



DEPARTMENT OF APPLIED
INFORMATION TECHNOLOGY

INTERACTIVE AND MULTIMEDIA-BASED DIGITAL TEXTBOOKS FOR FLIPPED LEARNING

Practices and Challenges of Science Teachers in International Baccalaureate
Diploma Programs

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| Thesis: | 60 higher education credits |
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| Supervisor: | Wolmet Barendregt |
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Abstract

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Purpose: The aim of this study was to explore the practices and challenges of teachers using interactive and multimedia-based Digital Textbooks (DT) in International Baccalaureate Science Diploma Programs (IBDP) and investigate whether they could support student-centered learning methods such as Flipped Learning (FL).

Theory: The study employed Activity Theory to investigate activities of teachers in their school environments.

Method: Perspectives, practices and challenges of seven teachers were captured through semi-structured interviews and non-participatory observations of classroom teaching activities over a period of 4 weeks.

Results: The study found that the DTs supported teaching activities for Flipped Learning, helped teachers to create solutions for diverse ability classrooms and aided self-directed learning of students. When integrated into teaching, DTs served as an additional interaction channel between teachers and their students. However, the level of integration among teachers was uneven due to significant differences in perceived benefits. Further, the findings showed that the availability of the DTs to students did not automatically translate into motivation of use and engagement. Thus, it is recommended that teachers identify and employ strategies and share their experiences to facilitate learning with the DTs. The current and future anticipated needs of teachers identified in this study should be also considered by the developers. Further, the study proposes the investigation of student motivation and engagement with DTs with a focus on learner needs in higher and standard level study tracks.

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1 Introduction

1.1 Background

The educational paradigm in the 21st century is shifting from transmitting and acquiring accumulated knowledge towards problem-solving, integrating and synthesizing knowledge. Consequently, traditional teaching-learning methods are being replaced by methods that emphasize student-centered learning and the use of technology in teaching (Kang & Everhart, 2014). An instructional model that gained significant attention in recent years is Flipped Learning. This student-centered approach reverses the traditional learning process by having students review learning materials prior to class. In the class, teachers guide students through problem solving exercises, peer-interaction and promote a differentiated, personalized learning (Yarbro, et al., 2014). Research shows that the FL approach can be helpful to teachers to create increased time for active learning and higher-order thinking when compared to traditional classrooms (Gough, et al., 2017). Throughout the FL process technologies such as videos and other digital resources can facilitate teaching and learning (Strayer, 2012; Bergmann & Sams, 2012; Bergmann & Waddell, 2012; Yarbro, Arfstrom, & McKnight, 2014).

As part of the new tools for learning, Digital Textbooks (DT) have also appeared and became increasingly popular in the past decade (Lin, et al., 2015). Interactive and multimedia-based DTs provide learners with an individualized study environment, offer a variety of multimedia contents such as videos, animations, virtual reality both for school and home, without the limitations of time and space. They connect information through hyperlinked words and concepts to related pages or external documents. With constantly updated content they can provide learners with the up-to-date knowledge (Kim, et al., 2012). Advanced formats of DTs provide learning diagnostics data and offers teachers an instant feedback of student learning.

Many teachers have positive attitude towards DTs and report about high levels of perceived benefit, higher motivation and learning desire from the students (Kim, et al., 2012). On the other hand, studies suggest, that using DTs might not translate into additional cognitive learning outcomes when compared to printed textbooks. This indicates that learning outcomes might not be dependent on the format of the textbook (Rockinson-Szapkiw, et al., 2012). However, rapid technological developments and the appearance of interactive and multimedia-based DTs, as well as the inconclusiveness of current research on the benefits of DTs suggests that further investigation is needed to understand the practices and challenges of using DTs in education. Can DTs support educators in meaningful ways and facilitate student-centered pedagogies like Flipped Learning? The perspectives, practices and challenges of teachers are especially important in this regard as it is generally they who decide whether and how to adopt information technologies or innovative technologies for teaching and learning (Lin, et al., 2015). This study explores the realities of teachers who attempt to work with interactive and multimedia-based DTs and investigates real-life contexts to identify their practices and the challenges.

1.2 Aims and Objectives of the Study

The aim of this study is to investigate teachers' aims, practices and challenges of integrating interactive and multimedia-based DTs intended for Flipped Learning in their teaching practices.

More precisely the study aims at investigating the following research questions:

- Are DTs being utilized by teachers?
- If so, why and how are DTs being used by teachers?
- Are the DTs being used for Flipped Learning practices? If so, how?
- What challenges do teachers face when using DTs?

1.3 Significance of the Study

In the classroom, it is the teachers who generally decide whether and how to adopt information technologies or innovative technologies. However, few studies have examined the perspectives of teachers on DTs. Existing research has mainly dealt with technological aspects or have focused on the perspectives of researchers on DT (Lin, et al., 2015). The present study contributes to addressing the existing gap in research and investigates the practices and challenges of teachers on the use of DTs in school settings. It is expected that the results can be used to better understand teachers' use and needs of interactive, multimedia based DTs. Moreover, the study can provide an insight for the publisher and developer in this study on how their product is being used in education, and inform their design.

1.4 Structure of the Thesis Work

The thesis work is structured in seven chapters. Chapter 1 provides an introduction to the research field. Chapter 2 elaborates the key concepts and theories relevant for the research. Chapter 3 introduces the research methodology as well as the applied analytical model. Chapter 4 provides an insight into the educational contexts of the study and presents case studies collected on teacher use and views of DTs. The data is analyzed and discussed in Chapter 5 based on the analytical model described in Chapter 3. Chapter 6 discusses the findings of the study, finally the last Chapter provides recommendations for design and future research.

2 Key Concepts and Theories

2.1 Digital Textbooks

The definition and features of DTs are continuously changing due to the development of technologies and new applications of these technologies in education. The following section provides an overview of current understandings and research on the use of DTs in education.

First, terminological diversity exists in the research. Terms like e-book, e-textbook, DT and e-reader are often used to refer both to the content and the container. In broad terms, DTs contain educational material and functions that can be used for educational purposes. Kim et al. (2012) define DTs as core textbooks for students, that incorporate textbooks, reference books, dictionaries and multimedia. Students can learn contents from these DTs that are tailored to their abilities and interests. Knight (2015) defines DTs as textbooks with structured textual and visual content using a digital format. Knight, et al. (2010) also differentiate textbooks based on the degree to which teachers and students use them. They define four categories: 1) integrated core resource, 2) core resource, 3) related resource and 4) peripheral resource. In core integration, the textbook provides the scope, sequence and learning activities with learning management system resources complementing the textbook. When used as a core resource, textbooks play a significant role in the structure of the course with course outlines relating to sections of a textbook. Textbooks as related resources provide a wide range of resources to support student learning with textbooks being one of the resources. Textbooks that provide background reading are reference or peripheral resource and would be regarded as optional (Horsley, et al., 2010).

There is also a lack of consensus on the specific features and types of DTs that may exist. They can look exactly like old print versions or they can include multimedia, active assessments, sharing, accessibility features and interactivity (Chesser, 2011). Nevertheless, research and practice are pointing to three general characteristics of DTs; adaptability, multimodality and interactivity (Regueria & Rodriguez, 2013).

2.1.1 Adaptability

Adaptability refers to the ability to adjust the format and the content of the DT to student characteristics. In other words, it refers to the extent to which the DT can be changed. Two types of DT can be differentiated based on their adaptability; 1) page-fidelity DTs and 2) reflowable DTs (Chesser, 2011).

Page-fidelity DTs are common forms of DTs. These are exact screen renderings of the printed pages. They rigidly maintain the layout of the paper version of the book and are built from pdf source files directly exported from the workflow of the publisher. Often the pdf source is then added into a third-party platform that offers some level of search and annotation function as well as digital rights management. According to Chesser (2011), proponents of this type of DTs argue that these books can easily be produced in great numbers by a single workflow. They do not

represent significant extra costs for the publishers and a wide range of books can be available very quickly. Besides, these books look familiar to students and teachers as they represent the format of a print book. On the other hand, page-fidelity books are static and often do not take advantage of basic media and communication capabilities technology can offer. Other concern is the large file sizes and difficulty in integrating multimedia. Media objects may be linked but with pdf sourced documents media objects cannot typically be embedded in the page. They do not cater for a variety of learners and require little or no change in teaching behavior to be used in the classroom. As there is no real classroom innovation, page-fidelity textbooks do not necessarily enrich learning (Chesser, 2011).

Reflowable DTs maintain all the content from the print textbook but often dynamically deal with elements of page layout. These DTs are typically created from XML source files instead of pdf and have fluid line and page breaks. Reflowable DTs enable their users to change font sizes, adjust windows without causing the entire page to resize. The background colors for pages, figures and box features can be also set according to user preferences. Proponents point out that reflowable DTs provide better experience on mobile and other smaller device screens. The format enables the integration of multimedia objects directly in line in the text. The primary disadvantage of reflowable DTs has been the investment cost as XML files. There are also variations among publishers of how the specification is defined and applied. Individual publishers develop their own unique delivery platforms (Chesser, 2011). Thus, in large schools and school corporations there is a need for cross-publisher platforms. In addition, there is a common expectation that DTs should tackle the problem of expensive print textbooks. However, the need for rich media and interactivity mean also higher development costs (Chesser, 2011).

2.1.2 Multimodality

Multimodality refers to integration of different interactive and multimedia elements such as videos, 3D animations or simulations. In summary, it refers to the possibility to present content in different formats and take advantage of the potential offered by new technologies. New versions of DTs often provide various interactive functions and a combination of textbooks, reference books, workbooks, dictionaries and multimedia contents, such as digital photos, animations, simulations, videos, virtual reality or websites both at school and a (Shepperd, et al., 2008)t home with no constraints on the time and space (Kim, et al., 2012). DTs can also support learning with functions such as highlighting, annotating, searching, bookmarking, referring and editing. The content can be easily updated by publishers and therefore students can have access to the latest knowledge. Features can also allow for teachers to assign relevant materials to students according to their individual needs (Cheng, et al., 2013).

2.1.3 Interactivity

Interactive DTs commonly allow students to share what they do such as annotations, highlights, reports and notes. Such features provide opportunity for collaborative learning and interaction among students. But communication happens not only between content and students. Interactivity

includes also the possibility of feedback and communication between teachers and students and even publishers (Regueria & Rodrigez, 2013).

2.1.4 Digital Textbooks in Teaching and Learning

In recent years, the use of DTs has appeared along with opinions on improving student reading and learning efficiency. Higher learning desires, greater self-motivation and enhanced learning capacities have been mentioned in several studies. As the implementation of DTs has increased, studies have begun to investigate teachers' perception (Lin, et al., 2015).

Kim, et al. (2012) found that teachers held positive perceptions about DTs. The authors surveyed 157 school teachers in South Korea to identify the factors influencing the use and acceptance of multimedia-based DTs. Their findings indicate that teachers were slightly inclined towards optimism about DTs and that teachers ranked positively towards all the seven constructs; enjoyment, educational impact, perceived benefit, intention to use, ease of use, interaction and content quality. Cheng, et al. (2013) also found that most teachers interviewed held positive attitudes toward DTs. Most teachers in the study were motivated by functions such as an attractive interface, instant feedback, note taking and the ability to play interactive content. McFall (2006) reported the e-textbooks helped teachers to assign students assignments and know which part required more attention as well as who had the correct understanding of the material. Furthermore, it aided teachers in classifying misunderstandings and assign student to assist their peers. As for the efficiency, the study argued that the use of e-textbooks had fully changed teaching approaches. Teachers reported that e-textbooks helped them to better connect with students and their learning and enabled more effective use of class time for teachers who did not prefer the use of traditional books. On the other hand, Lam and Tong (2012) observed that preservice teachers were more conservative with using DTs. Study participants were concerned about equity, maintenance, administrative and practical issues, student safety and student distraction.

2.2 Flipped Learning

In the Flipped Learning model, students first get introduced to new material outside of the class via reading or watching lecture videos. In-class time can be then spent on exploring topics and issues in greater depth. This allows teachers to maximize the use of face-to-face classroom interactions to check for and ensure that students understand and can synthesize the material. It frees up class time and allows for more individual and small group instruction (Brame, 2013). In the traditional teacher-centered model, the teacher is the main source of information and content expert who provides information to students via direct instruction lecture (Hamdan, et al., 2013). The teacher-centered approach emphasizes a passive student role in learning as teachers transmit knowledge outside of the context in which it will be used. The teacher is the primary information giver and evaluator and assessment is used to monitor learning with an emphasis on the right answers (Huba & Freed, 2000). In Flipped Learning (FL) the focus is on active learning through the students' own knowledge construction. The FL model (see Figure 1) represents a shift from a teacher-centered classroom towards a student-centered approach (Ng, 2015). It is defined as "a pedagogical approach in which direct instruction moves from the group learning space to the

individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment, where the educator guides students as they apply concepts and engage creatively in the subject matter.” (FLN, 2014). Applying Bloom’s revised taxonomy on FL, we can say that students are doing the lower levels of cognitive work outside of class, such as gaining knowledge and comprehension. During class time they can focus on the higher forms of cognitive work, where they get support from their peers and teachers (Brame, 2013).

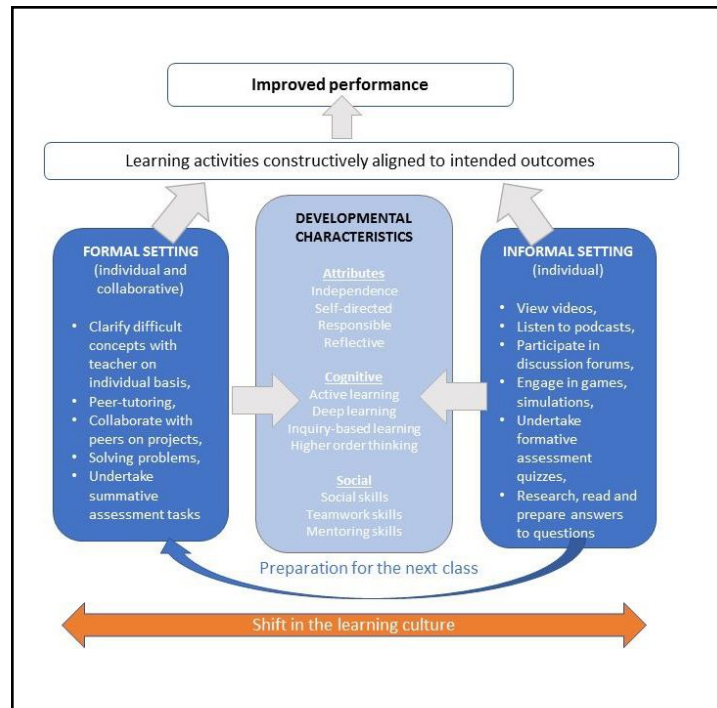


Figure 1 Model of Flipped Learning (Ng, 2015)

Estes, et al. (2014) propose a simple model for flipped instructional design shown in Figure 2. The pre-class, in-class and post-class activities in the figure reflect the general stages of flipped learning.

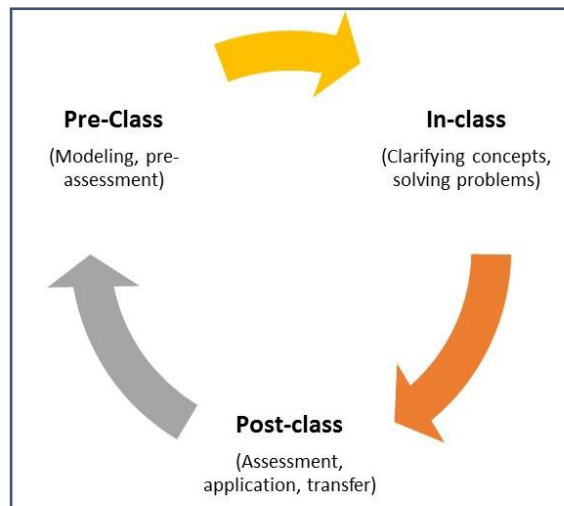


Figure 2 The Stages of Flipping a Class (Estes, et al., 2014)

Digital technologies are often used at pre-class stage to shift direct instruction from the group learning space to the individual learning space. However, the first exposure does not necessarily have to be high-tech. Resources used can vary from textbooks to lecture videos, podcasts or screencasts. The videos can be created by the teacher, or found online from other teachers or similar resources. Incentives can be used to encourage preparation such as for example points or quizzes. These pre-class assignments students complete can help the teacher and students to assess their understanding and focus on areas that need attention. For example, pre-class quizzes allow teachers to tailor their class activities to focus on the elements students are struggling with. Automated quizzes provide instant feedback and students can also easier pinpoint where they need help. (Estes, et al., 2014). Furthermore, pre-class writing assignments help students clarify their thinking about the subject and facilitate richer in-class discussions. Teachers can then maximize classroom time by adopting various methods of instruction such as active learning strategies, peer instruction, problem-based learning depending on the grade and subject matter. The activities will depend on the learning goals. The key idea of FL is that students use the class time to deepen their understandings and increase their skills at using their knowledge (Estes, et al., 2014).

Flipped learning allows for a variety of learning modes. Teachers often physically rearrange their learning space to accommodate the lesson or unit, which might involve group work, independent study, research, performance and evaluation. In these flexible environments, students can choose when and where they learn. There should be space both for collaborative work and individual work where students can work with fewer distractions. The arrangement of furniture can encourage these activities and take the focus off from the teacher (Hamdan, et al., 2013).

Reasons often mentioned for flipping the classroom is the increased interaction of teachers with students and that it allowed to teachers to become more like a mentor to students. Teachers can focus more on struggling students and differentiate instruction. Students could also develop better relationships with peers through collaboration in class. Recorded lectures tended to help struggling

students because they can re-watch portions of lessons that they do not understand. They could also watch the lectures at their own pace when it worked in their schedule. Flipping also made learning easier for absent students because of the availability of video lectures (Ng, 2015). Bergman and Sams (2012) point out that flipping the classroom created the opportunity to increase the involvement of parents as they had the ability to watch the lectures. This made the classroom more transparent and led to more discussion on student learning

Bergman and Waddell (2012) argued that in many flipped classrooms, the lecture becomes the centerpiece of instruction and passive learning is just removed from the inside of the classroom to outside classroom. Milman (2012) cautioned that students are not able to ask their teachers questions while they are viewing the lectures at home and language learners may struggle to understand the content. Access to internet and devices can be a problem in some of the homes due to income levels. Another concern is that students may not prepare at home, consequently, they will not be prepared for class (Herreid & Schiller, 2013). Bergman and Sams (2014) say that the implementation of flipped learning can be daunting for individual teachers as it requires a great amount of time and effort. The learning curve is a steep as teachers have not only have rethink how their classes should operate but also learn new technologies. They argue that collaboration among teachers is therefore often the successful way forward.

2.3 Activity Theory

The central tenet of this study is that educational tools cannot be understood by studying either the learning tool or the educational context in isolation from one another. Therefore, this study needed a theoretical lens that attends not only to the digital tool but also to the complex learning environments where they are introduced into. Activity Theory focuses on understanding human activities and processes as they continuously develop over a period of time and are influenced by their context. The unit of analysis in Activity Theory is human activity, namely what people do. A central concept of the theory is the tool mediation. This refers to the notion that people develop and use tools to achieve their objectives. Such tools can be both physical, such as mobile phones or computers, and conceptual, as for example software applications or in this study interactive, multimedia-based DTs. Using these tools, people perform activities which transform their individual minds. At the same time, people also modify the activities they are engaged in. Studying these activities helps to identify changes and possible contradictions that might exist in the activity. In summary, the Activity Theory seeks to explain that human activities are socially and culturally influenced. The activity theory framework allows several methods and techniques for evaluating the design and use of technology-based tools (Mwanza-Simwami, 2013).

The core idea of the Activity Theory originates from Lev Vygotsky. It is a concept focused on the mediation of the subject, the object and tools (or artifacts) in the interaction (Mwanza-Simwami, 2013). Later, more elements were introduced by Alexei Leont'ev, such as the concept of activity, object of activity and division of labor (Leont'ev, 1978). Leont'ev stressed that activities cannot exist without their objects. Division of labour was a result of individuals' specialization in making

and using tools (Kaptelinin & Nardi, 2012). In the 1980's and 1990's the activity system was further developed by Engeström (1987,1999). He integrated elements of Vygotsky's and Leont'ev's frameworks and introduced the new ideas of community, rules and outcomes. Thus, based on Engeström's view, Activity Theory constitutes seven elements; 1) subjects, 2) object, 3) tools, 4) community, 5) rules, 6) division of labour and 7) outcomes. The model of an activity system is represented as a triangle as shown in Figure 3. It is the theoretical model by Engeström (1987) that is applied in the present study.

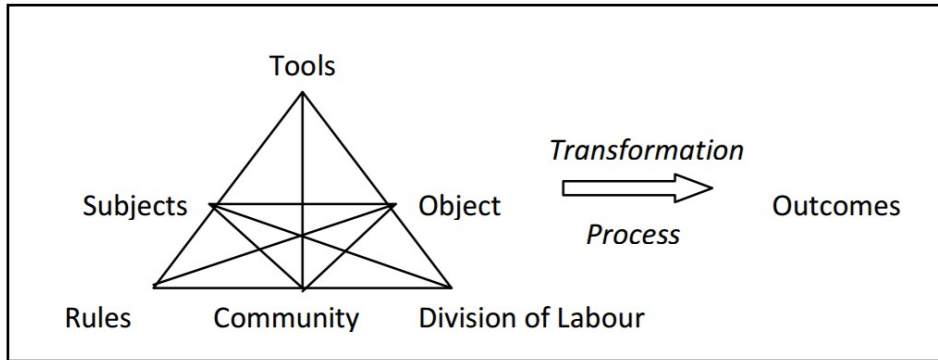


Figure 3 Activity triangle model (Engeström, 1987)

Subjects of an activity system represent the people who are involved in activity, e.g. the learners and teachers. Tools represent artifacts, such as the technology used to carry out activities. Object represent the objectives, motives and purposes of people for engaging in the activity. The objectives are then transformed into outcomes. Rules are elements that refer to regulations, cultural norms and practices of those involved in activity. Community components represent both the physical and conceptual environment in which the activity is carried out, e.g. a school community. Finally, the division of labour component reflects variations in roles and responsibilities when carrying out activities (Mwanza-Simwami, 2013).

In summary, the model clarifies the structure of an activity as well as the relationships that exist among the components of the activity system (see Figure 3). It investigates the objectives and motives of the people involved and can provide insight in the history of the development and use of the investigated technologies. It considers the rules, regulations and the division of the work as these also influence the activities (Mwanza-Simwami, 2013).

3 Research Methodology

3.1 Research Design

The research in this thesis took an interpretivist epistemological and a dialectical constructivist ontological position. This means that in developing knowledge and thought, social interactions play a critical role. Dialectical constructivism acknowledges the possibility that one must consider multiple meanings when assessing a singular event. It implies that social phenomena are not only produced through social interaction, but they were in the state of constant revision (Bryman, 2012). This focus enabled the researcher to investigate how people engaged in activities that involved goals and objects, outcomes, which drove that activity and the relationships among groups of people.

The researcher chose to undertake a multiple-case study design (Bryman, 2012) to investigate the practices and challenges of teachers in connection to using an interactive, multimedia-based DT in three selected schools. The data was collected in the schools through observations and interviews. The case studies documented and combined the observations and interviews. The framework for data analysis was based on the Activity Theory and complemented by the concept of Flipped Learning.

3.2 Sampling Strategy

3.2.1 Selection of the Schools

IB schools were selected for this study due to their accessibility to the researcher and the relative similarity of their learning contexts. These include that all IB schools have English as the language of instruction, teach the same curriculum, commit to same pedagogical principals and their students undergo the same external assessments worldwide. These common features of the schools allowed the researcher to better understand the practices and challenges of DT integration across a variety of classrooms.

The participating three IB schools were selected based on purposive sampling with the main criterion that each of the schools had a subscription to use the DTs in their Diploma Programs as well as 3 to 4 years of experience of use. Altogether six education institutions were approached in Sweden, Switzerland and the United Kingdom. One school from Sweden and two schools from Switzerland agreed to participate in the research study during March and April 2017.

3.2.2 Selection of the Digital Textbooks

The DTs selected for the study were unique among the IB approved resources as they were a completely digital web-based solution designed for FL. They had no printed textbook options, integrated interactive and multimedia functions and moved away from the simple page-fidelity design. More specifically, the DTs for IB Science Diploma Program (IBDP) subjects were selected as the focus of the study. Science subjects included Biology which was the most widely used and longest available DT of the publisher as well as Chemistry and Physics. This has provided the researcher the possibility to capture rich sets of data. Yet another important aspect was the

availability of the publisher/developer is Sweden as well as their willingness in participating in the study.

3.2.3 Selection of the Participants

The study involved altogether 7 teachers who participated on a voluntarily basis. Four Biology teachers, one Biology-Chemistry teacher, one Chemistry and one Physics teacher from IB Science Diploma Programs. Two of the selected teachers were also DT authors. One teacher filled the role of the Head of Science Department while one was Head of Biology. Due to the variety of roles teachers could provide insights about the DTs from various perspectives.

3.3 Data Collection Methods

Drawing on Activity Theory had some methodological implications. Namely, the research had to be conducted in real-life contexts and employ a variety of data collection methods to provide multiple perspectives of the learning activity. Therefore, the researcher chose to use semi-structured interviews with practicing teachers in their local school environment as well as non-participatory observations of their classroom teaching. This approach aided the researcher in understanding the activities in their real-life contexts and capturing a variety of perspectives on the use of the DT.

3.3.1 Semi-structured interviews

The researcher used an interview guide (see Annex 1) with open ended questions and the interview process had a flexible structure. This meant that the researcher used a script to a certain extent but questions could follow in a different order than indicated in the interview guide. Even questions that were not included in the guide were asked by the interviewer as she picked up on information from the interviewees. Nevertheless, the wording used was similar in each case. The interview sessions were no longer than one hour and they were recorded and transcribed. The interviews were conducted in English.

3.3.2 Non-participatory Observations

The focus of the observations was to document the activities of teachers and the students during biology lessons in IBDPs; whether and how the DT was a part of the activities. The researcher used an observation guide (see Annex 2) that aided the data collection. Then notes were reviewed and summarized using Excel. Observations were conducted under a period of four weeks between 26 March and 30 April; two weeks in Sweden and one week respectively in the two schools in Switzerland. The researcher followed the IBDP classes consecutively to capture the learning activities over a period of time. Moreover, the researcher prepared general notes that documented her overall experience of the school visits and contributed to understanding the specific school contexts. Finally, data from the semi-structured interviews and non-participatory observations were collected, analyzed with the help of the analytical framework and through the lens of the Activity Theory.

3.4 Analytical Framework

The Analytical Framework of this study is built on two cornerstones; 1) the Activity-Oriented Design Method (AODM) that applies Activity Theory and 2) the Model Flipped Learning by Estes, et al. (2014). AODM was used to analyze the activities of teachers with the DT. The FL model related the practices of the teachers to the pre-, in- and post-class stages of the FL. Figure 4. represents the Analytical Framework that integrates these two components.

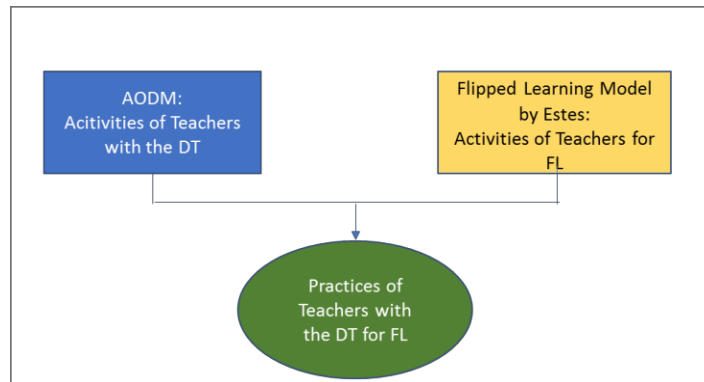


Figure 4 Analytical Framework

3.4.1 The Activity-Oriented Design Method (AODM)

AODM is an approach developed by Mwanza-Simwami (2011, 2013) that applies Activity Theory with the aim to characterize, analyze and evaluate practices with technology tools while considering motives and socio-cultural issues. AODM can be broken down into four stages. First, it is important to interpret the model of Activity Theory for practical application and translate its components. The questions to be considered are summarized in Table 1.

| | |
|-----------------------|---|
| Activity of Interest | What activity am I interested in? |
| Objective | Why is the activity taking place? |
| Subjects | Who is involved in the activity? |
| Tools | By what means are the subjects performing this activity? |
| Rules and regulations | What rules, regulation govern this activity? |
| Division of labor | Who is responsible for what when carrying out the activity and how are the roles organized? |
| Community | What is the environment in which the activity is carried out? |
| Outcome | What are the desired outcomes of carrying out the activity? |

Table 1: Questions for Translating the Components of Activity Theory (Mwanza-Simwami, 2013)

The second element of the AODM framework is the Activity Notation that breaks down the activity system into sub-activity systems. It connects elements of the activity system whose interactions are being investigated (see Table 2).

| Actors | Mediator | Objective (Purpose) |
|-----------|--------------------|---------------------|
| Subjects | Tools | Objective |
| Subjects | Rules | Objective |
| Subjects | Division of Labour | Objective |
| Community | Tools | Objective |
| Community | Rules | Objective |
| Community | Division of Labor | Objective |

Table 2: Sub-activity Systems of the Activity System (Mwanza-Simwami, 2013)

Activity Notation helps to generate and organize questions for the data collection. Questions that examine interactions in sub-activity systems derived from the Activity Notation are as follows:

1. How do Subjects use Tools to achieve their Objective?
2. What Rules affect the way the Subjects achieve the Objective and how?
3. How does the Division of Labor influence the way Subjects achieve their Objective?
4. How do the Tools that are used affect the way the Community achieves the Objective?
5. What Rules affect the way Community achieves their Objectives and how?
6. How does the Division of Labor affect the way the Community achieves the Objectives?

Finally, AODM maps operational processes to visually interpret and communicate findings on activities, sub-activities, activity components and relations, contradictions and problems identified (Mwanza-Simwami, 2013). Table 3 below represents the framework of AODM.

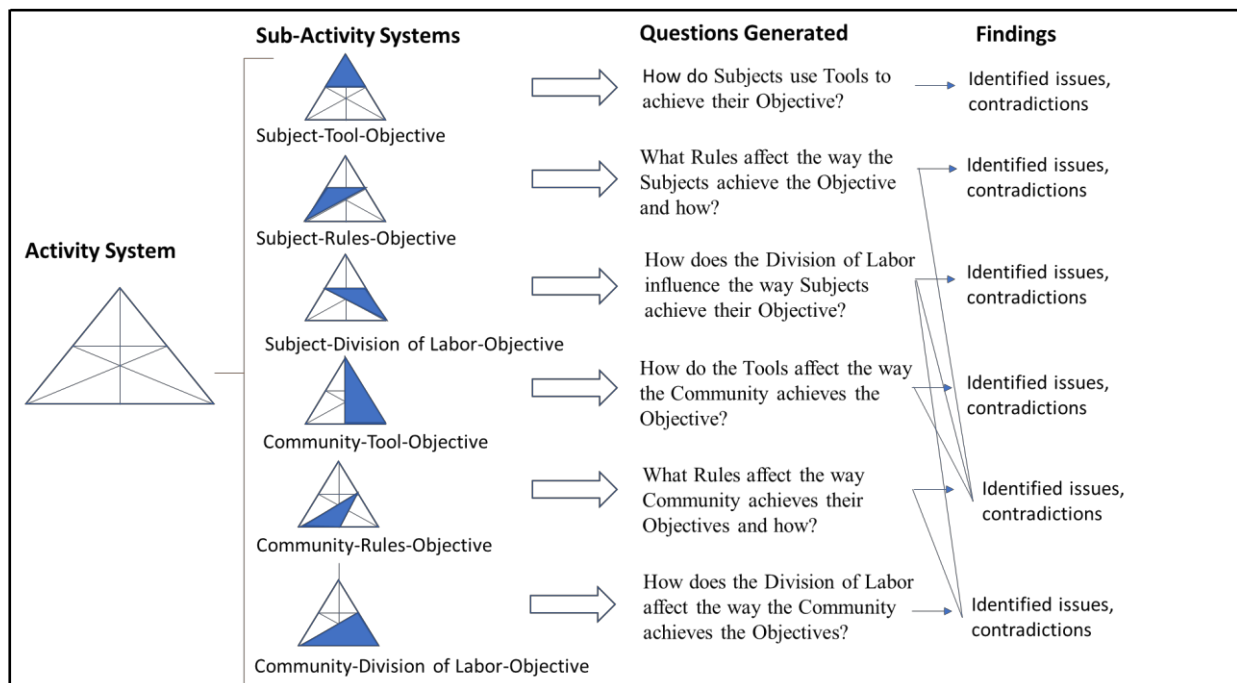


Table 3: AODM Framework (Mwanza-Simwami, 2013)

3.5 Limitations of the Study

The study focuses on DTs designed for Flipped Learning from one provider in Science subjects that was available to all the teachers in the study. Thus, the results cannot be generalized to all DTs. Further, the study is not intended for generalization as the teachers selected are neither representative of all teachers nor the respective programs and institutions. The scope of the study is limited to volunteering teachers in three education institutions. If given more resources, a wider array of cases could have been investigated and analyzed. Moreover, the study focused on the practices of teachers and did not intend to collect data on student use of DTs which could have further enriched the study.

3.6 Ethical Considerations

The research subjects were informed fully about the purpose, methods and intended possible uses of the research results. The confidentiality of information and anonymity of the participants was respected and maintained. This was insured through informed consent forms that gave the participant the opportunity to be fully informed about the nature of the research and the implications of their participation. The names of participants are not included on the transcripts, and documents use pseudonyms. Research participants were involved in the study entirely voluntary. The researcher was also aware of the differences between schools and different backgrounds of teachers and demonstrated sensitivity within all interactions.

4 Setting and Context of the Study

4.1 The International Baccalaureate Diploma Programs (IBDP)

The IBDP is a comprehensive 2-year program directed towards learners of 16-19 years of age. It aims to broaden students' educational experience and challenge students to apply their knowledge and skills while preparing them for university studies. The IBDP is currently available in 2487 schools worldwide and officially accepted by over 2000 universities. In 2016 there were 149,446 DP candidates with a diploma pass rate of 79.3% (IBO, 2017).

Curriculum

The IBDP curriculum consist of two parts; 1) DP Core and 2) six subject groups. The DP Core is comprising of the Theory of Knowledge (TOK), a Creativity, Activity, Service (CAS) project, and an extended essay (EE). In IBDP, students choose subjects from six subject groups. Each student takes at least three but not more than four subjects at higher level (HL), and the remaining at standard level (SL). HL and SL courses differ in scope but are measured according to the same grade descriptors, with students expected to demonstrate a greater body of knowledge, understanding and skills at higher level. Standard level subjects take up 150 teaching hours. Higher level comprises 240 teaching hours (IBO, 2017).

Assessment

The IBDP uses both internally and externally assessed components to assess student performance. Written examinations at the end of the DP form the basis of the assessment. Externally assessed coursework under authenticated teacher supervision forms part of the assessment for several program areas. In most subjects, students also complete in-school assessment tasks. These are either externally assessed or marked by teachers and then moderated by the IB. Students receive grades for each IBDP course attempted ranging from 7 to 1, with 7 being highest. A student's final Diploma result score is made up of the combined scores for each subject. The TOK and EE components are awarded individual grades and, collectively, can contribute up to 3 additional points towards the overall Diploma score. CAS does not contribute to the points total but authenticated participation is a requirement for the award of the diploma. The diploma is awarded to students who gain at least 24 points, subject to certain minimum levels of performance including successful completion of the three essential elements of the DP core. (IBO, 2017)

The IB awards the same number of points for higher level (HL) and standard level (SL) course. Students can retake subject exams and the highest grade obtained will contribute towards their diploma results (IBO, 2017). Table 4. and 5 give examples of the assessment model.

| Type of Assessment | Format of Assessment | Time (hours) | Weighting of final grade (%) |
|--------------------------|--|--------------|------------------------------|
| External | | 3 | 80 |
| Paper 1 | 30 multiple-choice questions | 0.75 | 20 |
| Paper 2 | Data-based, short answer and extended response questions | 1.25 | 40 |
| Paper 3 | Data-based, short answer and extended response questions | 1 | 20 |
| Internal | | 10 | 20 |
| Individual investigation | Investigation and write-up of 6 to 12 pages | 10 | 20 |

Table 4: Assessment model of IBDP Science Standard Level (IBO, 2017)

| Type of Assessment | Format of Assessment | Time (hours) | Weighting of final grade (%) |
|--------------------------|--|--------------|------------------------------|
| External | | 4.5 | 80 |
| Paper 1 | 30 multiple-choice questions | 1 | 20 |
| Paper 2 | Data-based, short answer and extended response questions | 2.25 | 36 |
| Paper 3 | Data-based, short answer and extended response questions | 1.25 | 24 |
| Internal | | 10 | 20 |
| Individual investigation | Investigation and write-up of 6 to 12 pages | 10 | 20 |

Table 5: Assessment model of IBDP Science Higher Level (IBO, 2017)

4.2 IBDP Science

IB Science subjects such as Biology, Chemistry and Physics are taught practically. This encompasses that students have opportunities to design investigations, collect data, develop manipulative skills, analyze results, collaborate with peers and evaluate and communicate their findings. Their investigations can be either laboratory based or they may make use of simulations and data bases. A central objective of the IB Science programs is that students should develop their skills to work independently on their own designs, but also collaboratively, including schools in different regions. This is to reflect the way in which scientific research is conducted in the wider community (IBO, 2017). A general overview of the curriculum elements is provided in Table 6 and 7.

| Component | Recommended Teaching Hours |
|--------------------------------------|----------------------------|
| Core | 95 |
| Option (choice of 1 out of 4) | 15 |
| Practical Scheme of Work | 40 |

Table 6: Standard Level IB Biology Curriculum (IBO, 2017)

| Component | Recommended Teaching Hours |
|-------------------------------|----------------------------|
| Core | 95 |
| Additional Higher Level | 60 |
| Option (choice of 1 out of 4) | 25 |
| Practical Scheme of Work | 60 |

Table 7: Higher Level IB Biology Curriculum (IBO, 2017)

4.3 The IBDP Digital Textbooks

The development of the DTs selected for this study started in 2012 when a publisher decided to provide a digital and interactive textbook for the IBDP. Their aim has been to “bring life to textbooks” and move away from the plain text format to an interactive and multimedia-based learning experience that would drastically increase learning efficiency. The DT has been developed through a collaboration with the International School of Geneva with the aim to develop a practical and easy-to-use digital resource for both teachers and students. The IBDP content is written by teams of practicing IB teachers, workshop leaders and examiners for a relevant and up-to-date curriculum. The DT is currently available in 10 subject areas: Biology, Mathematics, Business Management, Chemistry, Economics, Psychology, Physics, Environmental Systems and Societies. Most of the DTs have versions for SL and HL students.

4.3.1 Characteristics of the DTs for IBDP Science Subjects

The DTs have been developed for SL and HL with a content structure that follows the relevant IB curriculum topics. The intention of the Publisher was to design a DT that facilitates FL. Bloom’s revised taxonomy informed the design with the intention that the DT should cater to the lower-levels of the taxonomy (Brame, 2013). There is a student and a teacher version of the DT with different functions.

In the student version, students have access to the various subjects. The chapters within the subject area begin with a short overview of the material which is then further divided into subsections. This breaks the large content into smaller, “bite-size” parts. At the end of each subsection, students can self-click if they have completed the reading. The content is illustrated by multimedia elements such as images, videos and animations. At the end of each chapter, students can consult a checklist that summarizes the important points. They can then test their knowledge in multiple-choice questions, exam-style questions and gamified battles. Multiple-choice questions are automatically corrected. This builds up a profile of the students’ strengths and weaknesses and gives feedback to students about areas they should focus on. The exam style questions come with a marking scheme that helps students self-correct their answers and calculate marks. These questions and answers are written by curriculum experts in the style of past exam questions. However, they are not official questions or endorsed by the curriculum provider. The gamified battles allow students to challenge fellow learners or random student in the world in one-on-one knowledge tests.

The teacher version includes the DT with the content, assignments, statistics and management tools. Multiple-choice tests can be constructed from a pre-existing mall of questions, arranged and

assigned to students. The DT then tracks and provides the teacher with learning diagnostics data on the completion rates and results of each student. This provides a tool for teachers to adjust their efforts according to students results. Teachers are also able to see the general learning statistics of their students, their progression through the sections, questions and average performance on the questions. Both students and teachers have the possibility to provide direct feedback to the DT developers and report errors they might find.



Image 1:DT for IBDP

4.4 Case Study 1

School A is located in Stockholm, Sweden and has a strong academic and multicultural tradition. They currently offer four Swedish national programs and the IBDP, which all qualify students for university studies in Sweden or abroad. The School is an independent school in the Swedish education system and free of charge for the students. The mission of the school is to create and prepare students for the world of today and tomorrow and develop young people who are courageous thinkers, reflective learners and curious about the world in which they live in. Their approach emphasizes work ethic where involvement comes through hard work, creativity, commitment and dedication.

Altogether two interviews and 9 classroom visits were scheduled during 27. March 2017 and 06. April 2017. One Biology teacher with the Pseudonym Fredrik and one Chemistry teacher with the Pseudonym Christina agreed to participate in the interviews and observations. The Physics teacher agreed as well however he could not participate due to illness. Table 8. summarizes interviewees' general background information. The case study integrates the data from the interviews and observations and does not separate them in different sections. However, for greater clarity it is indicated when the data was captured from the teacher interviews.

| Pseudonym | Subject area in IBDP | Teaching Experience | Roles |
|-----------|----------------------|-----------------------|---|
| Fredrik | Biology SL, HL | 5+ years , 4 years IB | Teacher and Scientist, DT author, Head of Biology |
| Christina | Chemistry SL, HL | 4 years IB | Teacher, Head of Science |

Table 8: Interviewee Information School A

The observations included 9 lessons or 13.5 hours. Class sizes ranged between 8-20 students. The observations were conducted in Biology, Chemistry and Physics with the major focus on Biology. Table 9 shows data about the number and types of classrooms visited. In 44% of the observed lessons used the teachers the DTs in some way.

| Subject | Study Year | Higher Level (HL) | Standard Level (SL) | Sum |
|------------|----------------------|-------------------|---------------------|----------|
| Biology | 1 st Year | 2 | 3 | 5 |
| | 2 nd Year | 1 | 1 | 2 |
| Chemistry | 1 st Year | 1 | - | 1 |
| | 2 nd Year | - | - | - |
| Physics | 1 st Year | - | - | - |
| | 2 nd Year | - | 1 | 1 |
| Sum | | 4 | 5 | 9 |

Table 9: Classroom observations School A

4.4.1 Motivation of Use

Fredrik said that he was motivated to use the DT because the publisher visited his school during the previous terms and demonstrated the DT to his students. He felt that the people at the publisher were very motivated and cared about the usefulness of their product. The demonstrations helped the students to see the benefits of the DT. He thought that with the overwhelming amount of digital resources available to IB teachers and students, a human face made a difference:

“[...] they actually came to the school and helped to train the students. Students get involved. I mean, we could do that ourselves but I like that there is an actual face to this online textbook. Every fall they get the students up and running, give them a quiz, they show them how to do it, so students really see the benefit. And they are very, very motivated. Unfortunately, other textbooks say oh we have this available and sign up. But there are so many online things... and you don't really get the students.”

Christina said she was motivated by the fact that the DT provided her with an additional resource she could use beside other resources. She thought that the DT was helpful because it is “like doubling on the knowledge and consolidating it”.

4.4.2 Teaching and Learning

The classrooms where Fredrik and Christina taught were traditionally arranged with long rows of student desks facing the table of the teacher in the front. The Biology classroom had laboratory equipment along the walls and allowed the students an easy access during the experiment. Students used school laptops, which they took from secured metal cabinets and returned at the end of the lesson. They could also use their own laptop if they had. Fredrik and Christina sometimes allowed

students to use mobile phones during the classes but only for learning purposes. During classes, Fredrik changed between direct instruction, group work, and individual work. He often illustrated his teaching with practical examples, added interesting real-life stories and discussed questions with students. The atmosphere in his classrooms was relaxed and open. Fredrik used the DT in 3 out of 4 Biology SL classrooms and in 1 of the observed HL classes. In these cases, he used the DT to support his students' knowledge acquisition in the class or tried to flip his classroom.

4.4.2.1 In-class Knowledge Acquisition

Fredrik sometimes assigned short individual reading assignments from the DT during the class. After reading the section, students answered the control questions in the DT. This took no longer than 5-10 minutes. Then he discussed the questions together with the students and gave explanations when it was needed. Another time, he used images and models from the DT to illustrate a new topic area and help students to draw their own conceptual models with labels. In one case, the model in the DT aided knowledge application: his students could optionally consult the DT to help dissection of sheep hearts during laboratory work. Other than these occasions, he did not use the DT in the class. He thought that it was an optional resource rather suited for individual study and revision at home.

Nevertheless, he used a great variety of other resources in all his Biology lessons. These included slides prepared by him, ppt presentations of his students for peer-teaching, movies and videos that he selected from other IB resources, open-source materials, digital photos and illustrations, 3D images and 3D animations. He frequently used games in his classes which were popular with his students such as digital crossword, quizzes on Kahoots and Space Races on Socrative. He used the games for revisions of sections and for preparing his students for the final IB examination. In these games either individual students or groups raced against each other, depending the objectives. He said, the Space Race allowed for collaborative team work among smaller groups of students. Kahoot was suitable to review a great number of questions under time limitations. Students signed up for the games with pseudonyms they picked for themselves or their group. He said that his students preferred this anonymity and did not use the gamified battles in the DT. Christina said she liked to use Kahoot as well. She thought that the IB exam was very challenging for students who needed stamina and good time-management skills to manage the lengthy exams. She thought that gamified quizzes like Kahoot were useful for practice.

“[...] Obviously we reviewed them (questions) afterwards but the process when the 90 seconds are over, we went to the next question. So it does help. I mean, they were laughing so I am not being brutal. In my experience, there are students who are amazing, they know everything but when it comes down to exams, if they cannot put it on paper or they are not time efficient, they won't be able to achieve their real potential. So, I think it is really important with the IB that they are ready for it when they have the exams at the end of the 2nd year.” (Christina)

4.4.2.2 Flipped Learning

On one occasion, Fredrik assigned a pre-reading and sent out emails to the students with short assignment in preparation to in-class activities. However, most of the students missed to do the pre-reading and assignment for the following class. Therefore, he took a short time for reading at the beginning of the class when his students reviewed the section and answered the questions.

Other than this, he did not prefer to give home assignments. He told that sending home assignments from the DT was an additional activity to his already very stretched schedule. Creating assignment sheets a couple of times per week, selecting the students and sending them took some time. Especially, when he simultaneously had to prepare for laboratory work or teaching. Even when he found the time to do it, he could only reach those students who used the DT. Therefore, it was easy that it became low on his priority list. He recommended a scheduling tool for teachers as well where the system would automatically send out the home assignments at pre-set times.

4.4.2.3 Individual Revisions

Christina said she used the DT for consolidating chapters once per month. The questions and quizzes in the DT served as self-check points so students got a feedback on how successful they were at understanding a specific section. This was also an important feedback to her because if it was only for example 60% of students who answered the questions correctly, then she could look at those and go back for review. She told the DT was also useful when she had large classrooms for lab activity. Then she divided the group and while one group of students worked in the lab, the others worked on assignments or revision in the DT. Then they changed.

Fredrik thought that the DT provided an easier entry for study and revision than the printed IB Biology textbook that sometimes overwhelmed his students with its sheer size and weight. He said that the DT in Biology was logically structured and since it followed the IB curriculum, it was also easy to use. Besides, having different resources was also a good way for the students to see the different levels and approaches delivered to them. It made them question what level they needed to know for the exam. It was useful that the questions were connected and students could link back and revisit the sections where they had knowledge gaps.

However, he pointed out that not all students accessed and utilized the DT for learning. Fredrik thought that there were significant barriers to logging on to the resource and cautioned that the issue of motivation to access the DT was underestimated by DT. The introductory training sessions might have inspired the higher achievers, but others had problems:

“So the strong students, just that one session in the fall gets them using it. But the weak students not if there is no reinforcement.”

He thought the core issue was similar to the traditional dilemma of the printed textbooks; how to make the student open the book. He even speculated that opening a printed textbook might have been easier than opening a DT. As the DT was rather an off-site and out-of-the-classroom resource, students had to overcome distractions at home such TV, Twitter, Facebook, Instagram etc., then have a computer available, find the bookmark, then go to the site and log on. He said that this was a huge block. If a student did not log on the DT for months, there was a high probability that they forgot the password and lost interest in accessing the resource at all:

“It seems like it should be super easy but students have so many passwords. They have Twitter, then Facebook and Instagram. And then a biology online textbook password, it is not something a teenager has in the wallet.”

In such cases, it was extremely difficult for Fredrik to get the students use the DT again. Especially, because using the resource during class time was disruptive. This meant that students only read

and answered questions, which was not a good use of his time. Also, there was no local grading that he could have used to motivate student to do home assignments:

“So when you say homework, the good students do it but the weaker don’t. And I say you didn’t do your homework. And they, yeah what is the repercussion? Does that affect my grade? And then mmm we will talk to your parents. And they like, I am 18 years old.”

He suggested that the developers should attend to this issue.

“[...] the problem is not that they lose the students when they are on. Their problem is to get the student log on first.”

He said, that actively “pulling” the students into the DT could have been the solution. He suggested that a scheduling tool could enable students to set up their own learning schedules. Based on that they would need lots of auto-prompts, email that says for example: “Hey, it is Wednesday and you have decided yourself your schedule. Click this link and you will be on the textbook... and then there it is a happy, smiley textbook” (Fredrik).

He also pointed out that overachiever students preferred the printed textbook instead of the DT. He said the reason was that the DT was not high level enough. If the DT would have had the same detailed content as their printed textbook, the high achievers would have been fine to go online. He thought that the DT developers had to balance to make the DT easy, light and kind so that lower achiever students stayed online. On the other side, the IB required lot of details, terminologies and the level of the exam was halfway between high school and university. He added also it would be useful to find out if there is a relation between the achievements on the DT assessments and the exam outcomes of students.

4.4.3 Rules and Regulations

Fredrik told that IB has lots of rules for the schools but he is rather free to decide how he delivered the teaching. The only thing that really affected his work was that IB ethics regulations did not allow experiments on animals. They could be observed in their natural habitat but could not be touched or manipulated in any ways. He suggested that virtual animals would be of great use for biology education. Christina mentioned rules and regulations about Chemistry laboratory work.

4.4.4 Division of Work

Fredrik and Christina thought that their roles and responsibilities as teachers did not change due to the DT. They viewed the DT as an additional resource they could work with beside all the main printed textbook and other digital resources. However, both said that having the DT influenced students as they felt more responsibility and control over their education. For example, the DT gave students feedback on which areas they needed to improve so they could go back, revise or they came to the teacher and asked for more explanation. Fredrik said that some of the students felt they owned the DT to such extent that they saw them as their own notes that substituted note-taking in school. He warned his students that note-taking was diagnostic for succeeding in the exam but some of them thought that he was just old-fashioned. Christina liked that the learning diagnostics data enabled her to “hear” those students who were not comfortable speaking up in the class if they did not understand something.

4.4.5 Community

Fredrik said that there are many parents who were intensively involved in the education of their children. However, it seemed that the digital resources were owned solely by the students. He speculated that parents were not very familiar with digital resources for learning since they did not have them during their school time or they simply did not want to log onto their children's digital tools. Thus, the DT became a personalized tool for students that was entirely in their ownership. He also mentioned that he often shared and discussed his experiences with the DT and other digital tools with other colleagues. Christina was interested to know how teachers in other schools use the DT.

4.4.6 Future Perspectives

Christina was worried that introducing too many digital resources would negatively affect student health. She told that some of her students got migraine or eye-strain after using digital tools excessively. She thought that the DT is a good tool but schools should not go entirely digital. They should rather embrace a mix and match of different digital and non-digital approaches. Fredrik told that the DT developers think in terms of how to replace the teachers. He thought that digital learning tool providers in general are confident that they can remove the teacher if they have the right content. He felt, that teachers cannot be entirely replaced by the digital tools.

“[...] Because teachers are more expensive in comparison to digital tools. So, in the future schools could say that they only have two-third of the teachers on site who will have bigger classrooms and then digital tools will take care of the rest.” (Fredrik)

4.5 Case Study 2

School B is an international boarding school located in rural Switzerland. The School aspires to provide a balanced education to students that develops the mind, body and spirit. It aims at creating an environment where students can explore their world and achieve academic excellence. The School has 65 teachers and 365 students whereof 140 study in the IBDP. In 2016, 84% of students were boarders and 16% day students. 40% of the students had English as their mother tongue. School B is an independent school where students pay a tuition fee depending on the type of program and accommodation option. The School also supports fully-funded scholars and 10% of the students are recruited based on merit-based awards. Students in the IBDP achieved 4 points higher than the global average in 2016. Over 50% of IBDP students were awarded a 6 or 7 out of a possible top grade of 7 in 2016. The School follows a British model of education with students attending school on Saturdays as well.

Classroom visits and an interview were scheduled during 10. April 2017 and 16. April 2017. The Biology teacher with the Pseudonym Alan agreed to participate in the interview and observations. Table 10 summarizes his general background information.

| Pseudonym | Subject Area in IBDP | Teaching Experience | Experience with the DT | Roles |
|-----------|----------------------|---------------------|------------------------|---|
| Alan | Biology HL | 5+ | 4 years | Teacher, Head of Science, Head of Biology |

Table 10: Interviewee Information School B

The observations included 10 lessons or 15 hours. Class sizes ranged between 3-10 students. The observations were conducted in Biology. Table 11. shows data about the number and types of classrooms visited. In 46% of the observed lessons did the teacher use the DT in some way.

| Subject | Study Year | Higher Level (HL) | Standard Level (SL) | Sum |
|------------|----------------------|-------------------|---------------------|-----------|
| Biology | 1 st Year | 6 | - | 6 |
| | 2 nd Year | 4 | - | 4 |
| Sum | | 10 | - | 10 |

Table 11: Classroom Observations School B

4.5.1 Motivation of Use

Alan started to use the DT on the initiative of the IB coordinator of the school. Together, they looked at several digital resources and decided for the DT. They thought it was the best at that time and it was available in multiple subject areas such as Sciences and Economics.

4.5.2 Teaching and Learning

Alan was teaching in a spacious Biology classroom where tables were arranged in 3 groups with 6 seats at each. In the back, there was a long table with laboratory equipment for experiments and a row of 6 seats where students could sit individually. At the windows, there was a greenhouse and an aquarium. There were cabinets on the side where students could keep their textbooks, note files and revision files. Alan had large folders where he compiled printed sample exams and marking schemes which were available and accessible to students. Before and after the lessons, he often chatted with his students about extracurricular activities or answered their questions. The atmosphere in his classrooms was friendly and organized. During his classes, he changed between direct instruction and individual work. Sometimes his students worked in groups of 2-3. He put great emphasis on teaching students how to learn and provided them with many practical examples, such as learning through kinetics, abbreviations and making connections between the chapters, writing notes and using colors. Almost every lesson he emphasized the importance of reflection. He also offered the opportunity for students to consult him after teaching hours regarding their revision plans or if they had questions. Alan used the DT in 6 out of 10 Biology HL classroom to facilitate Flipped Learning and individual revisions.

4.5.2.1 Flipped Learning

He flipped the classroom with his 1st year students approximately on a weekly basis. First, he assigned pre-reading materials for students to prepare. Students could freely choose from the three different resources they had available: the DT, the printed textbook and a complementary digital resource to the textbook. It was observed that many of his students decided to do the pre-reading from the DT because it demonstrated their efforts through data, which they knew Alan would check. Other students prepared hand-written notes by using the textbook and showed him at the beginning of the class. Their preparatory work counted towards an effort grade. He explained how this worked:

“They have their mark reading and they know it counts towards their effort grades. To get their effort grades above the C on a scale from A to E, they have to get their minimum questions done. That is a minimum expectation of mine, therefore they know, they cannot get above C grade if they have not done that. They don’t have to get above the minimum but if they do, then know that it is going to count towards their effort grade and in terms of their mark reading that they get every 10 weeks. So it is just part of the ongoing school assessment policy.”

Alan used a quiz from the DT at the beginning of the class to check to what extent students understood the material. He also showed the general overview of their learning diagnostics from the DT and encouraged them to reflect about their results; what and why was not correct. He pointed out that the topics in the syllabus are interlinked and fit together like a jigsaw therefore pre-reading was very important to connect these parts. He reflected on the data from the DT and found that students had failed to make those connections. Then the in-class time he mostly spent on explaining, discussing and analyzing concepts with his students, investigating open-ended questions of why and how. At the end of the lesson he posed a question to guide the preparation for the next lesson. For example, students had to review and identify processes they would work with during the following lesson. He also gave a short preview of what will happen next time.

4.5.2.2 Individual Revision

During the final year of the IBDP, Alan said that he extensively focused with this students on reviewing materials and preparing students for the different parts of the final exam. He facilitated some of these activities with the DT. During one revision class for example, his students could decide whether they participated in the teacher-led group revision or worked individually on topics of their choice. Those students who chose the individual revision moved in the back of the room where they worked either from the DT or other resources. They read through a chapter, answered questions from the DT and wrote notes. From the teacher-led revision group, students could walk to the back and continue with individual work.

Another time, Alan helped his students to set up revision objectives for the following two weeks. He walked around in the classroom and consulted each student individually as they were working with their revisions. He also encouraged them to reflect upon their work by identifying learning outcomes and setting up their own targets. For cognitive engagement, he suggested students to write their revision notes by hand and suggested using colors. He said that students had to be able to interact with the paper and pen as they had to write the final exams by hand. Later he commented his approach:

“So, they take their files, I give them a marking grid, they give themselves a mark out of 5-10 and they write comments of why they think they got that one. I mark those comments on their mark and why I agree with it or why I move it up and down. And they have to identify learning outcomes from that. They have to identify what they need to do to improve their mark and write themselves targets. This part is the reflective process that gets them to look at what they are doing.”

He showed also learning diagnostics data from the DT to help his students reflect about their progress on the multiple-choice questions:

“At the end of the last term I shared with them (learning diagnostics). Look at the number of questions you have done, you should have done roughly 20 per topic. That is just the evidence that they are doing something. So, you should have roughly 400 at the moment. There are lots of students

with well over that. Some students are over 2000 questions. There are some that quite don't get into their book. Most of them tick into the minimum interactivity."

Alan said, the DT was a useful tool for students to set their own learning objectives and achieve them on their own time. At the same time, it provided also important feedback for him.

"The little checkpoints on the DT, you can see when they are doing the questions, when they are clicking those checkpoints. You can identify problems, you know that they have the ability to go back over something a couple of times. You can see these things happening. It is a way of getting instant feedback about your students' performance if you keep up to date and manage it. And that is a very useful tool for the teachers, to help them get to the point where they own their education."

However, the thought that the DT was no magical solution and just having it did not guarantee learning. It was also important to teach students how to use the DT, just as any other resource. He often emphasized during his lessons that students had to engage with the content actively:

"The DT does not guarantee anything. You still need to educate your students about how to use any resource. And you got to teach them how to use the DT just as you got to teach them how to use a textbook or a sheet. So, the DT is not that magical thing that will make your students brilliant. It will help, it is another resource, but it is only a resource and you can have the best resource in the world but if you cannot access or interact with it, it is completely useless."

He added that students had different preferences as well. Some students used the DT more than others. Some did not like the simplicity of the DT. Most of his students did the minimum interaction Alan required from them:

"One of my students, she just doesn't like it. She tried it, but she likes reading the textbook. She likes that level of material, she likes that high level of lots of explanations and she really enjoys the textbooks. She doesn't like the simplicity of the digital material."

4.5.3 Rules and Regulations

Alan said that the School B had guidelines for the internet which students signed when they used it for the first time. However, he was concerned about data protection issues. He added that for the DTs the School only provided the emails of the students and he felt that risks were reasonably mitigated. However, he added that the speed of change of the digital technologies was so fast that schools had hard time keep up with policies. He mentioned that the latest psychology research results about addictive behavior that changes adolescent neurochemistry had just been published. Several staff raised the issue but the school needed time to reflect upon these before making policies.

"I think, the problem comes for the management in the sense that technology changes so quickly that by the time you put a policy in place, it can already be obsolete. It is causing problems."

4.5.4 Division of Work

Alan said, that DT was changing the way he taught in minor ways because it enabled him to increase interaction with his students. In addition, he said that the DT could help students to become more responsible for their education and be a more independent learner:

"I think it does help them because they are more personally independent. I think you can use it to help them to set their own learning objectives and achieve them in their own time."

“I think the online digital platforms have given us a nice way of doing that (to become more independent) but still keep a nice little eye on them.”

According to Alan, the DT and other digital tools added a level of complexity to managing learning resources as the School had to administer and manage student lists and upload them online. He said, that digital tools changed the classic work of the Head of Department. 10 years ago, it was the responsibility of the Head of Department to manage physical resources. With the digital subscriptions, this shifted to administrators who managed whole cohorts across the School in multiple subjects in one go. He speculated that the DT might have reduced the workload at the departments while at the same time changed the location where the work needed to be done.

4.5.5 Community

Alan had departmental meetings with his Biology team every week. He said that the School did not dictate what resources teachers used but they often discussed the DT and other resources in the meetings. He told that some departments liked the DT more than others and added that Biology bought into it more than Physics and Chemistry. He thought that the reason for that could have been the quality of the DT or how the teachers felt about it:

“I think if you are open to changes and you are happy with these sorts of things, you will see them as another tool. It can be brilliant but some of them aren't very good. Just like most resources, some teachers are scared of them and some teachers think they are brilliant. Everybody has emotional response that are subject to past experience, perhaps sometimes ability. Personally, I think they are brilliant. Another way for interacting with students and you can find the merits of it. Just don't choose it when they are not very good.”

He thought that the DT did not influence the involvement of parents in the learning since most of the students in the School were boarders.

4.5.6 Future Perspectives

Alan pointed out that that IB will move all exams within the next 8 years onto being typed on screens and speculated that it would again change education. He thought that it brought up many questions. Are they going to have a digital filing system with digital files of material? How will IB ensure that students cognitively engage? Can they activate cognitive engagement through typing? How will teachers make sure they apply that in their teaching? He said, he did not know what would happen in a 5-year time.

4.6 Case Study 3

School C is an independent English-French bilingual school in a suburban area in Switzerland that integrates children and students from K-12. The School seeks to transform teaching and learning using new technologies and promote solid skills in information technology by integrating it in the learning environment on a daily basis. The School is an official Apple School where student use either Ipads or MacBooks that are on loan to them. Over 80 students of 30 nationalities follow the IBDP program.

Altogether four interviews and 12 classroom visits were scheduled between 24-27 April. Three Biology teachers and one Physics teacher with the Pseudonym Susanne, Thomas, William and

Agnes agreed to participate in the interviews and observations. Table 12. summarizes the background information of the participants.

| Pseudonym | Subject Area in IBDP | IB Teaching Experience | Experience with the DT | Roles |
|-----------|---------------------------|------------------------|------------------------|--|
| Susanne | Biology HL | 5+ years | 3 years | Biology teacher |
| Thomas | Biology SL, HL | 5 + years | 3 years | Biology teacher |
| William | Biology HL, Chemistry SL | 3 years | 2 years | Chemist, Chemistry and Biology teacher |
| Agnes | Physics HL, SL Math SL | 5+ years | 2 years | Physics and Math teacher, DT author, beta tester |

Table 12: Interviewee Information in School C

The observations included 12 lessons or 18 hours. Class sizes ranged between 7 and 15. The observations were conducted in Biology, Chemistry and Physics. Table 13 shows data about the number and types of classrooms visited.

| Subject | Study Year | Higher Level (HL) | Standard Level (SL) | Sum |
|------------|----------------------|-------------------|---------------------|-----------|
| Biology | 1 st Year | 4 | 2 | 6 |
| | 2 nd Year | 2 | - | 2 |
| Chemistry | 1 st Year | - | - | - |
| | 2 nd Year | - | 2 | 2 |
| Physics | 1 st Year | 2 | - | 2 |
| | 2 nd Year | - | - | - |
| Sum | | 8 | 4 | 12 |

Table 13: Classroom Observation School C

4.6.1 Motivation of Use

William, Susanne and Thomas said the DT was provided by their School and they considered it as an additional resource that their students could take advantage of. Thomas thought that it offered an easy portability option in contrast to the heavy printed textbooks. Agnes's motivation came from the fact that she was an assessment material author for the DT and was also a beta tester with one of her classrooms.

4.6.2 Teaching and Learning

The teachers taught in traditionally arranged rooms where the tables of students were arranged in rows and facing the desk of teacher in the front. They explained that they used the DT in different ways; to flip their classrooms, address diversity in the classrooms, give assignments or do revisions in- or post-class.

4.6.2.1 Flipped Learning

Thomas explained that he used the DT when he flipped his SL classroom once or twice a month. On these occasions, he assigned pre-readings from the DT together with a problem that students had to solve. Sometimes he prepared short videos and sent them to the students. Students could read their DTs or watch the videos prior to class, attempt the problem and check the answer on the DT. If they got it wrong they discussed it in the class. He told that around 80% of the students did the pre-class preparations but a good problem formulation was crucial. If it was too hard, it was difficult to solve. If it was too easy, there was no reason to discuss it in the class. Thomas also used the data from the DT to identify how students did on the pre-reading questions at home. Based on this information, he could decide to directly move on or visit the problematic areas during the class. However, the DT provided only pre-prepared questions. Therefore, Thomas also used another application that allowed him to scan printed questions and generate same sorts of datasets. He said he used it frequently because as an IB teacher he needed more control over what content the students were getting and what he thought would prepare them the best.

Agnes said she flipped her classrooms approximately once per term when the topic was too dry or long to teach in class. Under those circumstances she found it was better that students read the material prior to class. Her students used either the DT or watched videos at home. They then created short summary slides based on the pre-readings and presented them in front of the class. During the class, they discussed the concepts and features. She said most of her students came prepared but added that the FL concept worked best with enthusiastic students. Agnes added that she knew exactly at which point of the curriculum she wanted to flip her classrooms and it saved her huge amounts of time. However, she added that it depended on her students as well whether and how often she flipped her classroom.

Susanne explained that she used to flip her classrooms which she facilitated with a great variety of online interactive resources such as animations, videos or even songs. At the start of the year, she compiled 15-20 resources, shared and bookmarked them with the students. She said, she did not prefer to use the DT for knowledge acquisition, it was rather an optional resource for students. She told that it would be limiting to students if they watched only her videos or used a single resource. She explained that her students liked the freedom and ability to access multiple resources and choose the ones they preferred. Around 80% of the students did the pre-readings regularly. She said she tended to give positive feedback to those who prepared but others were not negatively affected if they missed out on something. She thought it was very important to develop students' sense of responsibility and efficiency. Therefore, she encouraged students to spend a short time on pre-reading, reviewing lessons or writing down what they have learned on a regular basis, rather than crash studying the night before a test.

William on the other hand did not want his students to read or watch any material prior to lessons, it was more important to him that they listened to his explanations and discussed the topics during class time, especially if the content was not easy. Otherwise, the DT was an additional resource for students for self-study. Approximately 50% of his students used the DT that way. He also told that he did not really look at the data as it was difficult for him to understand which control questions students did not understand:

“When you log in and have gone to it, it does give you some feedback. For example, it says here that some students had problem with question 11980 (he points on his screen). The thing is that it may not tell you where they went wrong. You have to go to the question 11980. I have no idea which one that is. It would be easier if I could just click on it.”

4.6.2.2 Differentiated Learning

Agnes used the DT in the classroom when she had students with a large range of abilities. For example, students who understood the material played a battle game in the DT while Agnes was helping those students who were struggling. She also used the DT when she had mixed classes with both SL and HL students. She created an assignment or a battle game form the DT to the SL students while she was focusing on the HL students for 15 minutes. She said, the battle games were quite popular.

4.6.2.3 Assignments and Tests

William said he used the DT in the classroom mostly for topic tests as it was very easy to create a test by dragging questions from the question mall. He also used it to create quick quizzes. Sometimes, typically in the beginning of the year, he let his students play battle games. He said it was very popular but students only chose people they knew.

Agnes said she used the DT for sending homework assignments. She liked the immediacy of the assessment reports and found it useful to see the different range of abilities of her students. She said, the reports saved her time because she understood which questions students did not understand and she could specifically focus on those ones in the class. She told that some of the students did the assessment questions until they got them all correct. Agnes thought that it was the immediate feedback and the sense of progression that motivated mainly the lower achievers. The DT proved to be especially useful for students who struggled with multiple choice questions. She said those who systematically went through the questions, did much better on the test. For example, 3 students who worked through the entire DT improved by two grades in their multiple-choice questions. She thought the difference was that working in the DT felt less than it really was. Students did a little each day, which made a great difference at the end. She also pointed out that using solely the DT would not have been sufficient to prepare her students for the final exam, since the exam had various types of questions and had to be hand-written on paper. Students needed an appropriate skillset that matched the exam requirements. She also added that high achievers preferred other resources over the DT.

4.6.2.4 Individual Revisions

Susanne, who taught only HL students, had the opinion that the level of the DT was not challenging enough. So, she let her students decide if they used it for background revisions at home. On average, 30% of her students used the DT occasionally, mostly before tests when they reviewed multiple chapters. Those who used the DT engaged with it to a varying extent; some reviewed several hundred control questions, others did only a few. However, it was a difficult for her to see if the students did really read a section or just scrolled down and stayed on the page for 10 minutes. Then it looked like they read the chapter but they did not. She thought it would be useful if the DT

gave her feedback also about text readings. She suggested for example questions within the text that students could only answer if they read the paragraph.

“Technically, if they just scroll down to the bottom and left the scrolling for 10 minutes then they look like they read it but they might not have. So, a DT that gives you feedback not just about quizzes and assignments but you know [thinking] some kind of in-text questions that you’d have to have a certain paragraph read to answer. That is just because 50% of the students love to read and a good 50% do not.”

She thought that she preferred the DT for the revision part rather than for knowledge acquisition. In her opinion, that the DT was perfect for SL students who were generally less interested in Sciences and thought that it was rather adapted to them with its interactive features, quizzes and the competitive game. In case of HL students, she thought the DT was not efficient use of time.

“It depends which resources I use in terms of how much time I have to spend and how much benefit the students get out of it. So that is why I don’t use the DT with my HL students. Because the time they would be spending reading and answering the questions, if I made it compulsory, would not push them far enough in the time frame they are supposed to go. So it is a balance. It has to be effective for me to want to use.”

4.6.2.5 Self-study

Agnes pointed out that part of her job as a teacher was to teach students how to learn. Students needed to gain a certain level maturity to prepare for university and she thought that the DT was helpful to them from this perspective. For example, if her students were not satisfied with their grades, first thing she did was to check if they did anything on the DT. If not, she advised them to spend a little time on it on a regular basis and see the progression. She thought it was not the only solution but it was an easy way to start. Susanne said that the DT could also allow absent or sick students to keep up with their learning on their own pace.

4.6.3 Rules and Regulations

William explained that teachers were free to teach as they wanted but added that IB had a no-experimentation policy on animals. Thomas thought it would be interesting idea to use virtual models of animals that one could move around and open, similarly to a 3D application of the human body he used. He added that the quality of simulations was an issue as well their price. On a similar note, William said that it is easy was relatively easy to find simulations but the questions was if they were good enough and had enough variables to manipulate and create enough data.

Agnes mentioned that according to school regulations students could use muted mobile phones in the corridors and listen to music with earphones during the breaks. In the classrooms, phones had to be switched off. However, she added that Pandora’s box was already open and students wanted to use their devices. She thought that schools and teachers should rather help students to use their devices in the best way.

“While they are sitting there mindlessly playing games, we can actually get them interested in using them and improve their learning. I think that is a better way. They will use it anyway.”

Susanne told that she authorized her students to use their mobile phones in certain classroom situations, for example when they did microscopy. Students could make their own films by using

their cameras. This helped them to create drawings afterwards without straining their eyes too much in the microscope lenses. It also allowed them to create their own video portfolios and review the recordings later at home as well.

4.6.4 Roles and Responsibilities

Susanne said the DT could help students to become more independent. She thought it was a motivational tool with its gamified features, such as the bars of effort and achievement, that helped students to visualize and track their own progress:

“It is a motivational tool for them like all the gaming technology where you have bars of effort and achievement. It is a very visual tool. Reading ahead of class or prior to revision is a useful regular exercise. It does motivate them in the sense that they get some kind of visual feedback and not just say; yes I did.”

Thomas pointed out that DT brought more responsibility for students in a stressful way. However, that was also due to the large IB syllabus that was impossible to teach in the given timeframe. He added that students were also drowning in the number of resources:

“There is just so much for them, that they don’t know what is important, what is not important, when they should be doing it. [...] So the amount of responsibility that we are putting on these student... I could not have dealt with it when I was their age. “

“We are giving them a service by giving them the resources. It is just like the internet. They can do anything with it. So much that it inhibits them and then they only go to Facebook and then they only got... the majority of people have like 10 websites. That is it. We know because they show us the websites. So it gets too much and they cannot manage. They do not know how. I see students who are overwhelmed, I see students who are scared and I see students who are confused.”

He said, that SL and HL classes were similar in that way, the overwhelmed feeling of students was there:

“The students in HL are hard workers or they are more gifted but the overwhelmed feeling is still there. Because they have a lot of content to cover [...]. So it is just much. They have like 5 books. It is crazy!”

Similarly, William said that the DT and other digital resources allowed student to work more at home. He thought, that the diversity of resources was useful to have the same topics explained from a different perspective:

“I think it is good that they have these different resources because I explain things on my own way. If I explain again, I can alter slightly but it would be still my way of explaining it. If it is from someone else’s point of view on the DT, maybe that is better for them. It is fine.”

However, he pointed out that signing up for too many resources had its dangers as students would not know where to go and what to look at.

Thomas told that at his previous IB work overseas the school monitored the progress of every student on each standard of the IB, including multiple choice questions, short answers and long answers. He added that at his current work he had no time to aggregate this amount of data by hand. The DT provided him only with had data on the multiple-choice questions. He said it would

be for example useful to have a system that would allow him to mark long answers at a faster rate by flagging up potential problems:

“There is that kind of a system that can read key words and help whether the kids are understanding the concept or not. [...] it could flag up potential problems.”

“For example, there is an 8-mark question and you need to have 8 comparison points. For the kids that is tough. For me that is tough and I have been teaching for a long time. So, I think if there is a system which could help me to manage the amount of time required for each of the student, that would be helpful.”

Agnes mentioned that the DT reduced her marking load to some extent on homework assignments due to the automatic marking. Nevertheless, the final exam was still on paper therefore the DT did not entirely replace the classical pen and paper work. She thought that no teacher would go completely digital as long the exams were conducted with pen and paper. While she thought that the DT is as additional tool to work with, she added that this would change as soon as the IB moves into digital examinations by 2025. She thought that with the introduction of the digital exams the work of teachers would change as well.

4.6.5 Community

Thomas thought that parents often did not know what their children were doing on their digital devices. The DT and other digital learning tools took away an element of the parental control and created a certain physical barrier which parents could not necessarily bridge. William told that parents sometimes came to parent meetings with the wrong impression that their child was working hard when it was not the case. They could also become quite offensive. The learning diagnostics data on the DT proved to be useful during parent meetings. William described a case when one of his student struggled with the subject as he did not prepare very much. William saw that the student never opened the DT. When he showed the resource to the parents, he could demonstrate the lack of activities there and could argue that the student should do more. After that, he saw that the student started to work through the topics and questions in the DT. Agnes also said that the DT empowered parents to help the students:

“When parents say on parent meetings that my child is achieving this level but should achieve this (higher) level then I can show them the resources available. A thousand assessment questions. All they have to do is log on and work their way through it. I can guarantee that it will help them in the path. So, it is passing responsibility back to students and parents. They have something that they failed at but it gives them a program to get from where they are to get to where they want to be. I think it is very important.”

She thought that many parents might not have been very familiar with a particular subject and the printed textbooks gave them little information on how the student progressed. However, the effort and progress bars in the DT visualized this information in a way that was easy to understand:

“If they see a bar and know that the student should get 60% in the assessment but does only 10%, or did not even log on, then it empowers the parent a little bit to help the student.”

4.6.6 Future Perspectives

Agnes reflected about the evolution of digital learning resources as it started with a CD in a back of the book with simple pdf copies. She added that publishers started to realize that digital

resources do not need to look like printed books and that was one of the reasons she liked the DT; it was not allied with a paper textbook. She thought that there was a huge variety of resources which could be available digitally that a paper textbook could not contain. She speculated the DT of the future will evolve to a point where it will stand on its own in the digital world and teachers will do things differently:

“You can embed simulations, you can embed videos and you can make it available in one place. In a world that is contained rather than just oh, here is a book and here is a website and look at this website. We have not quite yet developed a truly digital textbook but I think it is starting.”

5 Analysis

5.1 Elements of the Activity System

Figure 5. translates the elements of the Activity System following the AODM framework. Subjects in the activity systems represent the learners and teachers. Tools represent artifacts, such as the DTs used to carry out activities. Object represent the objective of preparing students for the final IB examinations. The objectives are then transformed into outcomes which is the graduation from the IBDP. Rules are elements that refer to regulations, cultural norms of those involved. Community components represent both the physical and conceptual environment in which the activity is carried out, e.g. parents, the larger school community and DT developers. Finally, the division of labour component reflects variations in roles and responsibilities among the stakeholders, in this case students, teachers but even parents.

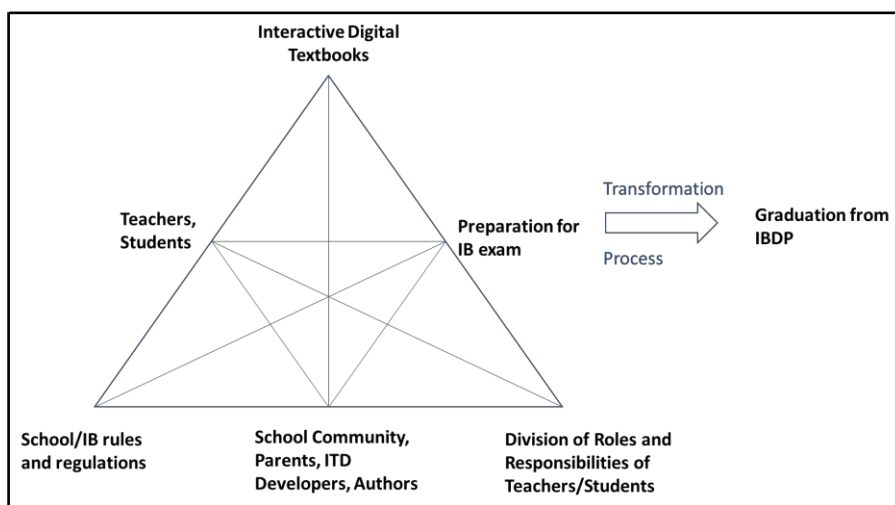


Figure 5: Activity System based on AODM

5.2 Analysis of the Activity System Dimensions

5.2.1 Subject-Tool-Objective

This dimension investigated the use of the DT by the teachers. The question generated from the analytical model was: How do Teachers use the DT to prepare students for the final IB exams? The following section analyses the various approaches of teachers while using the DT and identifies the issues and challenges.

5.2.1.1 Facilitating Flipped Learning

More than half of the interviewed teachers, 4 out of 7, reported using the FL method on a regular basis and 3 of them used the DT to facilitate some of the activities. Teachers flipped their classrooms with varying frequency; three of them used FL on a weekly basis and monthly bases while one teacher used it only few times during a term. Student motivation played an important factor for FL to happen. One teacher said, it worked best with enthusiastic students. If there were enough enthusiastic students in a group, the FL was a useful method. She required that students created their own slides based on the pre-readings and presented them to their peers during class.

This motivated students because if they had no slides, they had nothing to show to their peers. Another teacher said, that FL worked if there was an interesting problem formulation that encouraged students to prepare. The right level of problem formulation was important in this case; a too difficult problem could be hard to solve for students, while a too easy one might not result in meaningful in-class discussions. One teacher counted student preparation towards an effort grade in alignment to school policy that encouraged pre-class work.

In all FL classrooms, DT was an optional resource for students. Other resources included printed and digital IB and OER resources such as texts, videos, animations, songs etc. Only one teacher said that he created and sent his own videos to students. Another teacher emphasized that there is an abundance of multimedia resources already available to teachers and it was important to her to provide her students with a variety of engaging learning resources rather than limit herself to one source. She said, this allowed her students to construct their own knowledge and choose resources that supported their learning styles.

Two teachers created assignments from the DT prior to the lessons to facilitate pre-class student preparation. In these cases, they created short sets of multiple-choice questions from the question mall of the DT which they assigned to student together with a pre-reading or a video. As the students worked with the assignments, teachers received learning diagnostics data on their performance. The data was useful for identifying the possible gaps in understanding and they used it to address the issues during the in-class time. One teacher preferred to create the assignments with another application as well which allowed him to use his own set of questions. This provided him with a flexibility that the DT question mall did not have.

One teacher utilized the DT's learning diagnostics data for FL from the pre-class activities at the beginning of the lessons. He showed and discussed the results with the class and encouraged students to look at their own data to identify where and why they made mistakes. He encouraged them to use the data as an input for self-reflection on their own learning. He also investigated if students could link knowledge areas of the curriculum and encouraged students to reflect as well. Occasionally, he created short quizzes in the DT which he administered to students at the beginning of the lessons to further encourage student preparation.

In terms of post-class activities, three of the teachers reported that they used the DT to create and send assignments to students, and facilitated the revision of the material at the students' own pace.

5.2.1.2 Facilitating Differentiated Learning

3 out of 7 teachers reported using the DT for supporting differentiated learning in class in some ways. In one case, the teacher used the DT to address large ranges of abilities in her classrooms. During her lessons, those students who understood the new material could play the knowledge battle games for 10-15 minutes until the teacher payed extra attention to those who struggled with the material. Another teacher used the DT for revisions in the class. Students who preferred to follow the teacher-led revision of a topic did so while those who wanted could work individually on different topic revision from their DT or other resources. Students could freely move from the group revision to the individual revision space. Another teacher used the DT to deal with large class sizes during laboratory work. In these cases, she divided the students into two groups. While

one group worked in the laboratory, the other half of her class reviewed materials in the DT and solved quizzes and assignments individually.

5.2.1.3 Individual Revision

Most typically, the DT was used to facilitate individual revision either in the classrooms or at home. Five of the teachers used the DT this way as an optional resource. Only one teacher required an obligatory minimum interaction with the DT and counted the effort of students towards grades.

5.2.1.4 Assignments and Assessment

Three teachers used the DT to create tests and quizzes for assessment during face-to-face time from the question mall. The setup was easy and the learning diagnostics data helped them to save time on the grading. Two teachers used it rather to assess the level their students understood the pre-reading. Home assignments were sent either to facilitate FL or to review the material students learnt in class. In these cases, the learning diagnostics data helped teachers to identify gaps in the knowledge and focus on problem areas or re-visit issues during class time.

5.2.1.5 Individual Study Program

Two teachers said that they advised the use of the DT for struggling students and their parents who wanted to improve learning outcomes. In these cases, the DT was used as an outside classroom resource and provided a scaffold for self-directed studies. The teachers only followed the progression through the learning diagnostics data. As a teacher said, the DT offered a follow-through program with immediate feedback and a sense of progression which was motivational to students. According to this teacher, three of her students who consequently followed through every question in the DT, did improve their results on multiple choice tests by two grades.

5.2.1.6 Issues and Challenges

Motivation and Engagement

Levels of motivation and engagement with the DT varied among teachers. Their feedback pointed towards the need to differentiate between HL and SL students. Several teachers raised that the design of the DT is rather applicable to SL than HL students, due to its level of details. While those in the SL group studied the subjects because it was part of the DP curriculum, students in the HL track tended to be interested and planned university studies within the field. This indicates that the depth of the material presented in the DT could be sufficient for SL learners but might not be rich enough on details for some HL level teachers and students that would motivate its use.

One teacher addressed that low achievers might be less motivated to access the DT as well. He speculated that it might be due to distractions from other digital media outside the classroom and school. He proposed the idea of actively “pulling in” the student and proposed that a scheduling tool could perhaps bridge the problem. This could allow students to set up a preferred time for study in the DT and get a reminder with a link for easy access to the DT. The HL teacher who used the DT most comprehensively, pointed out that the availability of the DT itself did not guarantee engagement and learning. He needed to teach his students the skills how to engage with the tool for learning.

Teachers perception of FL influenced their engagement with the DT. Those teachers who flipped their classrooms, tended to use the DT as an optional resource for pre-class work. Others, voiced concerns that students were not ready for the FL method and mentioned issues with lacking pre-class preparation and the lack of opportunity to ask the teacher for clarification if they did not understand something.

It is also important to consider that teachers' perception of the DTs can be influenced by their feelings and previous experiences with digital technologies.

Resources

The use of the DT could be also affected by the availability of other resources. Teachers thought that the use of multiple resources was desirable since it provided students with multiple perspectives. This helped students to construct their own understanding of the material. However, as one teacher pointed out, too many resources could have the opposite effect and inhibit learning instead of facilitating it. He observed that the large diversity of printed and digital resources available to students confused and overwhelmed them both in the SL and HL tracks. There is therefore a possibility, that educational resources, among them the DT, might not have been used to their full potential for that reason.

The DT seemed to be distractive to some teachers and students when used during direct instruction. Two teachers explained, that the DT often presented a knowledge area differently from their approach. Therefore, they preferred if the DT or other digital resources were not open on the students' laptops during lecturing to prevent the split of attention. However, another teacher pointed out that his students were good at multitasking and did not see this as a disturbing factor.

The DT can be considered as an additional resource added on the top of other resources teachers already used. The administrative tasks in the DT, such as creating and sending out assignments, even if seemingly insignificant, further strained the limited time schedules of a teacher. Coupled with lacking motivation of some of his students to access the DT, this was not an efficient use of his time. He suggested that a scheduling tool could automatically send out pre-set assignments to students and save him time.

There were also health considerations raised by some of the teachers about the use of digital resources. These included concerns about eyestrain and migraine that some student experienced after excessive use. The increasing use of digital tools influenced hand writing skills of some students. Some got cramps and blister on their hands during the final examination period, as told by their teacher. Due to long the final exams written by hand, students had to be prepared to write on a paper with a pen. Teachers voiced that a mix and match of digital and non-digital tools is therefore necessary.

DT Features

Besides the earlier mentioned teacher and student planning tools, some of the inputs addressed possibilities of other specific features. A teacher pointed out that the DT worked well with multiple-choice tests and could be helpful to prepare students for that part of the final exam. He added that future tools that could reduce the time spent on correcting long answer type questions

by flagging potential issues would be helpful. The lack of possibility to include own questions in question mall made this teacher complement the DT with another digital resource.

5.2.2 Subject-Rules-Objective

This dimension investigated the Rules that affected teachers work. The question generated from the analytical model was: What are the Rules that affect the way teachers prepare students for the final IB examination? Thus, the following section analyses the Rules and identifies the issues and challenges.

IB regulations on resources, ethical considerations and assessment rules were those that teachers regarded most relevant in connection to using the DT. While teachers were free to teach in their classrooms as they wanted, IB required that student learn from a variety of resources. It was to ensure that students exposed themselves to different ways of thinking in the subject area, and constructed their own understandings based on the variety of resources. IB had officially approved resources which schools could select from. All the schools in the study offered at least one IB approved main printed textbook for students. Complementing these, the participating teachers used a great variety of other digital and non-digital resources. One teacher said, that his students had as many as 5 textbooks. Another teacher used 15-20 different online sources besides the printed textbook. These included IB approved resources, OER and teacher created resources. In these contexts, the DT was an optional choice to both students and teachers.

5.2.2.1 Issues and Challenges

Grading and the use of DT

Teachers' feedback indicated that the existence of a local grading system influenced the use of the DT. One teacher explained that in lack of a local grading policy it was difficult for him to motivate some of his lower achiever students to access and engage with the DT outside the classroom. In another school, students received effort grades and the teacher required minimum compulsory interaction with the DT. Only if students reached the minimum level, could they receive higher than grade C on a scale from A to D. Therefore, in that class all the students strived to fulfill the minimum requirement. While some student achieved well over this, most of the students remained at the minimum level.

IB ethical rules

Ethical regulations on the use of animals for experiments influenced the work of Biology teachers. One teacher suggested that interactive models of digital animals could be helpful to replace experiments on real animals and provide learning opportunities for students.

5.2.3 Subject-Division of Labour-Objective

This dimension investigated the Division of Labour and how it influenced teachers. The question generated from the analytical model was: How does the Division of Labour influence the way teachers prepare students for the IB examination?

5.2.3.1 Teacher- Student Responsibilities

Many of the teachers said that the DT did not change their roles and responsibilities. They rather felt that it was an additional resource that they could use to expand their interaction with students. One teacher said, that she could better “hear” those students who felt uncomfortable to speak up in front of the class. Other teachers reported, that the DT reduced their time they spent on correcting multiple-choice questions, tests and assignments. Learning analytics data could support pre-class preparation of teachers and helped them to use time more efficiently in the class. However, administrative tasks in the DT could also add to already busy schedules of teachers.

Most importantly, all the teachers agreed that the DT had the most impact on the roles and responsibilities of the students. The DT shifted more responsibility on the students for their own learning outcomes and empowered them to take control over their education. For example, the immediate feedback and revisions could help students to identify areas for improvement, set learning objectives and achieve them on their own pace. The gamified features such as the efforts and achievements bars were motivational to some of the learners as they gave them a visual feedback as they tracked their progress.

5.2.3.2 Parents

The feedback of the teachers across schools indicated that parents were often involved in the learning process in general, with exception of the boarding school. Some of them indicated that the DT and other digital learning tools took away an element of parental control and created a physical barrier which parents could not necessarily bridge. As some of the teacher pointed out, parents were often unfamiliar with the DT and students owned the digital learning tools for themselves. This was perceived positively by the teachers since it helped students to be more responsible for their own learning without any parental control

5.2.3.3 Shifting administrative tasks

In one school, the digital subscriptions changed the jobs of some of the stakeholders. The administrative tasks of maintaining and registering student lists online, shifted workload from the Science Department to central administrators who managed whole cohorts in multiple subjects across the school. Thus, this shift reduced the classical work of the Head of Department but at the same time changed the location where the work needed to be done.

5.2.3.4 Issues, Contradictions

The increased responsibilities of students for their own learning came along with stress, according to a teacher. The large syllabus coupled with a great variety of resources confused and overwhelmed students to the point of inhibiting learning for some. This feeling was observed by the teacher in both SL and HL groups to varying extents.

Teacher reports also indicated that some of the students owned the DT to such extent that it replaced their personal notes and substituted note-taking during class time. Many of the teachers indicated that active note taking was of key importance to passing the final exams.

5.2.4 Community-Tool-Objective

This dimension investigated the relation of the DTs and the community. The question generated from the analytical model was: How does the DT affect the way the community supports students to pass the IB examination?

5.2.4.1 Supporting Parents

Teachers said that parents sometimes had wrong conceptions about their children's learning. This became obvious for some of them during parent meetings. In some of these cases, the DT could serve as an easy-to-understand evidence of student efforts and could support the argument of the teachers if they thought that the student should do more. However, the active involvement of parents proved to be useful in cases when students struggled with the subject matter. In these cases, the DT was used to provide a step-by-step study program for students and parents to follow through.

5.2.5 Community-Rules-Objective

The next dimension investigated the relation of Rules and the Community. The question generated from the analytical model was: What Rules affect the Community when preparing students for the IB examination and how?

5.2.5.1 Assessment requirements

The most important influence mentioned were the knowledge and skill requirements of IB. Teachers had to prepare their students with appropriate knowledge and skills that helped them to master the assessments. One teacher pointed out that the DT was helpful especially with multiple-choice question, however it was not sufficient to prepare for the different types of exam questions. Moreover, the final tests were conducted on paper by hand. Thus, relying too much on digital resources, would not have been supportive for the exam preparations. Therefore, it was crucial for the teachers that student learning activities included hand-written activities beside using digital tools for learning. They speculated however that this trend will turn when IB introduces digital assessment. This is to be expected by 2025 with trials starting already some years earlier. Some predicted that with digital assessment, the importance of digital learning resources will significantly increase.

5.2.5.2 Issues and Contradictions

The concerns and issues raised were mostly about the future introduction of digital examinations. One teacher questioned for example whether the process of typing can support the same cognitive engagement as writing by hand. Other concerns included questions about how digital resources will be organized in the school and what functionalities digital resources should have when assessment becomes completely digital. How can digital tools facilitate for example, drawings, calculations and equations?

Teachers in one of the schools also voiced concerns that that rapid development of technologies made it difficult for them to update and introduce policies on the use of digital tools. This raised questions on how schools can stay ahead of the developments, especially when research results are being published with time lag.

5.2.6 Division of Labour-Community-Objective

The last dimension in this analysis concerns the relationship between the Division of Labour and the Community. The questions generated was: How does the Division of Labour affect the way the Community prepares students for the IB exam?

The finding in this dimension is strongly connected to chapter 5.3.3. namely to the role of parents. Some teachers found that the DT could help struggling students to improve their results on multiple-choice tests. In some cases, the teachers informed parents explicitly about the availability of DT which seemed to have a positive effect on student engagement with the resource. Parents might have been hindered by their unfamiliarity with a subject area and printed textbooks gave them little information on how the student progressed. However, information on effort and progress was visualized in the DT in a way that was easy for parents to understand. This empowered them to help the student.

An overview of issues and challenges based on the AODM is provided in Table 14.

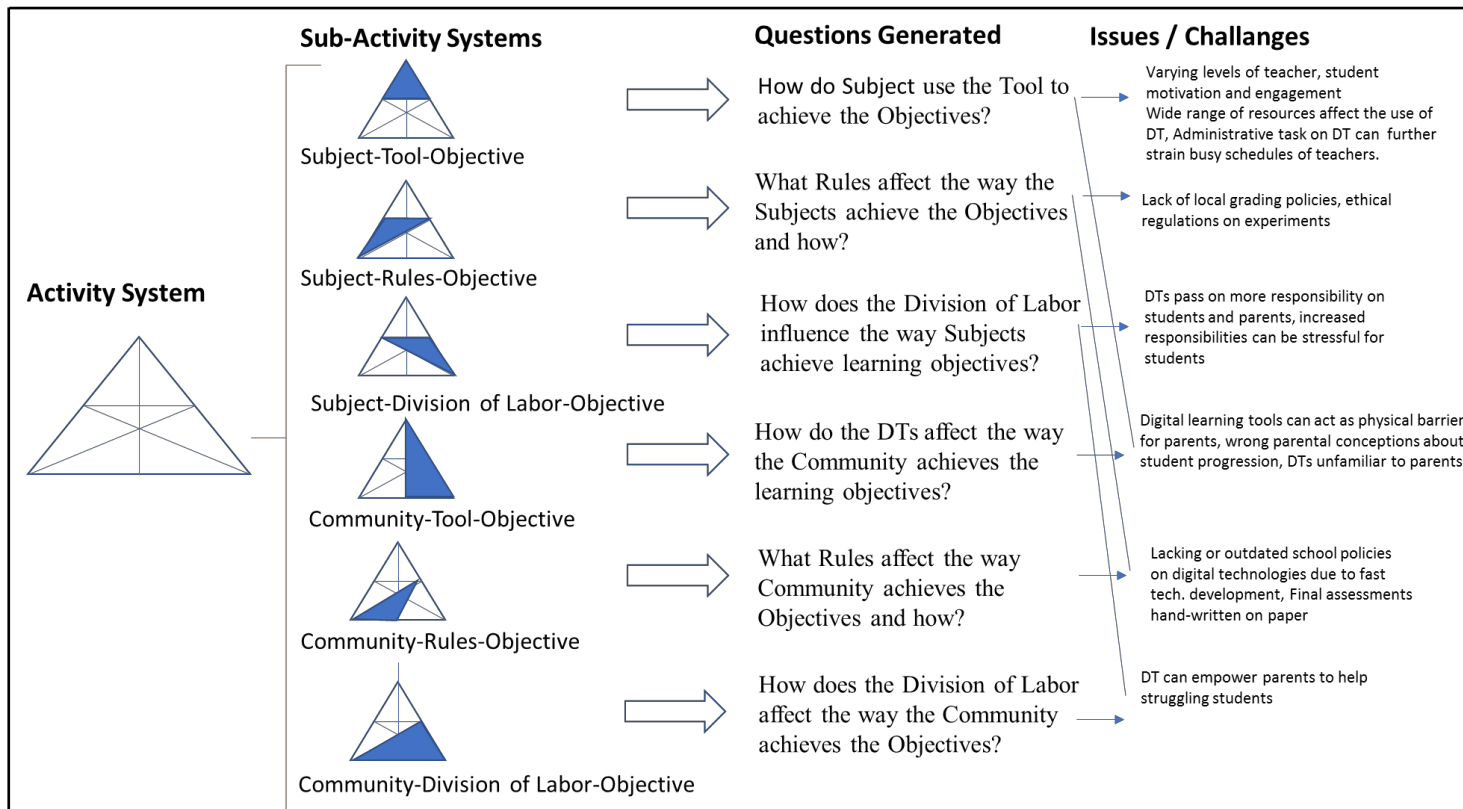


Table 14: Summary of Analysis based on the AODM Framework



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6 Discussion

Rationale behind the use of DTs were diverse. For most teachers, the DTs expanded the choice of resources for teaching and learning. With a clear structure tailored to the IB curriculum, teachers considered the DTs as an easy entry to the subject areas. Implementation in schools was also driven by the availability of the DTs in multiple subject areas and easy portability. In one case, a teacher especially emphasized that the annual, in-person introductory sessions provided by the DT publisher were helpful. However, the actual use of the DTs varied greatly among teachers as discussed in the following section.

6.1 Use of the DTs

Findings showed that teachers utilized the DTs to a varying extent. This supports the argument of Knight, Horsley and Huntly (2010) who found that the practical use of textbooks reflects a continuum and ranges from integrated core resource to peripheral resource. Finding of this study indicated that teachers had different preferences and practices reflecting the elements of a continuum. Some used it as peripheral resource, while others integrated them in their teaching with more or less frequency. At the lowest end of the scale, students read and worked from the DTs at their own time and their own initiative, but no teaching-learning activities were initiated by the teacher. In some cases, the DT could fill the role of a core resource, for example when it was frequently used to facilitate FL activities. The integration depended much on the individual perceptions of the teachers and to what extent they considered the DT as useful and efficient tool to achieve their teaching, learning objectives. For example, sending assignments, following and evaluating the learning diagnostics data added on the top of already existing tasks can burden the already busy schedules of teachers.

Teachers' use of DT was also influenced by the motivation of students to access the resource. Findings showed that some of the teachers introduced external motivation to encourage student engagement such as grades, assignments and quizzes. However, this was difficult in cases where there was no local grading system. Results of the study pointed towards the possibility that students' use of the DT could be influenced by factors such as student distraction in online environments, overloaded schedules and their perception of the DT as an efficient and engaging tool for learning. In addition, DTs shifted more responsibilities on students. While this was positively perceived by most teachers, some of them have voiced concerns, that the increased responsibility was also stressful to students. The great number and diversity of resources confused

some students and inhibited learning. For that reason, it is possible that the DTs and other digital resources might not have been utilized to their full capacity.

When integrated into teaching practices, DTs supported, both flipped and non-flipped methods. Some teachers used the immediate feedback on student performance to spot gaps in the knowledge prior to class, adjusted their teaching approaches accordingly, revisited problem areas, supported student metacognition of the subject area and encouraged reflective practices. They captured feedback from students who otherwise might not have spoken up in the classroom. Some of the teachers used the DT to address issues of diverse ability classrooms, differentiated revision activities in the class, and managed large number of students when limited lab space was available. In addition, the DTs were used to create and administer home assignments, quizzes and tests or facilitated the consolidation of a topic area. In such cases the DT could reduce marking load. DTs aided some of the teachers in supporting struggling students and served as a step-by-step learning guide to students. Further, the data on student effort and progress were in some cases aided communication with parents.

The different ways of DT use by teachers are listed in Table 15. at pre-, in- and post-class stages.

| Uses of the DT by teachers | | |
|---|--|--|
| Pre-class | In-class | Post-class |
| <ul style="list-style-type: none"> • Assigning pre- readings for knowledge acquisition • Sending quizzes, assignments in preparation to class • Using the learning diagnostics data to align in-class teaching | <ul style="list-style-type: none"> • Creating tests, quizzes for assessment • Demonstrating learning diagnostics data for reflection • Facilitating differentiated learning through games or individual revision activities | <ul style="list-style-type: none"> • Sending low assignments • Assigning individual revisions • Following sub progress • Using learning diagnostics data to support teacher-parent communication |

Table 15: The Use of DTs for Teaching

Knight (2015) pointed out the DTs are tools whose mere existence does not ensure that the quality of the teaching and learning experience will improve. How teachers and students perceive and use the DTs determines whether and how they can contribute to increased learning outcomes. Similarly, teachers in this study also pointed out that availability of the DT did not automatically translate into student motivation and engagement. Teachers had to educate their students how to interact with the DT, and make a use of it as a learning resource in tandem with note taking, reflective practices, formulating learning objectives or taking small incremental steps in the DT on a regular basis.

6.2 DTs and Flipped Learning

A slight majority of teachers in the study indicated using the FL method regularly or occasionally in their classrooms. Most of those teachers who flipped their classroom used the DTs to a varying extent and frequency. Most commonly they assigned pre-class preparation, administered quizzes

or short assignments and analysed the learning diagnostics data. Learning data could pinpoint eventual gaps in student knowledge prior to class and facilitated a more efficient use of teachers' time in the class. In some cases, the data was also used in-class to support self-reflection of students on their learning progress and metacognition across topic areas. Post-class use included typically assessments and revisions of the topics and solving multiple-choice questions.

Teachers who did not use the FL method raised issues of non-sufficient pre-class preparation of students. This reflects the concerns raised in other studies (Herreid & Schiller, 2013); if students do not prepare at home, they will not be prepared for class either. This could pose issues for in-class group activities that require the knowledge of the learning material (Ng, 2015). Some of the teachers in the study raised also concerns about leaving the students alone with a complicated subject matter and no possibility for explanations when questions arise. This echoes Milman (2012) who cautioned that students are not able to ask their teachers questions while they are viewing the lectures at home and therefore may struggle to understand the content. On a similar note, findings of this study indicated that accessing English language can be a challenge for some second language speakers and differentiating tasks of what students need to achieve in their pre-reading may be necessary.

Not all teachers in the study who used FL method used the DT. Findings indicated that some teachers and students in HL Science studies preferred a higher level of granularity than what the DTs provided. Further, some teachers preferred a wider array of engaging multimedia resources from multiple sources, which were helpful to encourage pre-class engagement of students, rather than using a single resource. Others liked to design quizzes with their own or other teachers' questions, instead of using pre-set questions from the mall. In summary, the study found two factors that influenced teachers' use of the DTs for FL. Firstly, teachers' perceptions on FL mattered. Those teachers who found FL difficult to implement, tended to consider the DT as related or peripheral resource. Secondly, teacher perception of the DT's quality and efficiency to achieve learning goals influenced the use of the resource. This supports the study results of Kim, et.al (2012) who found that perceived benefit was a strong influencing factor in the context of multimedia-based DT acceptance. Further, the study indicated that personal feelings or previous experiences with technology might also influence teachers' motivation of using the DT.

7 Recommendations

The study results indicated that the availability of the DTs to students did not automatically translate into motivation of use and engagement. Future research should investigate the influencing factors for motivation and engagement of students, especially with a focus on the needs of standard and higher-level learners. For teachers, it would be helpful to share their experiences and strategies to cross-fertilize ideas for teaching with the DTs. For developers, some concrete suggestions captured in this study could be investigated, such as implementing scheduling tools for teachers and students or actively “pulling in” students into the DTs with reminders and easy-to-follow links. Further, it can be also considered that some teachers need a greater variety of multimedia resources to engage students in pre-class activities for FL and flexibility when designing quizzes and assignments. Moreover, future change in IB assessment is already foreseeable. It will be important to understand how digital exams will change the needs of teachers and students and what it means for the design of DTs.

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Appendices

Appendix 1. Interview Guide

Interview Guide

Name of School:

Name of Teacher:

Date and time:

1. How long have you been teaching? What subjects have you been teaching? What digital textbooks have you been using and for how long?
2. What is the reason that you use the digital textbook?
3. How does the digital textbook help you to achieve learning goals?
4. What are the rules, regulations, norms that affect how you as a teacher can achieve learning goals? Any regulations what digital resources you can use and how at the school or IBDP?
5. What rules, regulations affect students learning goals? How do these rules affect students? (*examinations, tests?*)
6. Has the use of digital textbooks affected your roles and responsibilities as a teacher? If so, how?
7. How do these changed roles and responsibilities affect how your students learn? (G6)
8. Has the use of digital textbooks affected your students' roles and responsibilities in the learning? If so, how?
9. How do these changed roles and responsibilities of students affect the way they learn?

How does the use of digital textbook affect the way your students achieve the learning goals? In your opinion, what are the challenges of using the digital textbook?

Does the use of the digital book affect parental involvement in student learning? If so, how?

Does the use of the digital book affect school administration in some ways? If so, how?

Does the use of the digital book affect the teacher community in some way? If so, how?

Would you like to share anything else?



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Appendix 2. Observation Guide

Activity Observation Guide

Name of School:

Observed Class:

Learning Goals:

Date:

Recording:

| Time | What is the activity? | What is the core purpose of activity? | What is the role of the teacher? How is s/he involved in the activity? | What is the role of students? How are they involved? | What technology is used and how? |
|-------------|------------------------------|--|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |