroom. *Technology & Learning*, 32 (10), p. 46. https://www.techlearning.com/tl-advisor-blog/3360

O'Dwyer, A., & Childs, P. E. (2017). Who says organic chemistry is difficult? Exploring perspectives and perceptions. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(7), 3599-3620. https://doi.org/10.12973/eurasia.2017.00748a.

Olakanmi, E. E. (2017). The effects of a flipped classroom model of instruction on students' performance and attitudes towards chemistry. *Journal of Science Education and Technology*, *26*(1), 127-137. https://doi.org/10.1007/s10956-016-9657-x

OECD. (2017). New approach needed to deliver on technology potential in schools. https://www.oecd.org/education/new-approach-needed-to-deliver-on-technologys-potential-in-schools.htm

OECD. (2015). Employment of ICT specialists across the economy, as share of total employment. http://www.oecd.org/internet/broadband/ oecdkeyictindicators.htm

Osborne, J. (2007). Science education for the twenty-first century. *Eurasia Journal of Mathematics, Science and Technology Education*, *3*(3), 173-184. https://doi.org/10.12973/ejmste/75396

Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections*. London: The Nuffield Foundation. https://www.nuffieldfoundation.org/wp-content/uploads/2019/12/Sci_Ed_in_Europe_Report_Final1.pdf

Ozudogru, M., & Aksu, M. (2020). Pre-service teachers' achievement and perceptions of the classroom environment in flipped learning and traditional instruction classes. *Australasian Journal of Educational Technology*, *36*(4), 27-43. https://doi.org/10.14742/ajet.5115

Paristiowati, M., Fitriani, E., & Aldi, N. H. (2017). The effect of inquiry-flipped classroom model toward students' achievement on chemical reaction rate. AIP Conference Proceedings 1868(1):030006. https://doi.org/10.1063/1.4995105

Patton, M. Q. (1980). Making methods choices. *Evaluation and Program Planning*, *3*(4), 219-228. https://doi.org/10.1016/0149-7189(80)90036-1

Pedaste, M., Mäeots, M., Siiman, L. A., De Jong, T., Van Riesen, S. A., Kamp, E. T., ... & Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review*, *14*, 47-61. https://doi.org/10.1016/j.edurev.2015.02.003

Petillion, R. J., & McNeil, W. S. (2020). Student experiences of emergency remote teaching: Impacts of instructor practice on student learning, engagement, and well-being. *Journal of Chemical Education*, *97*(9), 2486-2493. https://doi.org/10.1021/acs.jchemed.0c00733.

Phillips, D. C. (1995). The good, the bad, and the ugly: The many faces of constructivism. *Educational Researcher*, *24*(7), 5-12. https://doi.org/10.3102/0013189X024007005

Phillips, D. C. (1997). Coming to grips with radical social constructivism. *Science & Education*, *6*(1), 85-104. https://doi.org/10.1023/A:1008658528097.

Piaget, J., & Duckworth, E. (1970). Genetic epistemology. *American Behavioural Scientist*, *13*(3), 459-480. https://doi.org/10.7312/piag91272

Pilgrim, M., Hornby, G., & Macfarlane, S. (2018). Enablers and barriers to developing competences in a blended learning program for specialist teachers in New Zealand. *Educational Review*, *70*(5), 548-564. https://doi.org/10.1080/00131911.2017.1345860

Pinto, R. (2019). The effect of western formal education on the Ghanaian educational system and cultural identity. *Journal of Negro Education*, *88*(1), 5-16. https://doi.org/10.7709/jnegroeducation.88.1.0005

Poon, J. (2014). A cross-country comparison on the use of blended learning in property education. *Property management*, *32*(2), 154-175. https://doi.org/10.1108/PM-04-2013-0026

Porter, W. W., & Graham, C. R. (2016). Institutional drivers and barriers to faculty adoption of blended learning in higher education. *British Journal of Educational Technology*, *47*(4), 748-762. https://doi.org/10.1111/bjet.12269

Prensky, M. R. (2010). *Teaching digital natives: Partnering for real learning*. Corwin Press.

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, *93*(3), 223-231. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x

Rasheed, R. A., Kamsin, A., & Abdullah, N. A. (2020). Challenges in the online component of blended learning: A systematic review. *Computers & Education*, *144*, 103701. https://doi.org/10.1016/j.compedu.2019.103701.

Richardson, D. (2008). Don't dump the didactic lecture; fix it. *Advances in Physiology Education*, *32*(1), 23-24. https://doi.org/10.1152/advan.00048.2007

Ritchhart, R., Church, M., & Morrison, K. (2011). *Making thinking visible: How to promote engagement, understanding, and independence for all learners*. John Wiley & Sons.

Roberts, D. A. (2007). Scientific literacy/science literacy. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education (pp. 729–780). Mahwah: Lawrence Erlbaum*.

Roberts, D. A. (2011). Competing visions of scientific literacy: The influence of a science curriculum policy image. In Linder, C., Östman, L., Roberts, D. A., Wickman, P.- O., Erickson, O. G., & MacKinnon, A. (Eds.), *Exploring the landscape of scientific literacy* (pp. 11–27). London: Routledge.

Romeu, T., Guitert, M., & Sangrà, A. (2016). Teacher collaboration network in higher education: Reflective visions from praxis. *Innovations in Education and Teaching International*, *53*(6), 592-604. https://doi.org/10.1080/14703297.2015.1025807.

Rotellar, C., & Cain, J. (2016). Research, perspectives, and recommendations on implementing the flipped classroom. *American Journal of Pharmaceutical Education*, *80*(2): 4. https://doi.org /10.5688/ajpe80234

Saldaña, J. (2009). Popular film as an instructional strategy in qualitative research methods courses. *Qualitative Inquiry*, *15*(1), 247-261. https://doi.org/10.1177/1077800408318323

Saputro, A. D., Rohaeti, E., & Prodjosantoso, A. K. (2019). Using inquiry-based laboratory instruction to improve critical thinking and scientific process skills among preservice elementary teachers. *Eurasian Journal of Educational Research*, *19*(80), 151-170. https://dergipark.org.tr/en/pub/ejer/issue/43338/548928

Scadding, H. (1989). Junior secondary schools—an educational initiative in Ghana. *Compare*, *19*(1), 43-48. https://doi.org/10.1080/0305792890190105

Scandura, T. A., & Williams, E. A. (2000). Research methodology in management: Current practices, trends, and implications for future research. *Academy of Management Journal*, *43*(6), 1248-1264. https://doi.org/10.2307/1556348

Schmidt, S. J. (2021). Helping students connect the macroscopic level to the molecular level. *Journal of Food Science Education*, *20*(4), 166-177. https://doi.org/10.1111/1541-4329.12232

Schultz, D., Duffield, S., Rasmussen, S. C., & Wageman, J. (2014). Effects of the flipped classroom model on student performance for advanced placement high school chemistry students. *Journal of Chemical Education*, *91*(9), 1334-1339. https://doi.org/10.1021/ed400868x

Seery, M. K. (2015). Flipped learning in higher education chemistry: Emerging trends and potential directions. *Chemistry Education Research and Practice*, 16(4), 758-768. https://doi.org/10.1039/C5RP00136F

Sevian, H., & Talanquer, V. (2014). Rethinking chemistry: A learning progression on chemical thinking. *Chemistry Education Research and Practice*, *15*(1), 10-23. https://doi.org/10.1039/C3RP00111C

Shelton, C. (2017). Giving up technology and social media: why university lecturers stop using technology in teaching. *Technology, Pedagogy and Education*, *26*(3), 303-321. https://doi.org/10.1080/1475939X.2016.1217269

Sigurðardóttir, M. S., & Heijstra, T. M. (2020). Mixed approaches to learning in the flipped classroom: How students approach the learning environment. *Canadian Journal for the Scholarship of Teaching and Learning*, *11*(1). https://doi.org/10.5206/cjsotl-rcacea.2020.1.8098

Silverman, J., & Hoyos, V. (2018). *Distance learning, e-learning and blended learning in mathematics education*. London: Springer.

Sinha, E., & Bagarukayo, K. (2019). Online education in emerging knowledge economies: Exploring factors of motivation, de-motivation and potential facilitators; and studying the effects of demographic variables. *International Journal of Education and Development using Information and Communication Technology*, *15*(2), 5-30. https://eric.ed.gov/?id=EJ1220780

Slavich, G. M., & Zimbardo, P. G. (2012). Transformational teaching: Theoretical underpinnings, basic principles, and core methods. *Educational Psychology Review*, *24*, 569-608. https://doi.org/10.1007/s10648-012-9199-6

Smith, J. J., & Greene, H. C. (2013). Pre-service teachers use e-learning technologies to enhance their learning. *Journal of Information Technology Education: Research*, *12*(1), 121-140. https://www.learntechlib.org/p/111353/

Smith, M. K., Wood, W. B., Adams, W. K., Wieman, C., Knight, J. K., Guild, N., & Su, T. T. (2009). Why peer discussion improves student performance on in-class concept questions. *Science*, 323, 122—124. https://doi.org/10.1126/science.1165919

Somnuek, P. (2014). The development of teaching and learning innovation by using instructional media for enhancement of learning achievement towards tourism product knowledge in tourism marketing class. *SHS Web of Conferences* Vol. 12, 2014. 4th International Conference on Tourism Research (4ICTR), https://doi.org/10.1051/shsconf/20141201040

Song, J., & Han, B. (2015). Green chemistry: a tool for the sustainable development of the chemical industry. *National Science Review*, *2*(3), 255-256. https://doi.org/10.1093/nsr/nwu076

Stake, R. E. (1995). *The art of case study research*. Sage.

Strayer, J. F. (2012). How learning in an inverted classroom influences cooperation, innovation and task orientation. *Learning Environments Research*, *15*(2), 171-193. https://doi.org/10.1007/s10984-012-9108-4.

Stronge, J. H., Ward, T. J., & Grant, L. W. (2011). What makes good teachers good? A cross-case analysis of the connection between teacher effectiveness and student achievement. *Journal of Teacher Education*, *62*(4), 339-355.

Sulaiman, J., & Ismail, S. N. (2020). Teacher competence and 21st century skills in transformation schools 2025 (TS25). *Universal Journal of Educational Research*, *8*(8), 3536-3544. https://doi.org/10.13189/ujer.2020.080829

Taber, K. S. (2017). Knowledge, beliefs and pedagogy: How the nature of science should inform the aims of science education (and not just when teaching evolution). *Cultural Studies of Science Education*, *12*, 81-91. https://doi.org/10.1007/s11422-016-9750-8

Talanquer, V., & Sevian, H. (2014). Chemistry in past and new science frameworks and standards: Gains, losses, and missed opportunities. *Journal of Chemical Education*, *91*(1), 24-29. https://doi.org/10.1021/ed400134c

Teddlie, C., & Tashakkori, A. (2009). *SAGE* handbook of *mixed methods* in *social* & *behavioral research* (2nd ed.). Thousand Oaks, CA: Sage.

Tellis, W. (1997). Application of a case study methodology. *The Qualitative Report*, *3*(3), 1-19. https://doi.org/10.46743/2160-3715/1997.2015

Tolmie, A., Muijs, D., & McAteer, E. (2011). *Quantitative methods in educational and social* TIMSS (2011). *International Mathematics Report: Findings from IEA's 2011 Trends in international Mathematics and Science Study at the 4th and 8th Grades*. Chestnut Hill. International Study Centre, Boston College.

Tomas, L., Evans, N. S., Doyle, T., & Skamp, K. (2019). Are first-year students ready for a flipped classroom? A case for a flipped learning continuum. *International Journal of Educational Technology in Higher Education*, *16*(1), 1-22. https://doi.org/10.1186/s41239-019-0135-4

Trinidad, J. E., Ngo, G. R., Nevada, A. M., & Morales, J. A. (2020). Engaging and/or effective? Students' evaluation of pedagogical practices in higher education. *College Teaching*, *68*(4), 161-171. https://doi.org/10.1080/87567555.2020.1769017

T-TEL Ghana (2015). Mid-Inception Report. Government of Ghana/Department for International Development. Accra. http://cemis.gtec.edu.gh/resources/Research%20and%20evidence%20-%20teacher%20education%20in%20Ghana/T-TEL%20CURRICULUM%20REFORM%20STUDY%20REPORT.pdf

Trowbrıdge, L., Bybee, R. W., & Powell, J. C. (2004). *Teaching secondary school science*. New Jersey: Merrill.

Ural, E. (2016). The effect of guided-inquiry laboratory experiments on science education students' chemistry laboratory attitudes, anxiety and achievement. *Journal of Education and Training Studies*, *4*(4), 217-227. https://doi.org/10.11114/jets.v414.1395

Uzezi, J. G., & Zainab, S. (2017). Effectiveness of guided-inquiry laboratory experiments on senior secondary schools' students' academic achievement in volumetric analysis. *American Journal of Educational Research*, *5*(7), 717-724. https://doi.org/10.12691/education-5-7-4

van Berkel, B., De Vos, W., Verdonk, A. H., & Pilot, A. (2000). Normal science education and its dangers: The case of school chemistry. *Science & Education*, *9*, 123-159. https://doi.org/10.1023/A:1008765531336

van Manen, M. (1990). Beyond assumptions: Shifting the limits of action research. *Theory into Practice*, *29*(3), 152-157. https://doi.org/10.1080/00405849009543448

van Niekerk, M., & Delport, M. (2022). Evolving flipped classroom design in a cost/management accounting module in a rural South African context. *Accounting Education*, 1-29. https://doi.org/10.1080/09639284.2022.2029748

Van Wyk, M. M. (2018). Economics student teachers' views on the usefulness of a flipped classroom pedagogical approach for an open distance eLearning environment. *The International Journal of Information and Learning Technology*, *35*(4), 255-265. https://doi.org/10.1108/IJILT-07-2017-0068

Vanslambrouck, S., Zhu, C., Lombaerts, K., Philipsen, B., & Tondeur, J. (2018). Students' motivation and subjective task value of participating in online and blended learning environments. *The Internet and Higher Education*, *36*, 33-40. https://doi.org/10.1016/j.iheduc.2017.09.002

Vaughan, M. (2014). Flipping the learning: An investigation into the use of the flipped classroom model in an introductory teaching course. *Education Research and Perspectives*, *41*, 25-41. https://eric.ed.gov/?id=EJ1031290

Vygotsky, L. (1962). *Thought and language*. Cambridge, MA: MIT Press

Vygotsky, L. S., & Cole, M. (1978). *Mind in society: Development of higher psychological processes*. Harvard University Press.

Warfa, A. R. M. (2016). Using cooperative learning to teach chemistry: A meta-analytic review. *Journal of Chemical Education*, *93*(2), 248-255. https://doi.org/10.1021/acs.jchemed.5b00608

Whalen, J. (2020). Should teachers be trained in emergency remote teaching? Lessons learned from the COVID-19 pandemic. *Journal of Technology and Teacher Education*, *28*(2), 189-199. https://www.learntechlib.org/primary/p/215995/

Williams, T. D. (1964). Sir Gordon Guggisberg and educational reform in the Gold Coast, 1919-1927. *Comparative Education Review*, *8*(3), 290-306. https://doi.org/10.1086/445083.

Wilson, K. (2020). What does it mean to do teaching? A qualitative study of resistance to flipped learning in a higher education context. *Teaching in Higher Education*, 1-14. https://doi.org/10.1080/13562517.2020.1822312

Yidana, P. (2018). Examination of Ghana's ICT in education policy within the context of globalization. *Journal of Communication Media Society*, *5*, 120-142. http://repository.gij.edu.gh/xmlui/handle/123456789/69

Yılmaz, Ö., & Malone, K. L. (2020). Preservice teachers' perceptions about the use of blended learning in a science education methods course. *Smart Learning Environments*, *7*(1), 1-21. https://doi.org/10.1186/s40561-020-00126-7

Yin, R. K. (1994). *Case study research: Design and methods* (2nd ed.). Newbury Park, CA: Sage Publications.

Zainuddin, Z., & Attaran, M. (2016). Malaysian students' perceptions of flipped classroom: A case study. *Innovations in Education and Teaching International*, *53*(6), 660-670. https://doi.org/10.1080/14703297.2015.1102079

Zayapragassarazan, Z., & Kumar, S. (2012). Active learning methods. *Online Submission*, *19*(1), 3-5. https://eric.ed.gov/?id=ED538497

Zheng, B., Ward, A., & Stanulis, R. (2020). Self-regulated learning in a competency-based and flipped learning environment: Learning strategies across achievement levels and years. *Medical Education Online*, *25*(1), https://doi.org/10.1080/10872981.2019.1686949

Zhu, C., & Justice Mugenyi, K. (2015). A SWOT analysis of the integration of e-learning at a university in Uganda and a university in Tanzania. *Technology, Pedagogy and Education*, *24*(5), 1-19. https://doi.org/10.1080 /1475939X.2015.1093537

Original publications (Papers I – IV)

Aidoo, B., Macdonald, A., Gyampoh, A. O., Baah, K. A., & Tsyawo, J. (2022). Factors influencing teachers' online teaching competence in higher education. *Social Education Research*, 148-160. https://doi.org/10.37256/ser.3120221315

Aidoo, B., Macdonald, M.A., Vesterinen, V.M., Pétursdóttir, S., & Gísladóttir,B. (2022). Transforming teaching and learning with ICT using flipped classroom approach: Dealing with COVID-19 pandemic. *Educational Sciences*, 12(6), 4255. https://doi.org/103390/educsci12060421

Aidoo, B., Vesterinen, V. M., Macdonald, M. A., Gísladóttir, B., & Pétursdóttir, S. (2022). Perceptions of Ghanaian pre-service teachers on benefits and challenges of the flipped classroom: A Case Study. *Contemporary Educational Technology*, 14(4), ep37755. https://doi.org/10.30935/cedtech/12163

Aidoo, B., Anthony-Krueger, C., Gyampoh, A. O. G., Tsyawo, J., & Quansah, F. (2022). A mixed-method approach to investigate the effect of flipped inquiry-based learning on chemistry students learning. *European Journal of Science and Mathematics Education*, 10(4), 507-518. https://doi.org/10.30935/scimath/12339

Paper I

Paper II

Paper III

Paper IV

Appendix A Informed consent

I ...., agree to take part in the project of blended learning research to be organized during the COVID-19 pandemic to examine the student-teachers' perceptions of learning. The researcher explained the project's purpose and how it will be executed. The researcher provided resources and training on the implementation of the project. I have read the transcript mentioned above and agree with its publication. I am fully aware of the implications of publication and accept any associated risks, especially anonymity issues.

Appendix B Online competence teaching questionnaire

1. What is your gender   Male   Female
2. What is your age?
3. What is your current level of education   i. Ph.D. ii. MPhil/MEd/MA/MSc iii. BSc/BEd/BA
4. What is the mode of obtaining your current level of education?
   i. Distance ii. Mainstream iii. Online   iv. Mainstream and distance
   v. Online and mainstream
5. How many years of teaching experience do you have
   i.   0-10   ii. 11-20   iii. 21-30   iv. 31-40
6. I have my personal laptop/computer for my teaching Yes/No
7. The university/college provides laptops/computers for my teaching Yes/No
8. There is an internet connection in my classroom Yes/No
9. There is a projector in my classroom Yes/No
   Respond by indicating i. No knowledge ii. Some knowledge iii. Sufficient knowledge
10. I know how to apply ICT, which applies to any of my teaching lessons.
11. I know how to use different pedagogical approaches applicable to online teaching.
12. I know how to sear for information on the internet, browse websites, and engage in discussions forums to support my online teaching.
13. I know how to find helpful information about the curriculum for my teaching on the internet.

Respond by indicating i. Not at all ii. Sometimes iii. Always

14. I create Google docs and use Powerpoint presentations to deliver my lessons online.
15. I make use of simulations, virtual labs, and e-labs to teach my students.
16. I make videos of concepts and experiments for my students to watch and have interactive discussions with them.
17. I usually create a virtual classroom and chat platforms for my teaching and have a face-to-face discussion with students.
18. I use interactive webpages for my teaching and classroom projects.
19. I provide support for my students to obtain information, and learning materials, do exercises, and tests online using learning management systems.

Respond by indicating i. Strongly disagree ii. Disagree iii. Neither agree nor disagree iv. Agree v. Strongly agree.

20. I participated in professional development activities related to ICT during the pandemic.
21. I participated in professional development activities related to internet use and general applications during the pandemic.
22. I participated in subject-related training related to ICT for teaching.
23. I participated in training on pedagogical issues related to integrating ICT into my teaching.
24. I participated in training on digital operations for my teaching.

Appendix C Student-teachers survey questions

1. Do you have regular access to a computer or laptop? Yes/No

2. Do you have regular access to the internet? Yes/No

3. Which of the following types of video-viewing technologies do you have regular access to?

    i. DVD player ii. Smartphone iii. Tablet iv. Other

4. Where do you have regular internet access?

    i. School ii. Home iii. Mobile devices

5. If videos were assigned to watch outside the classroom, where would you view the videos?

    i. Home ii. School ICT lab iii. On my Android phone

6. Would you find digital video lessons helpful?

    i. Very useful ii. Somehow useful iii. Not useful at all

7. Are you familiar with the flipped classroom? Yes or No?

8. What experience have you had with the flipped classroom..................................

Appendix D Student-teachers focus group questions

1. Can you describe three benefits (if any) of learning in the inquiry-based classroom environment compared to a regular face-to-face lecture approach?
2. Write three benefits (if any) of flipped learning (face-to-face and online learning)
3. Explain at least three challenges and barriers you faced when learning chemistry in a face-to-face using an inquiry-based classroom environment.
4. Can you tell me any other three challenges when lessons were done using the flipped classroom approach?
5. Although there were some challenges you encountered, can you describe your experience learning chemistry in the flipped inquiry-based classroom.
6. What can you say about your experiences when learning chemistry face-to-face compared to the flipped classroom learning environment?
7. What features of the two different approaches are helpful to you? Think about the lectures, classroom discussions, reading or watching videos at home before class, classroom activities, or group work.

Appendix E Chemistry Achievement Diagnostic Test

Demographic data

Student email or registration number:

What is your gender   Male   Female

What is your age   i. 16-20   ii. 21-25   iii. 26-30

Pre-test

Section A – One-word test items. Provide one response that best fits the descriptions below.

1. The main element in organic compounds is ………………
2. An element that does not form part of the longest chain of an organic compound…
3. The main use of alkanes is for……………….
4. The IUPAC name of $CH_3CH_2CH_2CH_3$ is ………
5. An organic compound containing a double bond between two carbon atoms belonging to an ……… group.

i. Alkane   ii. Alkene   iii. Alkyne   iv. Alcohols

Section B – Multiple choice items.

6. What is the IUPAC name for $CH_3CHClCH\ (CH_3)CH_2CH_2Br$?
   A. 1-bromo-4-chloro-3-methylpentane B. 5-bromo-2-chloro-3-methylhexane
   C. 1-bromo-4-chloro-3-dimethylhexane D. 5-bromo-3-chloro-3-methypentane
7. The IUPAC name for the hydrocarbon $(CH3)_2\ C{\equiv}CHCH3$ is:
   A. 2-methyl-3-yne B. 2-methylbut-2-yne C. 2-methylpent-1-yne D. 2-methylpent-2-yne
8. What is the name of the compound $(CH3)_2CH_2CH{=}CH_3$?
   A. 4-methypent-1-ene B. 1-methylpent-1-ene C. 4-methylpent-4-ene
   D. 2,2-dimethylpent-1-ene
9. What is the IUPAC of $CH_3CH{=}CHCH(CH_3)$
   A. 4,4-dimethylprop-2-ene B. 4-methylpent-2-ene C. 4-methylpent-1-ene
   D. 3, 4-dimethylpent-3- ene
10. An element or compound which does not form part of the longest continuous chain of organic compound is.

A. Isomer B. Substituent C. Catalyst D. Hydrocarbon

11. An alkyl group has a general formula of

A. CnH2n + 2 B. CnH2n + 1 C. CnH2n D. CnH2n -1

12. The IUPAC name for $CH_3CH(CH_3)CH(Cl)CH(CH_3)CH_2CH_3$ is

A. 2,4-dimethyl-3-chlorohexane B. 3,5-dimethyl-4-chlorohexane

C. 4-chloro-3,5-dimethyl hexane D. 3-chloro-2,4-dimethylhexane

13. What is the name of the hydrocarbon with a triple bond?

A. Alkane B. Alkyl C. Alkene D. Alkyne

14. Which one of the following compounds exhibits geometrics isomerism?

A. $CH_3CH_2CH_3$ B. $CH_3CH{=}CH_2$ C. $CH_3CH{=}CHCH$

B. D. $CH_3CH_2CH_2CH_3$

15. What is the name given to an organic compound containing only carbon and hydrogen?

A. Aromatic B. Isomer C. Halogen D. Hydrocarbon

16. Which of the following compounds undergoes an addition reaction?

I: $CH_3CH_2CH_2CH_3$ II: $CH_3CH{=}CHCH_3$

III: $CH_2{=}CH_2$ IV: $CH_3CH_2CH_2CH_2OH$

A. II only B. I and II C. II and III only D. I, II and IV

17. An organic compound containing a double bond between two carbon atoms belonging to an ……… group.

A. Alkane B. Alkene C. Alkyne D. Alcohol

Post-test

Section A – One-word test items. Provide one response that best fits the descriptions below.

1. The major reaction that alkanes undergo is …………….
2. The ability of carbon to form four bonds is due to its ……….
3. Hydrocarbons that contain only single bonds between carbon atoms are……….
4. The IUPAC name of $CH_3CH_2CH_2CH_2CH_3$ is …………
5. Compounds with the same molecular formula but different structures are……….

Section B – Multiple choice items.

6. A group of organic molecules with the same functional group but different carbon chain lengths are.

A. Functional group B. Isomerism C. Homologous series D. Cracking

7. A formula that shows the actual number of atoms of each element in a compound

A. Molecular formula B. Empirical formula C. Structural formula

D. Display formula

8. What is the IUPAC of $CH_3CH{=}CHCHCH_2(CH_3)$

A. 4-methypent-1-ene B. 1-methylpent-1-ene C. 4-methylpent-4-ene

D. 2,2-dimethylpent-1-ene

9. The molecular formula of the alkane 2,4-dimethylhexane is?

A. C_8H_{18} B. C_8H_{20} C. C_9H_{18} D. C_9H_{20}

10. What is the IUPAC name of the following compound $CH_3CH(CH_3)CH_2CH_3$?

A. 2-methylbutane B. 3-methylbutane C. Pentane D. 2-methylpentane

11. One of the major use of alkanes is?

A. Fuels B. Oxidizing agent C. Catalyst D. Flavours

12. Which of the following compounds have stereoisomers?

I: $CH_3CH{=}CHCH_3$ II: $(CH_3)_2CH{=}CHCH_3$

III: $CH_3CH_2CH{=}CHCH_3$ IV: $CH_3CH{=}CHCl$

A. I and II B. I, II and III C. I, II and IV D. I and III

13. Which of the following is an example of saturated hydrocarbon

A. $CH_3CH_2CH_3$ B. $CH_3CH{=}CHCH_3$ C. $CH_3CH_2CH_2OH$ D. CH_3CH_2COOH

14. The IUPAC name of $CH_3CH_2CH_2\,CH_2CH_3$

A. Propane B. Butane C. Ethene D. Pentane

15. The IUPAC name for the hydrocarbon $(CH3)_2C{\equiv}CHCH_2CH_3$ is:

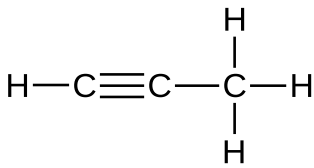
A. 2-methyl-3-pentyne B. 2-methylbut-2-yne C. 2-methylhex-1-yne D. 2-methylhex-2-yne

16. The type of reaction and major product of the following reaction is

$CH_3CH{=}CHCH_3$ (g) + H_2 (g) $\rightarrow$ $CH_3CH_2CH_2CH_3$ (g)

A. Addition and propane B. Addition and butane C. Addition and butene
D. Addition and pentane

17. The general formula to which the compound above belongs is



A. CnH2n + 2 B. CnH2n + 1 C. CnH2n D. CnH2n-2

Appendix F Teacher educators' interviews questions

1. What are your views on using ICT to teach your courses?
2. Do you have any experience using digital tools in your lessons?
3. If you used digital tools, what were the effects on you as a teacher, if any?
4. How often are videos used in your course to deliver new information?
5. What is effective about the instructional strategies you use?
6. Have you used a flipped classroom before? Please describe this experience
7. If you have used a flipped classroom, will you continue to use it in the future?
8. If you have not used flipped learning, will you use it in the future?
9. How would you describe students' effort in your chemistry classroom?
10. What is your definition of a student-centred learning environment?
11. What teaching method(s) have you been using in your classroom, and why do you use it?
12. How do you organize or prepare your class for teaching and learning?
13. What teaching style do you often employ?
14. Do you think the same teaching technique or method applies to teaching all content areas? If not, which is the best teaching method for teaching scientific concepts?
15. How do you use such pedagogies in class?
16. Briefly describe how you use ICT and implement the flipped approach in your classroom.
17. How will you describe your role in the flipped classroom compared to the traditional lecture classroom?
18. Do you make your videos? If so, how do you make them, and the amount of time it takes to create each video?
19. Can you tell me any benefits and challenges of implementing flipped classrooms?

Appendix G Sample course outline

EBS132: GENERAL CHEMISTRY COURSE CONTENT AND LEARNING OUTCOMES

This chemistry course is a component of the General Science course. It is designed to consolidate and expand on the content and skills students have acquired from their lessons in Integrated Science at the Senior High level particularly topics in chemistry. It also reflects some topics treated at the basic and senior high levels. Topics studied in this course include atomic structure and electronic configurations, chemical bonding, the mole concept, chemical formulae and their nomenclature, reaction stoichiometry, pure and impure substances (mixtures) including their separation, acids basis and salts, and aspects of the chemistry of carbon compounds.

SECTION A: TOPICS OUTLINE

UNIT	TOPIC	SUBTOPIC
7	CHEMISTRY OF CARBON COMPOUNDS	i. classification and nomenclature of alkanes, alkenes, and alkynes ii. isomerism iii. sources, preparation, physical and chemical properties, reactivity, and uses of alkanes, alkenes, and alkynes, alkanols and alkanoic acids – sources, preparation, structure, shape, physical and chemical properties, uses. iv. petroleum

SECTION B: DETAIL TOPICS OUTLINE AND LEARNING OUTCOMES

CLO 8: classify and name different types of organic compounds. NTS 2c, 2e, 2f, p.13; 3h, 3j p.14	i. Group a given organic compounds into alkanes, alkenes, alkynes, alkanols and alkanoic acids. ii. Write the names of given organic compounds
CLO 9: describe the structure of different organic compounds. NTS 2b, 2c, 2e, p.13; 3h, 3j p.14	i. Tell the difference in structure of different organic compounds. ii. Draw the structure of given organic compounds. iii. Describe the structural (chain, position, and functional group) and geometric isomerism
CLO 10: discuss the physical and chemical properties of organic compounds. NTS 2c, 2e, 2f, p.13; 3h, 3j p.14	i. Describe the physical and chemical properties of organic compounds. ii. Compare the chemical and physical properties of organic compounds
CLO 11: describe the preparation and uses of organic compounds. NTS 2a, 2b, 2c, 2e,2f, p.13; 3e, -3o p.14	i. Explain the laboratory preparation of three named organic compounds. ii. Describe the uses of three named organic compounds

SECTION C : ASSESSMENT OUTLINE

Course Assessment (Educative assessment: of, for and as learning)	**Component 1:** Formative assessment (quizzes, class tests, class exercises, and assignments) Summary of Assessment Method: Quizzes, class test, class exercises and assignments on Unit 1 - 7(core skills to be developed: critical thinking, creativity, and personal development) Assessment Weighting: 20 % Assesses Learning Outcomes: CLO 1, 2, 3, 4 (Units 1 – 4) **Component 2:** Formative assessment (group and/or individual teaching) Summary of Assessment Method: Students will be involved in assessing their colleagues (peer assessment) Assessment Weighting: 20 % Assesses Learning Outcomes: CLO 5, 6, 7, 8, 9, 10 and 11 (Units 5-8) **Component 3:** Summative assessment Summary of Assessment Method: End of semester examination (composed of multiple-choice questions and essay-type questions) on Units 1 to 8 (core skills to be developed: critical thinking, creative thinking, problem solving, innovation, and personal development) Weighting: 60 % Assesses Learning Outcomes: CLO 1-11. The grading system will be guided by the following: A=80-100 %; B+=75-79 %; B =70-74 %, C+ =65-69 %, C= 60-64 %, D+ = 55-59 %, D = 50-54 %, FAIL<50 %
Instructional Resources	1. Visual aids such as marker boards 2. Audio-visual aids such as computers (with internet connectivity) and projectors, television, DVD discs and DVD player. 3. Activity aids such as visits to basic schools

Reading materials:

1. Abbey T. K., & Essia J. W. GAST Core Science for senior secondary school.
2. Galyoun I, Eghan J. M., Darkwa K. B. Owusu-SekyereJ. R. Zugle, (2008). *Black Star Series Integrated Science for Senior High Schools,*