Implementing Blended First Year Chemistry in a Developing Country Using Online Resources

Charisse T. Reyes
Monash University, Australia/University of the Philippines Open University

Sara H. Kyne
Monash University, Australia

Gwendolyn A. Lawrie
University of Queensland, Australia

Christopher D. Thompson
Monash University, Australia

Abstract
Decades of rapid development in information and communication technologies (ICTs) have resulted in tremendous global evolution in computer and online instruction. Many developing countries, however, are still struggling to successfully integrate ICTs into their teaching and learning practices, subsequently leading to slower rates of adapting digital learning pedagogies. To understand how blended instruction might operate in higher education in a developing country, this study explored students' perspectives on the implementation of blended learning in a first-year chemistry program delivered in the Philippines. Through the resource-based learning framework, multiple types of online learning resources were employed for blended delivery of topics on periodic trends, chemical bonding, Lewis structures, molecular shape, and polarity through the learning management system, Moodle. To understand students' experiences, a mixed methods approach was employed through a survey, focus groups, and learning analytics. Despite the scarcity of technological resources (such as access to a reliable internet connection), 57.5% of 447 student respondents favoured blended learning because of the flexibility, wider access to various types of interactive learning resources, variety of learning activities, and perceived increase in learning productivity. While most respondents (75.7%) had ICT skills sufficient for education, significantly fewer had access to computers (19.7%). 40.0% of students self-reported that they preferred a traditional mode of instruction primarily due to the perceived difficulty of chemistry as subject matter and the perceived need for face-to-face discussions, including concept explanation and Q & A opportunities.

Keywords: Blended learning, first-year chemistry, resource-based learning

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In contemporary teaching, it is now commonplace to use a combination of both traditional face-to-face and online instruction and interactions. This is broadly defined as blended learning (Bonk & Graham, 2005; Crawford & Jenkins, 2017) and comes in various forms. Blended learning is now ubiquitous in developed countries with the widespread adoption and availability of digital learning technologies, as predicted almost two decades ago (Bonk & Graham, 2005). This has resulted in an increased level of integration of computer-mediated instructional modalities with the traditional face-to-face learning experience. Consequently, rapid developments in blended learning pedagogies have intensified the need for stakeholders (i.e., teachers, students, and school leaders) "to take advantage of learning opportunities afforded through improved personalisation, collaboration, and communication enabled by learning technologies" (Watterston, 2012, p. 12) towards a continuous learning process.

Through an effective mix of traditional classroom teaching with online activities, blended learning provides innovative educational solutions and other benefits over any single learning delivery mode (Singh, 2003). To support learning, the explosion of information and communication technology (ICT) resources has become an important pedagogical consideration, such that use of technology to enhance practice does not challenge traditional pedagogies, rather it can support the transformation of teacher-centric teaching practices into more collaborative and constructive learning activities (Yelland et al., 2008).

A key aspect of successful blended learning is the seamless integration of ICT resources, both online and digital. However, while such integration is routine in developed countries, the widespread adoption of ICT to support learning in developing economies is constrained by limited infrastructure, high costs of electricity, slow internet speeds, insufficient continuous staff development (Sarvi & Pillay, 2015), and other social and cultural factors (Tubaishat et al., 2006). Educational institutions in developing countries must be both creative and efficient when using available resources to ensure the delivery of a sustainable program (Mercado et al., 2012).

In this study, an instructional approach to implementing blended learning in a university first-year chemistry context in a developing country is presented. As part of the design of blended first-year chemistry, existing internet-based resources are explored and leveraged as a viable option for instructional delivery. Students' perceptions of their blended learning experiences and learning analytics data from the learning management system (LMS) were also considered in this study. The following questions guided the research:

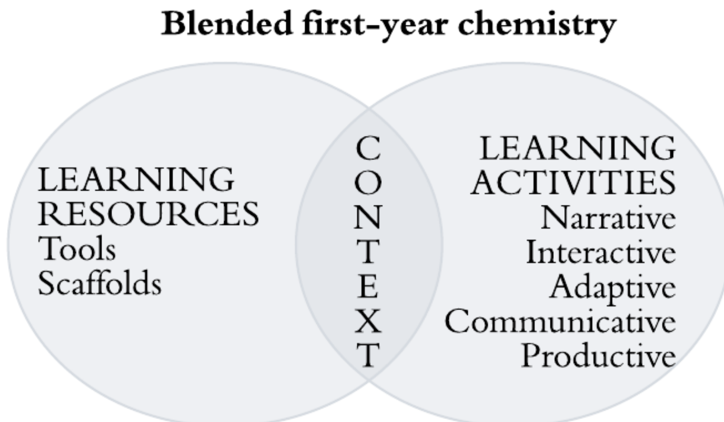
1. What are effective ways to implement blended first-year chemistry in a tertiary institution in a developing country?
2. What opportunities and challenges become evident in employing online resources for blended first-year chemistry informed by the perspectives of the students from a developing country?

Literature Review

Tertiary science education is fertile ground for the development and integration of ICTs to enhance teaching and learning practice in a blended environment. ICTs in tertiary science education present considerable opportunities to respond to the emerging, rapid evolution of learner-centred pedagogies which encourage "collaboration, knowledge creation and knowledge sharing" (Wallet & Melgar, 2014, p. 19). Appropriate instructional design for blended learning creates high-quality teaching materials and methods for specific groups of students, considers how students learn, effectively helps them achieve their academic goals, and ensures they receive instruction in a form that is meaningful to them (Purdue University Online, n.d.).

This study employed two frameworks to inform the instructional design of blended first-year chemistry at a university in a developing country (Figure 1). The resource-based learning (RBL) framework was applied to inform the process of selection and combination of learning resources that were sourced from the internet and employed in the blended learning environment. Laurillard's conversational framework (LCF) (2002) guided the design of learning activities using these online resources.

Figure 1
Study framework based on RBL and Laurillard's conversational framework



Resource-Based Learning (RBL) Framework for Identifying and Employing Resources in Blended Learning

The approach to sourcing and implementing a variety of resources in a learning environment was first proposed by Beswick in 1977 (Hill, 2012) and was referred to as RBL. Beswick (1977) focused on how students learned from their interactions with varied resources as he encouraged movement away from traditional, direct, fact-based instruction towards a student-centred generation of knowledge and understanding (Beswick, 1977, cited in Hill, 2012). In 2007, Hannafin and Hill defined RBL as the "use and application of available assets to support varied learning needs across contexts" (p. 526). Although RBL was initially presented without embodying a particular epistemology (Hannafin & Hill, 2007), Hill (2012) explained that many of its key ideas are rooted in constructivist theory of learning such as "knowledge is constructed, prior knowledge and experience impacts learning, contextualization is important, and learning is an active process" (p. 2850). In line with these tenets, Hill (2012) defined the four basic components involved in RBL:

1. Resources—including, but not limited to, media, people, places, and ideas, all used to support the learning process
2. Contexts—defined situations or problems that orient learners to a need or problem
3. Tools—assist with the creation and/or use of resources
4. Scaffolds—any supports provided to assist learners as they are engaging in a task

By employing the RBL framework, resources are implemented within established contexts, through the aid of tools for creation and use, and with scaffolds that guide and support students in differentiated interpretation, use, and understanding (Hannafin & Hill, 2007; Hill, 2012). In this era of massive ICT growth, accessible online resources have proliferated rapidly allowing RBL to achieve wider applicability across a variety of learning contexts, including blended learning. A more dynamic learning environment has resulted from the number and variety of resources, their enhanced availability, and the ability to repurpose the resources to enable the accommodation of diverse learning needs. Hannafin and Hill (2007) noted several factors that further increase the suitability of resources for learning in an online environment, such as adaptation for previously unavailable contexts, increased flexibility in their use, and enhanced capability to manipulate and share resources across multiple contexts and purposes.

Laurillard's Conversational Framework (LCF) for Effective Use of Technology

The successful integration of technology in blended learning requires the provision of support for authentic, meaningful, and active learning (Yelland et al., 2008). One way to achieve this is to take a more cognitive approach to the design of the learning activities and take advantage of the numerous types of media resources that abound on the internet. Bates & Poole (2003) argued that media can be useful for providing learners activities and exercises in support of their learning in a technology-mediated environment.

LCF (2002) for the effective use of learning technologies aims to help teachers think about teaching and learning from the perspective of the students. LCF is a complex framework of teaching and learning based on an iterative process between conception and practice (Laurillard, 2016, 00:35). Learning involves the integration of concepts and practice, which occurs when both teacher and student engage in discursive activities where they can share each other's understanding and generate action. When teachers give feedback on this action, it modifies students' conception of the subject which results in better practice. This iterative dialogue of concept and practice is "discursive, adaptive, interactive, and reflective" (Laurillard, 2002, p.86). LCF guides the classification of media resources through which the dialogic process of blended teaching and learning may be achieved. Based on LCF, media resources can be classified into narrative, interactive, adaptive, communicative, and productive forms. Laurillard further recommends that these media resources be used in combination to achieve the optimum balance for specific learning contexts with the provision for teacher-student dialogue.

Blended Learning Implementation in the Philippines

The slow growth of blended learning in the Philippines has been attributed to cost and lack of sufficient infrastructure, yet despite these obstacles. several studies have reported blended learning implementation at minimal cost through free online platforms and learning managements systems. University students enrolled in biological sciences (Beltran-Cruz & Cruz, 2013) and education (Robles, 2012) courses were introduced to blended delivery through Facebook, Edmodo, and Blackboard (free version). Even though this was a low-cost implementation, students perceived a better learning experience (Beltran-Cruz & Cruz, 2013), and exhibited evidence of improved academic performance (Robles, 2012). Cost of internet and access to it were also identified as significant barriers to online learning (Marcial et al., 2015), and to promote blended learning in regions where internet and computer technology are inadequate, low technology resources have been employed. A Bricolage approach using existing ICT resources was encouraged by Aguinaldo (2013) to provide a foundation for the implementation of blended learning in a rural public university in the Philippines.

The growth of blended learning is expected to continue to accommodate the diverse needs of students, educators, and institutions (Spring et al., 2016). However, despite promising advantages for enhanced learning experiences, blended learning has not been widely implemented in many developing regions, primarily due to a lack of sufficient ICT infrastructure. Where resources to develop original content are scarce, such as in developing regions, blended learning delivery is faced with complex challenges to design contextualised and culturally appropriate learning materials (Spring et al., 2016). In 2008, Larson and Murray argued that it was critical to provide language translations for the open educational resources designed and developed within the Blended Learning Open-Source Science or Math Studies Initiative (BLOSSOMS) implemented across various developing countries. This initiative allowed BLOSSOMS to promote local cultural and educational norms in the free resources delivered through the internet and other lower-technology platforms (i.e., CD, DVD, videotape). The last two decades have seen an increase in blended learning implementation and research across developed and developing countries (Anthony et al., 2020). This research contributes to the perspective that much more needs to be done to promote online teaching in countries with a culture of traditional face-to-face teaching.

Methodology

An RBL package was prepared for blended delivery, consisting of learning resources and activities that met the learning goals prescribed by the first-year chemistry curriculum. This RBL package also served as a study guide for each topic. Learning resources were identified and carefully curated to support the following five topics in first-year chemistry: (a) periodic table and trends, (b) introduction to chemical bonding, (c) Lewis structures, (d) molecular shapes, and (e) polarity. The researcher who is not part of the course teaching staff designed the RBL package to be implemented over a two-week period. Due to the variety of online resources readily available from the internet, the researcher developed the following criteria to guide the selection of resources:

1. The quantity and scope of relevant learning resources should be sufficient to meet the learning objectives.
2. There should be a variety of resources from credible sources that provide accurate and up-to-date information.
3. Resources should be fully accessible even with a low-bandwidth internet connection.
4. Resources should be hosted on reliable websites that are less likely to be susceptible to link death.
5. Resources should have an open-access license (Sandanayake, 2019) or should reside in the public domain to avoid potential copyright breaches.
6. Resources are in the English language, the university's medium of instruction.

By applying the RBL framework, a combination of online resources was employed for instructional delivery. Resources employed for content delivery ranged from text, videos, interactive simulations, and interactive presentations. Online quizzes and problem sets were designed and implemented by the researcher to provide formative assessments. The four components of the RBL framework in this blended delivery were reflected in the online resources that aimed to meet the learning objectives (i.e., the context), through the aid of tools for creation and use, and with scaffolds that guide and support students in differentiated interpretation, use, and understanding (Hannafin & Hill, 2007; Hill, 2012). Tools that aided students to create evidence of their understanding and to process and evaluate information were already embedded within some of these online resources. To provide the necessary scaffolding to assist learners in engaging with the tasks, all online resources and activities were curated and annotated. Guided by the selection criteria listed above, curation involved extensive selection of numerous resources available from the internet ensuring that there was sufficient variety and number of accessible learning resources providing accurate and up-to-date information.

Screenshots of sample resources are provided in Figure 2. Annotation produced a summary and description of each resource to help students navigate learning by providing information on important aspects of, and procedures to, use the resources and fulfil the tasks. Moodle was used as the LMS for this blended delivery. Based on the RBL framework, an RBL package for each topic was designed to contain each of the following sections:

1. Introduction
2. Learning Objectives
3. Learning Activities
4. Self-check

An ungraded, formative assessment for each topic was employed in the form of either a Moodle quiz, an external online quiz, problem sets, posting on an online bulletin board or participating in a discussion forum. A portable document format (PDF) version of the RBL package was posted on the course site for students to download. This was done so that students could access the learning materials without needing to access the Moodle course site if the site was inaccessible (for example due to connectivity issues).

Instructional Setting

The participating university in this study is the second largest constituent university (CU) of the premier national university in the Philippines, which is a university system comprised of eight constituent universities and one autonomous college. The campuses of the university system are spread throughout 17 strategic locations in the country. This participating CU is in the province of Laguna in the Southern Tagalog administrative region (Region IV-A). It is approximately 65 kilometres south of Metropolitan Manila, the country's capital, and centre of government and economy.

The first-year chemistry course involved in this study is usually offered to students enrolled in this university in the first semester of each academic year. On some occasions, the course is also offered during the second semester if there is demand from repeating students (i.e., students who failed to pass during the first semester) or transferees from other universities. The academic year in this university begins in August and ends in July of the following year. It includes two semesters and a shorter midyear term. Each semester has 100 class days spread across 16-18 weeks and one final examination week, while the midyear term includes 28 class days across 4-5 weeks and two days of final examination.

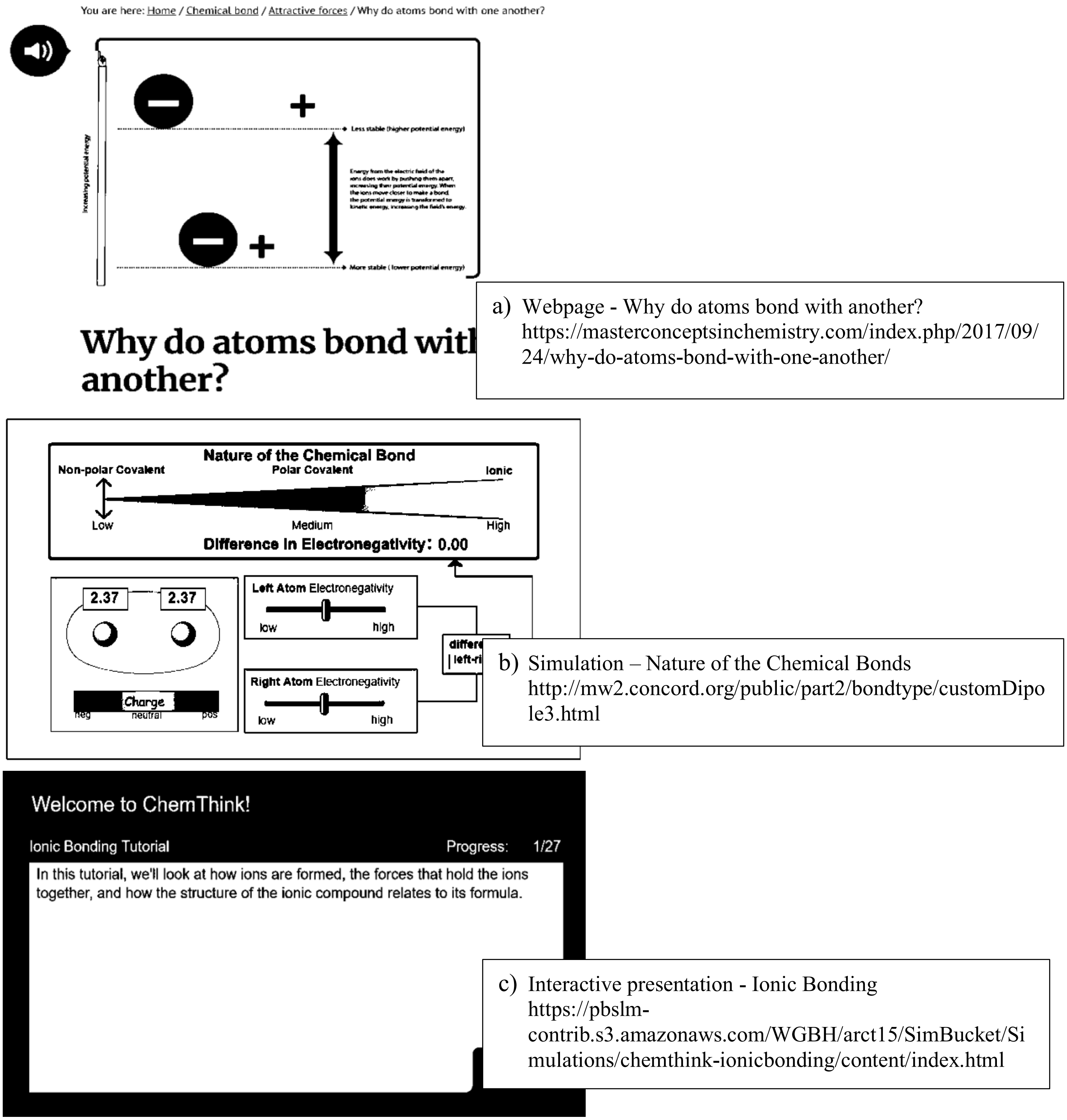
Data Collection

Statement of ethics

The research adhered to ethical standards and guidelines as the nature of study demanded. Consent was collected of the participants and the statistical analysis was performed using non-identifiable data.

Figure 2

Sample Resources Used in the Development of the RBL Package



a) Webpage - Why do atoms bond with another? https://masterconceptsinchemistry.com/index.php/2017/09/24/why-do-atoms-bond-with-one-another/

b) Simulation – Nature of the Chemical Bonds http://mw2.concord.org/public/part2/bondtype/customDipole3.html

c) Interactive presentation - Ionic Bonding https://pbslm-contrib.s3.amazonaws.com/WGBH/arct15/SimBucket/Simulations/chemthink-ionicbonding/content/index.html

Student Survey

To promote a greater response rate, researchers preferred a pen-and-paper survey (Appendix A) to an online survey. Surveys were manually distributed to students after lecture sessions and in laboratory classes seven days after the end of the two-week implementation period. Completed surveys were returned by respondents, either through the designated submission box or through their lecturers or laboratory instructors.

The survey contained 11 questions, including four demographic questions, five multiple choice questions about previous high school stream, university program, technological skills and resources, and preferred learning mode, and an open-ended question to explain the latter. The internal consistency of the survey instrument was evaluated through Cronbach's alpha (IBM SPSS 25.0) on a pilot test (Romero Martínez et al., 2020) with a sample size of 70 students. The reliability of the survey yielded a value of $\alpha = 0.752$ which indicated an acceptable level of internal consistency (Taber, 2018). The face and construct validity of the survey was evaluated by a science education expert who was not part of the research team. Content analysis was performed on responses to open-ended questions to obtain observable themes, and coding was done with moderate agreement between two coders (Cohen's $\kappa = 0.687$).

In addition to demographic information, the survey consisted of multiple choice-type questions related to students' ICT skills and the perceived usefulness of various types of online resources and activities provided to them on the Moodle course site. Students were also asked about their preferred mode of instructional delivery and the reasons for their choice. Students were given seven days to complete the survey. A total of 447 complete and anonymous survey responses (45.4% response rate) were obtained. Students were coded as Student 1 to Student 447.

Focus Groups

Following the implementation of the survey, students were invited to participate in focus group discussions (FGD) to further elaborate on their answers to the survey. Participants were given a blank copy of the previously distributed survey at the start of the session to serve as a guide in the focus group discussion (Appendix B), to help them recall their answers to the questions, and to encourage them to elaborate on their responses for richer explanation. Forty-five students voluntarily participated in one of the 16 FGD sessions offered (maximum group size of 5). Student participants were coded as Participant 1 to Participant 45. Each FGD lasted for around 25-40 minutes. Participants were anonymised and all discussions were audio-recorded. Recordings were transcribed in the participants' first languages i.e., English, Filipino or Tagalog. Excerpts of the transcripts in Filipino and Tagalog used in this report were translated into English. Content analysis was performed on transcripts to obtain observable themes, and coding was done with strong agreement between two coders (Cohen's $\kappa = 0.871$).

Participants

Participants were students enrolled in a first-year chemistry course offered during the first semester of the academic year 2019-2020 at the second largest constituent university (CU) of the premier national university in the Philippines.

A total of 985 students across eight lecture sections participated in this study. Each section had an average class size of approximately 120 students and was facilitated by a lecturer. All 985 students were enrolled in a Moodle course site and were grouped according to their lecture sections. For nearly all students, this was the first time they were enrolled in Moodle and their first experience with an LMS. A small number of students had been exposed to online platforms before; however, this was typically limited to posting of announcements and the use of file repositories.

All students enrolled in the Moodle course site ($n = 985$) were invited to participate in the survey seven days after the end of the two-week implementation period. Pen-and-paper surveys were manually distributed to students after a short verbal announcement from their teachers at the conclusion of a lecture or laboratory classes. Students were informed that responding to the survey was voluntary, that they could withdraw at any time, and that withdrawal would not affect their academic record. A statement reiterating these terms was included with the survey. No incentive was offered for completing the survey.

A total of 447 students participated in the survey. Female respondents comprised 58.6% while 38.5% identified as male. Most respondents were 18-19 years old (87.7%) and recent high school graduates under the relatively new basic education curriculum of the Philippines (K-12 curriculum). Most students (91.5%) completed the Science, Technology, Engineering and Mathematics (STEM) strand (Appendix C). These students qualified for admission to their respective undergraduate academic programs (Appendix D) through the nationwide college admission test administered by the university.

Survey respondents completed high school in 49 of 81 provinces in the Philippines (Appendix E), with one respondent from an international high school outside the country. Respondents originated from various provinces around the country (Appendix E), and therefore 24 different Philippine languages and 2 dialects were spoken by the respondents. Most students (77.6%) spoke at least two languages with a majority mainly using the Philippines' official languages—Filipino (61.1%) and English (66.9%) (Eberhard et al., 2019). While 4.5% of respondents reported not speaking Filipino or English in their homes (Appendix C) they had met the institutional admission language requirements.

Learning Analytics Measurements

Analytics data from Moodle were obtained from the standard log dataset. RStudio (version 3.6.1) was used to clean and process the data to obtain a tidy data set. Standard log data were exported to obtain the number of clicks students made during the two-week implementation period. Student data were anonymised during the data cleaning and processing.

Data Analysis

Anonymous student responses from the pen-and-paper survey collected after the blended learning implementation were encoded manually in a spreadsheet prior to analysis. Descriptive statistics were performed on the quantitative data collected from question numbers 1 to 11. Responses to the open-ended question to explain students' answer on question # 11 were coded inductively using NVivo 11. The moderate agreement of almost 70% between two coders was determined through Cohen's κ inter-rater reliability measurement.

Focus group discussions were audio-recorded and transcribed into text by the researcher (CR). Transcriptions were imported into NVivo 11 and coded inductively to identify themes through saturation. A strong agreement exceeding 80% between two coders was likewise determined through Cohen's κ inter-rater reliability measurement.

After downloading the standard log dataset from Moodle, RStudio was used to process the data to generate a heatmap of hourly LMS actions performed by the students within the two-week implementation of the RBL package. Each cell in the heatmap generated in this study represents a cluster of collective LMS activities performed by students for every hour of the day within the implementation period. The colour of each cluster or cell indicates the quantity of student clicks and recorded by Moodle (Moodle terms in parentheses) such as clicks leading to the course site (course viewed) and the learning resources (course module viewed), as well as the clicks to access the quizzes (course module viewed) and the discussion forums (discussion viewed).

Findings

Learning Resources and Activities for Blended First-year Chemistry

Resources and the Implementation of the RBL Framework

The Philippines has previously been categorised under a group of regions that have commenced applying ICT in education and testing various strategies (UNESCO, 2011, cited in Kennepohl, 2012). The country's uptake of ICT for education has remained low, as evidenced by its ranking 107th in the world's ICT Development Index in 2016 (UNESCO, 2018). Given the limitations of the ICT infrastructure in the Philippines, the primary consideration in the design of the blended delivery of selected first-year chemistry topics was the accessibility of the instructional materials. In the context of a learning environment in a developing country, RBL presented itself as a suitable framework that enabled the use of resources which were readily accessible online. Existing resources, many of which were open educational resources (OERs) (Sandanayake, 2016), were packaged into learning activities for utilisation in the blended delivery of first-year chemistry topics instead of creating new online resources. Table 1 summarises the quantity and media forms of learning resources used in one of the topics delivered in this study. A complete list of resources used for all five topics is presented in Appendix F. Thirty-five online resources and activities were sourced from the internet, packaged as learning activities, and posted on the Moodle course site. All learning materials were in English (the medium of instruction at the University).

Table 1
Learning Resources Employed for Blended Delivery of Introduction to Chemical Bonding

Media Form and Number [1]	Resource Name	Source of Resource
Web page (2)	Chemical Bonding: The Nature of the Chemical Bond	https://www.visionlearning.com/en/library/Chemistry/1/Chemical-Bonding/55
	Why do atoms bond with another	https://masterconceptsinchemistry.com/index.php/2017/09/24/why-do-atoms-bond-with-one-another/
Simulation (1)	Chemical Bonds	http://mw2.concord.org/public/part2/bondtype/customDipole3.html
Interactive presentation (2)	Ionic Bonding	https://pbslm-contrib.s3.amazonaws.com/WGBH/arct15/SimBucket/Simulations/chemthink-ionicbonding/content/index.html
	Covalent Bonding	https://pbslm-contrib.s3.amazonaws.com/WGBH/arct15/SimBucket/Simulations/chemthink-covalentbonding/content/index.html
Electronic book (1)	Naming Compounds	https://courses.lumenlearning.com/boundless-chemistry/chapter/naming-compounds/
Practice set (2)	Worksheet 1: Naming Ionic and Covalent Compounds	https://www.gardencity.k12.ny.us/cms/lib/NY01913305/Centricity/Domain/584/Ionic_CovalentNameRace.pdf
	Worksheet 2: Naming Ionic and Covalent Compounds	http://misterguch.brinkster.net/PRA015.pdf
Online quiz (3)	Review Quiz: Periodic Trends	Moodle

	Practice Quiz: Naming Ionic and Covalent Compound	https://www.quia.com/quiz/3124061.html?AP_rand=1897061935
	Quiz on Chemical Bonding	Moodle
Online forum (1)	Ask us!	Moodle

[1]*Note*. Numbers in parentheses indicate quantity.

The four components of the RBL framework were enacted in the use of online resources for this blended delivery. For each of the five chemistry topics included in this study, selected online resources addressed the learning objectives of the first-year chemistry course. Tools for using resources, processing content, and generating evidence of understanding were provided as needed. For each learning activity using resources, scaffolding was put in place to aid students in completing the tasks. An example of how the RBL components were enacted is shown in Table 2.

Table 2
Example Enactment of RBL Framework Components in the Design of a Learning Activity for an Online Resource for the Topic of Molecule Shape

Components	**Particulars**
Topic	*Shapes of Molecules*
Learning objective (context)	Identify the shape of the molecule based on the VSEPR theory
Learning resource	Molecule Shapes (a PhET simulation available at https://phet.colorado.edu/sims/html/molecule-shapes/latest/molecule-shapes_en.html)
Media form	Simulation
Scaffolding (Hill, 2012)	Procedural scaffolding in the form of step-by-step instruction to use and explore the simulation. Conceptual scaffolding by highlighting the important concept being demonstrated by the simulation Strategic scaffolding in the form of a prepared worksheet to accompany the online resource (i.e., simulation)
Excerpt from the annotation (instructional text for the resource provided in the RBL package)	Let us begin this section by exploring the simulation "Molecule Shapes". This will introduce you to the concept of molecular geometry. The simulation will demonstrate the implication of the Valence Shell Electron Repulsion (VSEPR) theory on the resultant geometry of a molecule given the number of its bonding and non-bonding (lone) electron pairs. There are two sections in this simulation. Follow the instructions and complete the tasks for the first section before proceeding to the second one. A document in pdf version is provided below which contains the Worksheet for Parts 1 and 2 of this activity. Further instructions on how to explore the simulation is provided in the same document.

Learning Activities and LCF

Learning resources were categorised into media types and the learning activities they support were informed by the LCF. Table 3 illustrates how these media types were employed in the learning activities designed for each topic included in this study. As shown in Table 3, learning activities were designed according to the form of the media learning resource (Laurillard, 2002).

To avoid creating new resources, narrative media resources that were readily available online in text format, web pages, and videos were employed to present introductory topics in periodic trends and properties and Lewis structures. Most of these narrative media contained not only plain text but also images and audio components that allowed students to integrate the information represented in multiple modes. Adaptive and interactive media resources such as web-based hypertexts and simulations were employed to demonstrate concepts (i.e., how chemical bonding occurs, explore various molecular shapes).

Table 3
Different Learning Tasks Supported by the Media Type Employed in This Study Classified According to the LCF

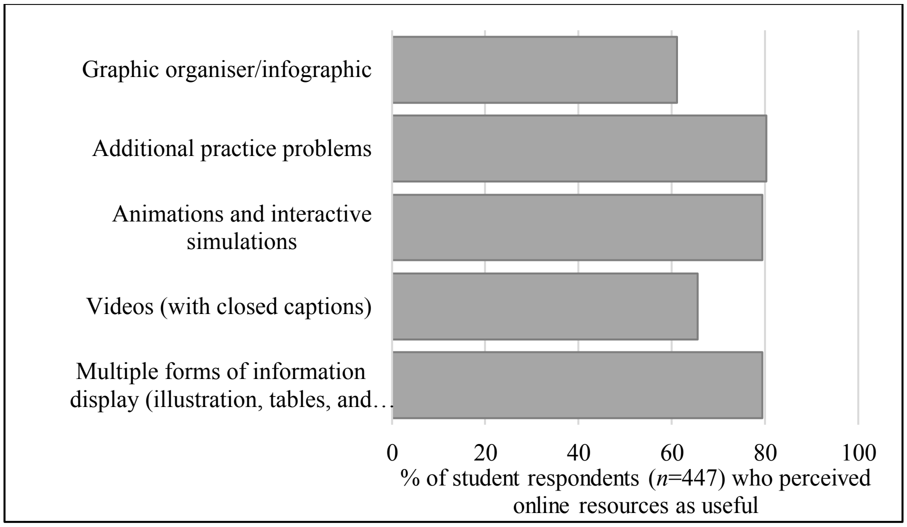
Media type	Media Form	Learning activity(ies) Supported
Narrative	Text, web page, video, infographic, ebook, wiki page	Gathering of concepts through reading, watching videos, summarising and reflection about learning
Interactive	Hypertext, hypermedia	Pursuing other information beyond those directly presented through varying responses from input-based exploration of the resource
Communicative	Online discussion forum	Online discussion with peers
Adaptive	Simulation, interactive presentation	Virtual experimentation Exploration of various cases (based on students' input to the simulation)
Productive	Online quiz, problem set, online discussion board	Practice problem solving Formative assessment Online presentation of output

Students' Perceptions on the Utility of Various Online Learning Resources

Survey results showed that students generally found multiple modes of presenting information useful (Figure 3). Most student respondents deemed the provision of additional problem sets (80.3%) and videos (65.5%) useful. Students in FGD elaborated on how these resources had been useful to them personally (Table 4). A majority of FGD participants found the resources were very helpful because they could change the pace of their study whenever necessary. According to one participant,

> In the lecture, [I] cannot simply stop the lecturer during his/her discussion if there is something that [I] do not understand, and [I] am embarrassed to ask questions in the lecture where everybody in the class would stare at me. With the resources provided, [I] can pause reading the content in the text to allow myself to understand, or to go back while watching videos, or to fast-track to the next topic if I know that I have already learned this topic.

Figure 3
Perception of Student Respondents on the Usefulness of Other Types of Learning Resources



Note. These are students' responses from a multiple-answer type of question (Question #9 in Appendix A)

Table 4
Benefits of Employing Various Forms of Resources in First-year Chemistry Course as Perceived by the Students

Resource	Students' Self-reported Perceived Benefits	Sample Quotes
Animation and interactive simulation	Helpful in visualisation	"Animations for interactive learning are the ones that really helped me since in chemistry, it is difficult to visualise the molecules. It really helped visualise the geometry of molecules."
	Provides avenue to discover other possibilities	"Using animation and interactive simulations, it is us who discover the possibilities in the concepts that we are learning."
Videos	Concise presentation of information	"The links to videos really helped. Concepts are explained more concisely in videos than in the lecture."
	Good alternative for reading long texts	"I prefer watching videos rather than reading long texts because reading requires a lot of time. They present the same information anyway."
	Shorter study time	"Because they are short videos, and they present concepts that are similar to the ones presented in the lecture, my required study time shortened."
Additional practice problems	Opportunities to test understanding	"With the additional practice problems, we are able to practice what we learned from the readings."
	Helpful in tracking progress	"It helps me test my learnings and makes me aware what knowledge I have acquired. The additional practice problems enable us to become aware of how much we have learned and which ones we need to further study."

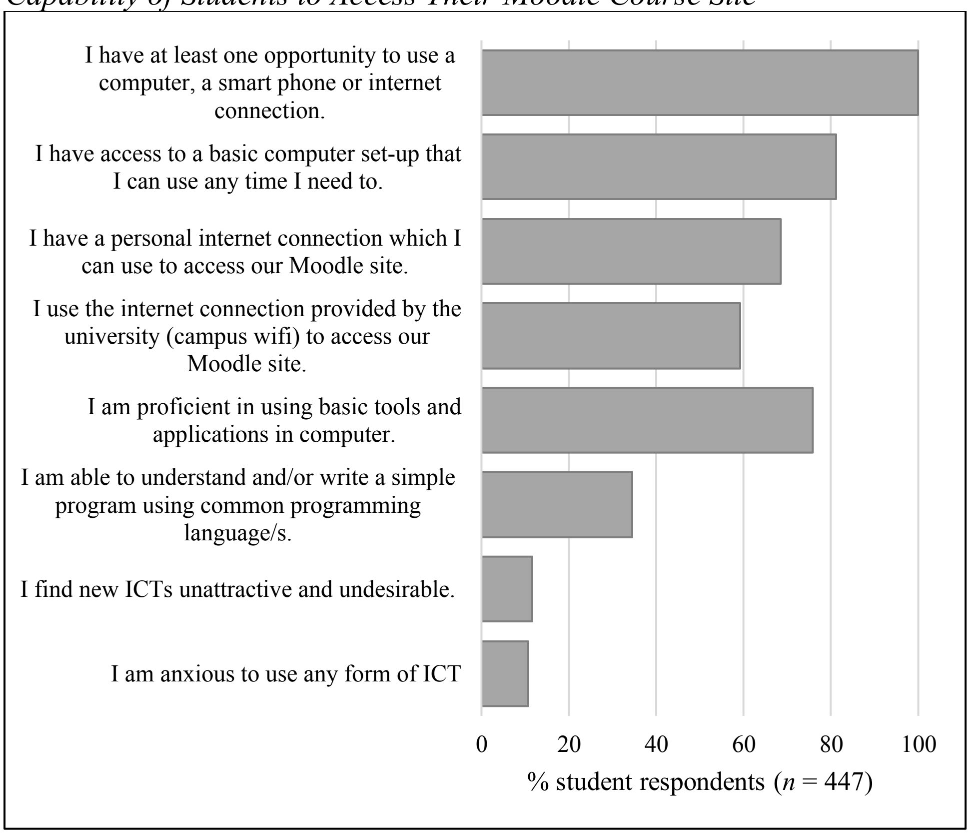
Graphic organiser/infographic	Serves as a simple guide for the topics being covered	"Sometimes, lecture notes are not easy to understand but with the infographic on periodic trends made it easier for me to understand the lesson."
	Helpful in tracking progress	"The infographic on periodic trends served as a list of the concepts that I need to study."

Students' Diverse Backgrounds and Capability to Access Online Resources

Participants in this study were from various provinces in regional Philippines and originated from widely diverse social and academic backgrounds, having completed different high school qualifications. For almost all students, this was the first time they had experienced a blended-learning environment. For example, only a small percentage of high schools (28%) possess ICT capabilities for use in pedagogical purposes (UNESCO, 2018). Despite their diverse originating provinces, this large cohort of students shared a common lack of prior exposure to blended learning. This is likely to have impacted their experiences as they transitioned from traditional face-to-face instructional delivery to blended learning. Participants in this study reported not having equal access and/or skill and confidence to employ digital technologies in their learning. Students reported a range of ICT capabilities to access their Moodle course site (Figure 4).

Figure 4

ICT Skills and Capability of Students to Access Their Moodle Course Site



Note. These are students' responses from a multiple-answer type of question (Question #10 in Appendix A)

Survey results revealed that 81.2% of respondents had ready access to a basic computer set-up which they either personally owned, borrowed, or rented. In addition, most respondents (68.5%) accessed the Moodle course site through their personal internet connection through home broadband or mobile data (68.5%), or through the university's wi-fi connection (59.3%). However, a notable 5.1% of respondents had neither an internet connection at home nor used the campus connection. This small group of students may have accessed the Moodle course site through computer shops which are prevalent around the campus. Users pay a rental fee of PhP20.00 (approximately US$0.40) per hour to use computers with internet connection or to connect their personal devices to the internet.

More than 75% of the respondents self-reported that they were adept with basic tools and applications in computer and/or smart phones, including document processing, spreadsheets, presentations, and publisher. A significant number of respondents (34.5%) claimed more advanced ICT skills to understand and/or write computer programs. Although all respondents had access to at least one form of ICT (i.e., smart phones, computers), 10.7% of respondents remained anxious about ICT. Furthermore, some respondents (11.6%) expressed disinterest and dislike of new ICTs such as new phone applications and computer software. To employ digital technology in teaching and learning, Frawley (2017) underscored the importance of continuously challenging our assumptions about students' relationships with technology and to provide appropriate support and options for students to navigate outside their traditional learning environment. In this study, preliminary support was provided by a brief introductory talk about blended learning, a customised Student Guide to Moodle, and an introductory email containing instructions on how to proceed with their blended learning.

Students' Blended Learning Experience in First-year Chemistry

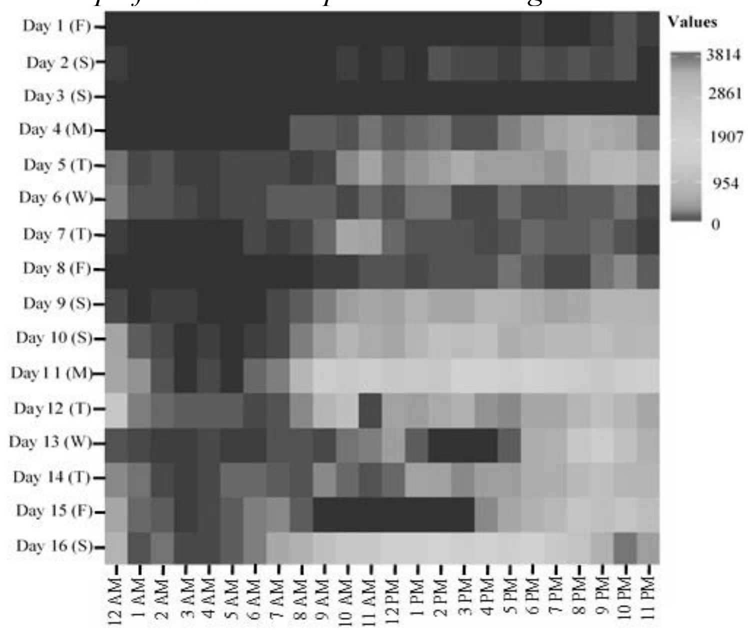
Further insight into the experiences of students during the blended learning mode was obtained through learning analytics measurements of their interactions on Moodle. Figure 5 shows the hourly volume of clicks made by students in Moodle over the two-week period. Students made a total of 231,434 clicks, averaging 14,464 total clicks daily and 15 (± 7) clicks per day per student; this included all clicks recorded by Moodle (Moodle terms in parentheses) leading to the course site (course viewed) and the learning resources (course module viewed), as well as the clicks to access the quizzes (course module viewed) and the discussion forums (discussion viewed).

The heatmap (Figure 5) displays the relative number of clicks as a function of time: cold (i.e., blue) colours in the heatmap indicate low number of clicks, while higher number of clicks is indicated by warm (i.e., orange) colours. The relative intensity in colour indicates the relative magnitude in numbers of clicks. An increase in activity of students commencing from the day the course opened on Day 1 (Friday) is observed in Figure 5, with prominent peaks during weekends and Mondays, and the days leading to the last day of submission of requirements for formative assessments on Day 16 (Saturday). Lower average daily clicks (4248 clicks per day) were recorded on the first eight days of implementation (Day 1 to Day 8), after which, there was a constant and evident increase in LMS activities on most days (average daily clicks of 24,680 on Days 9 to 16).

The lower activity on the LMS observed on the first week reflected time spent becoming familiar with the new learning environment. Over time, the number of clicks increased as students became more familiar with the LMS. This observation serves as a good reminder that when a new learning environment is introduced, students should be allowed some time to learn how to navigate the new environment. While students may become skilled at navigating the LMS to access resources and tools for learning (Kintu et al., 2017), it is critical to provide support for students during their adjustment to the new learning environment. This may take the form of technical support (like the user manual provided to the students in this study and individual emails addressing common issues on logging in and accessing learning materials and activities) and pedagogical support in terms of the number of learning activities expected of students at the early part of the implementation of the new learning environment.

The highest number of daily clicks was recorded on Day 16 (total of 56,954 clicks), with a highest peak at 23:00 (3,814 clicks). In addition to the activity peaks shown, the heatmap likewise captures the days and times when there was zero activity resulting from unavailability of the course site due to a server upgrade, and power and internet outages. Power interruptions occurred at the university during the whole day of Day 3 (Sunday); activities on the course site resumed only on Day 4 (08:00, Monday). Interruption in activities on the course site occurred for 3 hours on Day 13 (14:00-16:00, Wednesday) due to a server upgrade, and on Day 15 (09:00-15:00, Friday) due to a university-wide power interruption.

Figure 5
Heatmap of LMS Actions per Hour During the Two-week Blended Learning



Students' access to ICT was further limited by the university's unreliable power supply and slow internet connection. The fundamental inadequacy of ICT resources available for the students in a developing country such as the Philippines remains a primary barrier for implementing blended learning. In their survey on global blended learning implementation, Barbour et al. (2011) reported limited growth in online learning in the Philippines due to lack of infrastructure that supports online learning. Unfortunately, electricity and internet connection in the Philippines remain below demand capacity even at this present time. Cost of electricity ranks second highest in Asia (Lectura, 2018) while internet speed in the country has remained below the global average in both mobile internet and fixed broadband internet (Speedtest, 2020). The impact of readily available ICT infrastructure on blended learning implementation in the Philippines was evident, not only in students' newly gained learning experiences in a blended environment but also in observable interruptions in learning activities during power outages. The unreliable supply of expensive electricity coupled with slow internet connection have had a significantly negative impact on the interest in blended learning of some participants of this study as shown in Table 5.

Table 5

Opportunities and Challenges Perceived by Students with Blended Learning Using Online Resources Based on Survey Open-ended Responses[1]

Variable	Blended learning
Opportunities	• Presents variety of interactive learning resources and learning activities that facilitate easier understanding of the concepts but are not afforded in a lecture class (43) • Fosters complementary perspectives and benefits from both online and face-to-face modes (49) • Provision for flexibility of learning i.e., learn at own pace, relieves pressure of learning within timed lectures (70) • Cultivates self-directedness in learners i.e., time management, self-evaluation of progress (22) • Promotes fun and interesting learning environment (11)
Challenges	• Expensive and scarce ICT resources (computers, mobile phones) for studying purposes (3) • Unreliable internet connection (13) • Lacks student-teacher and student-student interactions (60) • Stimulates negative impacts of isolation and self-studying i.e. procrastination (22)

[1]*Note.* Number inside parentheses indicate the number of student responses.

Students' Preference in Learning Mode in First-year Chemistry

When asked which learning mode they preferred, 57.5% of student respondents chose blended mode while 40.0% preferred traditional face-to-face lectures. The remaining 2.5% preferred a fully online mode. Students who preferred the blended learning mode cited a wider range of learning resources and activities than the PowerPoint lectures available in the traditional delivery as the reason for their preference. Students also preferred self-paced learning, giving them "control in terms of when [they] can/choose to study the topics," and that "there are different lessons that can be explained better through videos and interactive programs." These findings support the argument of Davis and Frederick (2020) who concluded that online courses integrated with multimedia resources favour students' diverse learning preferences and promote students' performance and learning experience. Furthermore, students valued the perceived flexibility and accessibility of blended learning since some "students [were] able to learn even after class hours." Student responses to the open-ended questions in the survey led to identification of a numbers of themes as given in Table 5.

While most students found multimedia resources useful in the blended learning environment, a significant number of students preferred face-to-face lecture sessions. The primary reason for their preference was their need for interaction with their lecturers and peers. Based on the survey responses, some students preferred "to have an interaction between the students and the professor" and a "direct communication between [the student's] peers and teacher," while others perceived that "[t]here are some topics that are easier when discussed by the professor," "hearing it from the professor and writing it (notes) down helps [the student] in retaining the lessons." Previous studies (Shea, Li, & Pickett, 2006; Shea et al., 2010) have demonstrated that a sense of community is significantly associated with perceived learning gains. The need for face-to-face interactions with their lecturers and peers by students is an indication of the importance of making social presence more pronounced in an online environment. Garrison & Arbaugh (2007) defined social presence in an online environment "as the ability of learners to project themselves socially and emotionally, thereby being perceived as real people in mediated communication." As they shifted from a traditional face-to-face mode to an online environment, students who were used to an environment with very distinct social presence may struggle adapting to an online environment where social presence is fostered inexplicitly. For example, in this study, communicative media resources such as discussion forums were employed to provide an avenue for open communication for students to express themselves socially. Students were likewise encouraged to post questions at the end of each topic for lecturers to respond to. Unfortunately, students were not yet familiar with this medium of interaction to develop their community of learning, i.e., their peers and lecturers in the timeframe of the study.

Discussion

Online learning has been widely integrated in the teaching of many disciplines in higher education in many developed countries. Teaching with online platforms has taken advantage of rapidly evolving ICTs to complement face-to-face teaching through blended, flipped, or hybrid learning models. For over two decades, academic institutions in these countries have established a systematic use of LMS as a core aspect of their teaching.

In contrast, many developing countries are still struggling to successfully integrate online learning with their traditional teaching. Many of the pedagogical innovations routinely used in developed countries have not yet reached classrooms in developing countries due to high cost of building ICT infrastructure or the lack of a quality internet connection. The cost and time required to build an online learning environment consisting of learning resources for content delivery can also be attributed to the slow growth of blended learning for teaching and learning. In a developing country such as the Philippines, these factors have significantly limited the growth of online learning in many disciplines in higher education.

This study explored the possibility of implementing blended learning in first-year chemistry in a premier state university in the Philippines. Application of the RBL framework supported the combination of readily available online resources to deliver a blended learning environment for five topics that are common to general chemistry. Although the use of an LMS is already a core aspect of teaching first-year chemistry in many developed countries, this was the first time that blended learning using an LMS (Moodle) was implemented for first-year chemistry at this university. The LMS was designed to promote a community of online learners interacting not only with the content but also with their peers. This study attempted to foster learning within the online platform by allowing students to perform a variety of learning activities through the online learning resources. This was achieved through the application of the RBL framework that guided the use of readily available, quality online learning resources for a learning design with various learning activities which were guided by the LCF.

Findings from this study suggest that there is substantial potential for utilising a combination of readily available online resources to facilitate blended leaning in first-year chemistry within a limited online learning capacity. Student perceptions of the benefits of blended learning reflected the impact of a carefully designed RBL package containing a variety of learning resources and learning activities. Compared to traditional lectures, most participants preferred blended learning because of the flexibility it afforded, further perspectives it provided, and the new learning experiences it allowed.

Limitations

When interpreting the findings, we acknowledge that the implementation period was limited to two weeks. While the data gathered during this period provided a glimpse of students' immediate behaviour in a new learning environment, a longer period of implementation would have allowed for an understanding of students' behaviours after they became accustomed to the learning environment. Given the positive impact of our initial intervention, we are planning a longer intervention for future research. This will allow students to become more at ease with the new learning environment and lead to further discovery of how students cope with a sense of community in an online learning environment.

Furthermore, this study focussed on the perception of students on the implementation of blended learning in a first-year chemistry with the use of online resources. It did not explore the impact of the new learning modality on students' learning. No pre- and post-test were conducted to determine whether the new modality caused a positive or negative effect on students' learning. In the future, when we can implement the study over a longer period, we will investigate the impact of blended learning modality on students' academic achievement in first-year chemistry.

Future Directions

While students perceived many benefits from blended learning, the challenges that came with online delivery were undeniable. The persistence of unstable electricity supply and unreliable internet connection negatively impacted the blended learning experiences of a significant number of student participants. At the beginning of this study, the researchers had anticipated these challenges, hence, the design incorporated parameters for easier access of the learning materials. This foresight allowed the researchers to compensate for the scarcity in ICT resources and other facilities that the students encountered through the flexibility and accessibility features integrated in the design of the blended learning delivery.

Based on this study, the researchers recommend an expanded implementation of blended learning, both in terms of time (for example, an entire semester) and topic (for example, other chemistry courses).

More in-depth exploration of further opportunities to strengthen interactions among teachers, students, and the content within a blended learning environment and the challenges that may hinder them are strongly recommended. With the rapid developments in ICT and considering the trend of lowering cost of online learning through readily available online learning resources, now is the strategic time to expand blended learning to include the way chemistry is taught in a developing country. It is hoped that by keeping up with current trends in education, improvements in pedagogical practices in chemistry may advance academic institutions in a developing country to become more competitive in the global community.

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Declarations

The author(s) received approval from the ethics review board of Monash University, Australia for this study.

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Appendix A

Survey for the implementation of blended learning in first-year chemistry

Part A. Your background information

On boxes provided, please put a tick mark to your chosen answer.

1. What program are you enrolled in? (*Please choose one*)
   - ☐ BS Agriculture
   - ☐ BS Agricultural Chemistry
   - ☐ BS Biology
   - ☐ BS Chemistry
   - ☐ BS Mathematics
   - ☐ BS Applied Mathematics
   - ☐ BS Chemical Engineering
   - ☐ BS Food Technology
   - ☐ BS Math and Science Teaching
   - ☐ Doctor of Veterinary Medicine
   - ☐ Other Please provide ________________

2. What is your age? ________

3. What is your gender orientation?
   - ☐ Female
   - ☐ Male
   - ☐ Non-binary
   - ☐ Rather not say

4. What is your status as a student?
   - ☐ Full time
   - ☐ Part time

5. Which senior high school strand did you complete?
   - ☐ ABM
   - ☐ GAS
   - ☐ HUMSS
   - ☐ STEM
   - ☐ TVL
   - ☐ Sports
   - ☐ Arts and Design
   - ☐ Others, please provide ___________________
   - ☐ I completed the old basic education curriculum.

6. What province is your high school located? _____________________________

7. What language/s are spoken at your home? (*Please list all*) ________________

8. Are you a recipient of a scholarship program or grant that supports you financially at university?
   - ☐ Yes
   - ☐ No

Part B. Your learning experiences

The following questions seek to capture your experiences on learning the topics covered in the last two weeks i.e., periodic trends, chemical bonding, Lewis structure, molecular shapes and polarity. To help you answer these questions, recall the way the lessons were delivered in the previous two weeks of your study.

9. Which of the following did you find useful for your study? (*Tick ✔ all that apply*)
   - ☐ Closed caption (CC) videos or videos with subtitles
   - ☐ Multiple forms of information display (i.e., text, tables, illustrations, and diagram)
   - ☐ Animation and interactive simulation supplementary to the lecture
   - ☐ Additional practice problems of various types
   - ☐ Graphic organisers and infographics that accompany lecture notes

10. Which of the following statements do you identify with? (*Tick ✔ all that apply*)
    - ☐ I lack digital experience because I am anxious to use any form of information and communications technology (ICT) which includes the use of smart phones and computer (desktop or laptop).

- ☐ I find new ICTs including new applications and software unattractive and undesirable.
- ☐ I have access to a basic computer set-up (personally owned, rented or borrowed) that I can use any time I need to.
- ☐ I have a personal internet connection (home Wi-Fi, mobile data) which I can use to access resources and activities from our Moodle site.
- ☐ I use the internet connection provided by the university (campus Wi-Fi) to access our Moodle site.
- ☐ I am proficient in using basic tools and applications in computer (or smart phones) such as Microsoft Office or Mac OS (document processing, spreadsheet, presentations, publisher, etc.).
- ☐ I am able to understand and/or write a simple program using common programming language/s.
- ☐ I have never had an opportunity to use a computer, a smart phone or internet connection.

11. Which was your preferred mode of delivery of the topics taught over the past two weeks? (*Choose one mode only*)
    - ☐ Traditional lecture class (PowerPoint, board and pen)
    - ☐ Blended mode (mixture of lecture and online component)
    - ☐ Fully online

    Briefly explain your response to question #11.

    ____
    ____
    ____

Appendix B

Guide questions for the focus group discussion on the blended learning implementation of first-year chemistry

Instructions for the students: The questions for this discussion refer to your learning experiences with resources and activities specifically covering the topics on electronic configuration, Lewis structure, molecular shapes and hybridisation.

1. In the survey, you were asked to identify which learning material/s were helpful in your study. Why did you think these learning material/s is/are most helpful?

2. Were there any aspects of the blended delivery of the topic that makes it difficult for you to access, understand or complete?

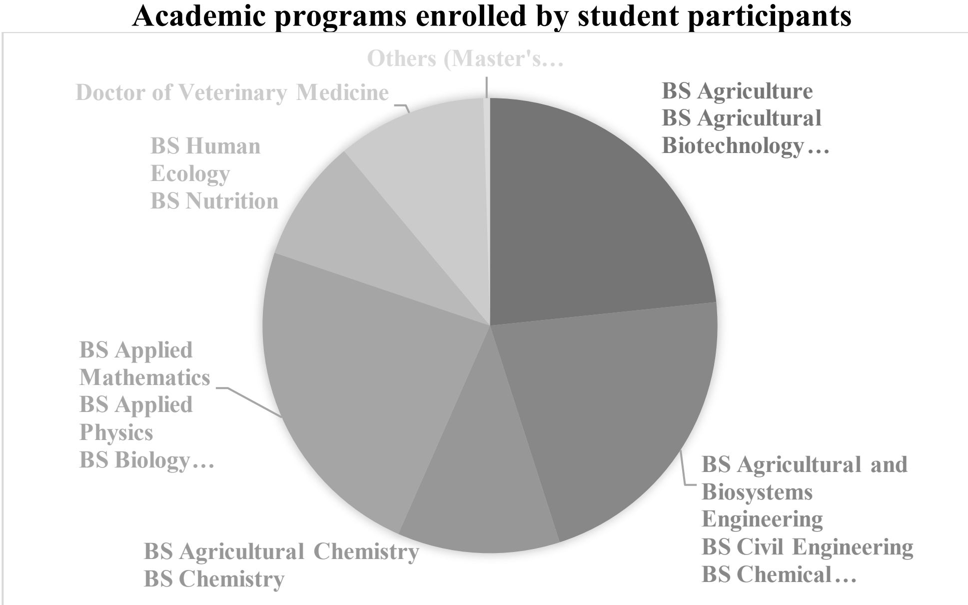
Appendix C

Respondents' demographic information

	Number of respondents (*n* = 447)
Gender	Female = 262 (58.6%) Male = 172 (38.5%) Non-binary = 7 (1.6%) Rather not say = 6 (1.3%)
High school strand completed	Science, Technology, Engineering and Mathematics (STEM) = 409 (91.5%) Accountancy, Business and Management (ABM) = 8 (1.8%) Humanities and Social Sciences (HUMSS) = 8 (1.8%) Technical Vocational Livelihood (TVL) = 3 (0.7%) General Academic Strand (GAS) = 8 (1.8%) Completed basic education curriculum (prior to 2016) = 11 (2.5%)
Respondents' originating provinces	Laguna = 140 (31.3%) Metropolitan Manila = 95 (21.3%) Luzon (excluding Metropolitan Manila and Southern Luzon) = 167 (36.2%) Visayas = 13 (2.9%) Mindanao = 28 (6.3%) Outside Philippines = 1 (0.2%) Not indicated = 3 (0.6%)
Major languages spoken by respondents	English = 299 (66.9%) Filipino = 273 (61.1%) Tagalog = 171 (38.3%) None of the above = 20 (4.5%)

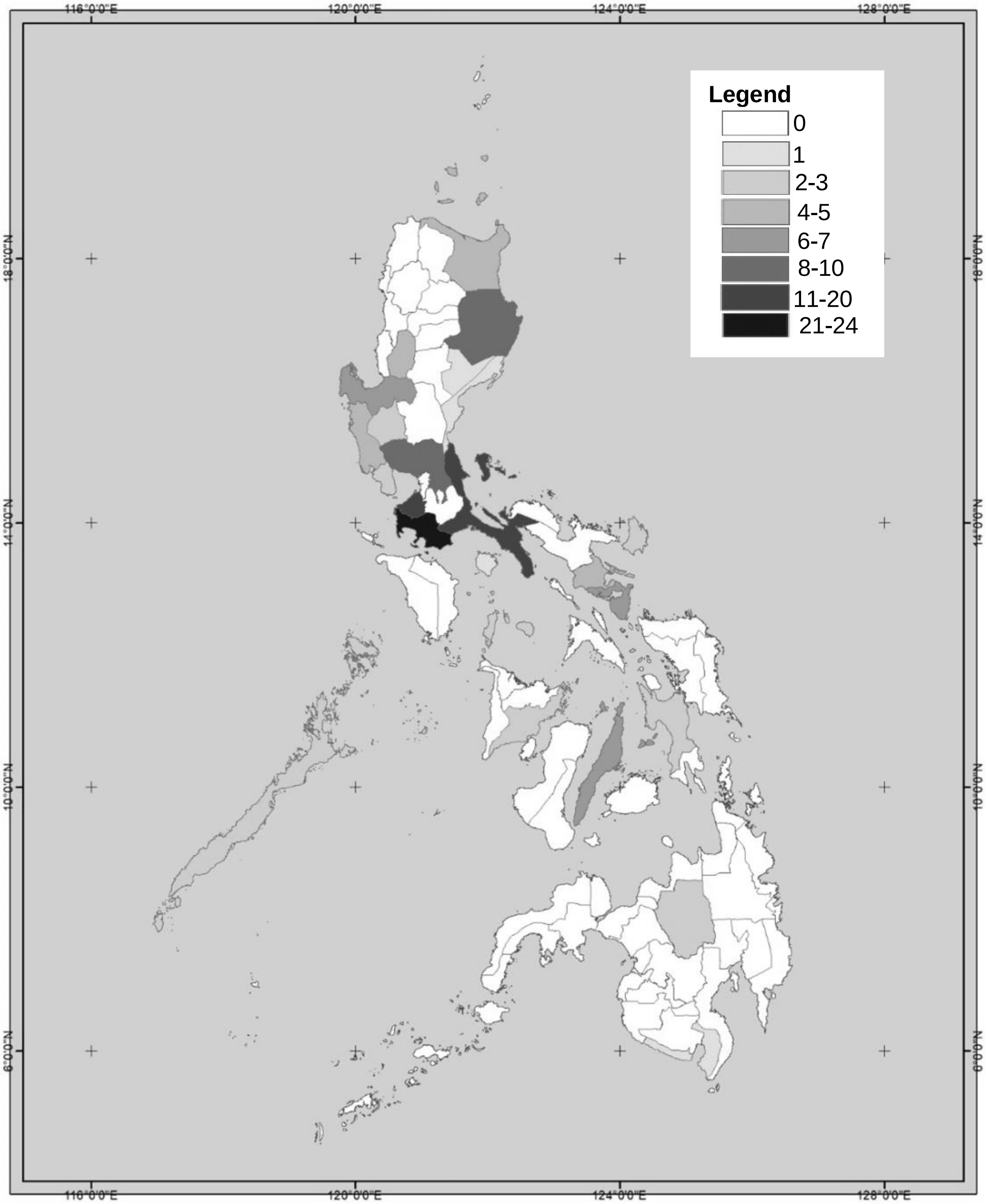
Appendix D

Academic programs enrolled by student participants



Appendix E

Originating provinces of survey respondents
(Shading corresponds to the number of respondents from each province)



Appendix F
Learning resources that were employed for blended delivery of first-year chemistry topics

Topic	Media form and number [1]	Particulars	Source of resource
Preliminary resources (Moodle student guide and electronic book)	Text (1)	Student guide to the Moodle course site	Prepared by the researcher
	Hypertext (1)	Atoms First (2nd ed)	https://openstax.org/details/books/chemistry-atoms-first-2e
Periodic table and periodic trends	Web page (2)	Development of the Periodic Table	https://www.rsc.org/periodic-table/history/about
		The Evolution of the Periodic System	https://www.scientificamerican.com/article/the-evolution-of-the-periodic-system/
	Hypertext (1)	IUPAC Interactive Periodic Table	http://www.rsc.org/periodic-table
	Video (1)	The Periodic Table and Trends	https://www.youtube.com/watch?v=hePb00CqvP0
	Infographic (1)	Mastering Periodic Trends (ACS)	https://www.acs.org/content/dam/acsorg/education/students/highschool/chemistryclubs/infographics/mastering-periodic-trends-infographic.pdf
	Electronic book (1)	Periodic Trends	https://opentextbc.ca/introductorychemistry/chapter/periodic-trends-2/
	Online quiz (1)	Quiz on Periodic Trends	http://www.uplifths.org/ourpages/auto/2015/3/31/54112596/PeriodicTrendsPracticeSUB1106.pdf
	Online forum (2)	Chemistry in my name	Moodle
		Ask us!	Moodle
Introduction to chemical bonding (including naming compounds)	Web page (2)	Chemical Bonding: The Nature of the Chemical Bond	https://www.visionlearning.com/en/library/Chemistry/1/Chemical-Bonding/55
		Why do atoms bond with another?	https://masterconceptsinchemistry.com/index.php/2017/09/24/why-do-atoms-bond-with-one-another/
	Simulation (1)	Chemical Bonds	http://mw2.concord.org/public/part2/bondtype/customDipole3.html
	Interactive presentation (2)	Ionic Bonding	https://pbslm-contrib.s3.amazonaws.com/WGBH/arct15/SimBucket/Simulations/chemthink-ionicbonding/content/index.html

		Covalent Bonding	https://pbslm-contrib.s3.amazonaws.com/WGBH/arct15/SimBucket/Simulations/chemthink-covalentbonding/content/index.html
	Electronic book (1)	Naming Compounds	https://courses.lumenlearning.com/boundless-chemistry/chapter/naming-compounds/
	Practice set (2)	Worksheet 1: Naming Ionic and Covalent Compounds	https://www.gardencity.k12.ny.us/cms/lib/NY01913305/Centricity/Domain/584/Ionic_CovalentNameRace.pdf
		Worksheet 2: Naming Ionic and Covalent Compounds	http://misterguch.brinkster.net/PRA015.pdf
	Online quiz (3)	Review Quiz: Periodic Trends	Moodle
		Practice Quiz: Naming Ionic and Covalent Compound	https://www.quia.com/quiz/3124061.html?AP_rand=1897061935
		Quiz on Chemical Bonding	Moodle
	Online forum (1)	Ask us!	Moodle
Lewis structures	Wiki (2)	Drawing Lewis Structures	https://chem.libretexts.org/Bookshelves/General_Chemistry/Map%3A_Chemistry_-_The_Central_Science_(Brown_et_al.)/08._Basic_Concepts_of_Chemical_Bonding/8.5%3A_Drawing_Lewis_Structures
		Violations of the Octet Rule	https://chem.libretexts.org/Bookshelves/Physical_and_Theoretical_Chemistry_Textbook_Maps/Supplemental_Modules_(Physical_and_Theoretical_Chemistry)/Chemical_Bonding/Lewis_Theory_of_Bonding/Violations_of_the_Octet_Rule
	Practice set (1)	Practice Problems on Lewis Structure	Uploaded by the researcher
	Online quiz (1)	Quiz on Lewis Structures	Moodle
	Online forum (1)	Ask us!	Moodle
Geometry of molecules	Simulation (1)	Molecule Shapes	https://phet.colorado.edu/sims/html/molecule-shapes/latest/molecule-shapes_en.html

	Wiki (1)	Geometry of Molecules	https://chem.libretexts.org/Bookshelves/Physical_and_Theoretical_Chemistry_Textbook_Maps/Supplemental_Modules_(Physical_and_Theoretical_Chemistry)/Chemical_Bonding/Lewis_Theory_of_Bonding/Geometry_of_Molecules
	Online bulletin board (1)	Draw and share on Padlet	https://padlet.com/cha_reyes/n53itd5149h5
Polarity	Hypermedia (1)	Polarity of Molecules	http://glencoe.mheducation.com/olcweb/cgi/pluginpop.cgi?it=swf::640::480::/sites/dl/free/0003152012/931049/Polarity_of_Molecules.swf::Polarity%20of%20Molecules
	Web page (2)	How to determine molecular polarity	https://preparatorychemistry.com/Bishop_molecular_polarity.htmhttps:/preparatorychemistry.com/Bishop_molecular_polarity.htm
		How polarity makes water behave strangely	https://www.youtube.com/watch?v=ASLUY2U1M-8
	Video (1)	Influence of shape on a molecule's polarity	Uploaded by the researcher
	Problem set (1)	Exercise on molecular shape and polarity	Uploaded by the researcher
	Online quiz (1)	Quiz on Polarity	Moodle
	Online forum (1)	Ask us!	Moodle

[1]Numbers in parentheses indicate quantity.