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Digital Inequality in Access and Achievement for Students: Germany’s Adoption of the European Commission Digital Education Action Plan

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Digital Inequality in Access and Achievement for Students: Germany's Adoption of the European Commission Digital Education Action Plan

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DIGITAL INEQUALITY IN ACCESS AND ACHIEVEMENT FOR STUDENTS: GERMANY'S ADOPTION OF THE EUROPEAN COMMISSION DIGITAL EDUCATION ACTION PLAN

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Abstract

Much like social and economic inequality, digital inequality has established itself as an important facet of societal inequality that must be observed critically if students are to succeed in the emerging knowledge economy. This research studies digital inequality in the German context as a result of the current adoption of the Digital Education Action Plan recommended and legitimized by the European Commission using a social exclusion perspective. The research used data gathered by Trends in International Mathematics and Science Study (TIMSS) 2015 from the fourth-grade German participants to first of all understand the relationship between at home access to the internet, computers and tablets and student achievement, and to observe the difference in performance between students who have access to the digital resources at home and those who lack access. Secondly, the research used parents' educational and occupational levels, home access to the internet, computers and tablets and number of digital information devices at home as predictors of students' achievement in Mathematics. An independent samples *t* test and a multiple regression analysis were run to determine if a relationship exists and the significance level. Students who have home access to the internet performed better and students who did not have home access to their personal computers and tablets performed better as well. Parents' educational and occupational levels and home access to the internet and personal computers and tablets all significantly predict student achievement scores on TIMSS. Number of devices in the home was an insignificant predictor. These results have policy implications, especially for the adoption of the Digital Education Action Plan.

Keywords: digital inequality, digital literacy, social exclusion

Chapter 1: Introduction

The European Commission in 2018, proposed a "Digital Education Action Plan" (European Commission, 2018, p. 1). This plan includes 11 initiatives that should improve digital literacy and technology use in schools across Europe (European Commission, 2018). The plan outlines three priorities with measures that would help member countries address their slow pace of technological advancement in schools (European Commission, 2018). This action plan is in response to the current stance that digital literacy is necessary to succeed in the burgeoning knowledge economy (Pagani, Argentin, Gui & Stanca, 2016) and it has become important for national systems of education to build digital competences (OECD, 2016) for their students. While building digital competences within the school walls carries a high measure of importance (Calvani, Cartelli, Fini, & Ranieri, 2009), a different area that is often neglected is the influence that parents' digital literacy, socio-economic status and students' access to and use of technology at home have on digital skills and student performance (Ono & Tsai, 2008). This study focuses on the relationship of home access to technology on student performance. The research will answer the broad question: How does access to and use of technology at home relate to and predict student performance in mathematics as measured by TIMSS 2015?

The research begins by identifying the problem of digital inequality and the relevance of studying the issue. The second section of the paper gives a general background of the German educational system and her relationship to the European Commission. It also addresses the literature in the field that exists around the concept of digital inequality, the European Commission's soft power and the explication of the theoretical background for this paper. The third chapter focuses on the methods and statistical analysis of the TIMSS 2015 data, followed by a presentation of the results of the analyses and then, it concludes with a presentation of the implications of the results and provides policy recommendations.

1.1. Problem Statement

Digital capital proves to be just as important as human, social, financial and cultural capital (Robinson et al., 2015) as the knowledge economy requires individuals to go beyond being technology savvy to being digitally literate. The digital divide- that is, the gap between people who have access to digital resources and those who do not (Norris, 2001)- has been compounded by the gap in digital engagement and this could potentially alter an individual's life course (Robinson et al., 2015). In a world where technology has been integrated into everyday life processes, the digital environment now serves as a place where connections are made, and relationships are sustained, thus having ramifications for social capital (Park, 2012). Universities, institutions and organizations are slowing phasing or have completely phased out paper applications and documentation with a large part of this information being housed in a digital environment (the Cloud) and this is evidence of how lack of digital capability can be detrimental to an individual who needs to access these resources (Iske, Klein, Kutscher, & Otto, 2008).

Germany is chosen for analysis because despite its large economy and stance as a developed country, it still lags in technological advancements when compared to countries with the same development index (Naudé & Nagler, 2017). The research examines how the European Commission's Digital Education Action Plan is being adopted using Germany as a case study and provides support that the current action plan might lead to social exclusion of certain groups if the right infrastructure is not provided before the digital action plan is adopted. This digital action plan assumes that all students have the same opportunities to succeed, which in this case is access to and use of technology and internet and neglects the influence that social and cultural capital might play in widening or closing the digital gap (Pagani et al., 2016).

Although the European Commission sets the agenda and Germany is expected to follow it, it is important to note that the European Commission has no policy making power on educational policies at member state levels (Tsebelis & Garrett, 1996). Decision making power lies with the member states and in the case of Germany, a large part of the decision-making power for education falls to the Länder (State governments) with the federal government playing a minor role (Davoli & Entorf, 2018; Wößmann, 2007). This research targets policy makers, Ministers of education and decision makers in the field of education who urge schools to implement the digitization policy. Such policies have implications for equality and achievement for students, especially marginalized students who lack home access to digital resources which can ultimately lead to social exclusion (Park, 2012; 2017). This paper will not advocate for the exclusion of technology from schools but rather, it will bring to light the issues that must be addressed before the full potential of the move to digitization can be fully harnessed to benefit the students and the larger society.

1.2. Significance of the Problem

It is necessary to look at digital inequality as digital skills and capabilities are essential to fully participate in the society (Drori, 2006). In looking at cases of digital inequality, it becomes clear that the digital divide mirrors inequality and social stratification in the society, especially along the lines of socio-economic status, migratory status, education level and age (Drori, 2006). Digital inequality has become a social problem that can be likened to the social problems of poverty and access to education (Drori, 2006). This is made even more obvious by the intervention of international organizations and for-profit IT organizations who try to provide and build infrastructure to technologically connect parts of the developing world (Drori, 2006). According to the International Telecommunication Union (2018), it was estimated that only 51.2% of the world population uses the internet. According to the Pew Research Center, nearly one in five children cannot complete their assignments as a result of lack of access to technology (Anderson & Perrin, 2018). According to the International Telecommunication Union (2018), at the end of 2017, only approximately 33.3 million people out of Germany’s population of 82.79 million had fixed broadband internet. This research has policy implications, especially for historically marginalized groups such as students with migrant or refugee status. It is clear that access to digital resources only in the school environment is not sufficient to meet the needs of today’s learners with students being unable to complete assignments because the necessary resources are unavailable at home (Anderson & Perrin, 2018). Considerations at the policy level need to be made to accommodate the needs of students who lack access to these resources at home.

1.3. Comparative and International Context

The definition and characteristics of what constitutes research in the Comparative and International Education (CIE) field has been a topic of constant debate (Bray & Thomas, 1995; Crossley &Watson, 2003) because of the interdisciplinary nature of the field that makes its boundaries seem fluid (Cook, Hite & Epstein, 2004; Epstein, 2008; Foster, Addy & Samoff, 2012). Therefore, it becomes necessary to situate this research as part of the broader discussion in the field (Davidson, 2018). Despite the interdisciplinary nature of the field, it is heavily influenced by social science research and methodology (Crossley &Watson, 2003) and this research draws its methodological and theoretical perspectives from the fields of education, policy studies, sociology and poverty studies.

Globalization and the involvement of international organizations such as UNESCO, the OECD and the European Commission in global educational governance and their publications of policy recommendations and research have marked a reconceptualization of the field of CIE (Crossley, 2000; Crossley &Watson, 2003). This research analyzes the adoption of the digitization of education plan that was handed down from the European Commission to all her member states as a recommendation for school improvement.

International comparative research is marked by the global competitiveness that is made possible through international comparative tests such as Trends in International Mathematics and Science Study (TIMSS) organized by The International Association for the Evaluation of Educational Achievement (IEA) and Programme for International Student Assessment (PISA) organized by the Organisation for Economic Co-operation and Development (OECD) (Crossley, 2000; Crossley &Watson, 2003). This research uses the country as the unit of analysis and draws on data from international comparative tests organized by the IEA.

Crossley &Watson (2003) identified the purposes of the field of CIE and this research satisfies two of the purposes which are:

> Satisfy intellectual and theoretical curiosity about other cultures and their education systems; and better understand the relationship between education and the wider society;
> Identify similarities and differences in educational systems, processes and outcomes as a way of documenting and understanding problems in education, and contributing to the improvement of educational policy and practice. (Crossley &Watson, 2003, p. 19).

This research explores the possible relationship between access to digital resources at home and educational outcomes in the school with the hope of contributing to the discussions around the policy adoption and implementation of the digital education action plan. This research in no way implies causation as there are confounding variables that might also affect student outcomes in mathematics that are not directly related to access to technology and digital resources at home. It only aims to identify a possible relationship between access to technology at home and student performance on TIMSS.

Identifying a possible relationship and exploring the intersections between access to digital resources and achievement for students has policy implications in the German context. This would mean a closer inspection of the groups that have the potential of being excluded as a result of large-scale digitization of education. This calls for disaggregation of data at the local level to understand if there is an intersection between socio-economic status, migratory status and home access to digital resources and the means and methods that can be put into place to alleviate these situations.

Chapter 2: Literature Review and Theoretical Perspective

This section begins by providing an overview of Germany's educational system and her involvement in the European Commission's Digital Education Action Plan before moving into the explication of the key concepts in this study. It is necessary to address the key concepts because in order to understand the dynamic between inequality and social exclusion, one must understand the concepts that surround the digital divide as it relates to digital literacy and the necessary skills that students ought to gain by consistent use of technology for capital gaining activities (Hargittai & Hinnant, 2008; Park, 2012). This section also explores the soft power that the European Commission wields in their agenda-setting role and the way that countries are pressured to buy into the ideas set forth as a means of gaining legitimacy. The section concludes by presenting the theoretical background upon which this study is built.

2.1. Background Context

2.1.1. German educational system. Germany runs a decentralized educational system with autonomy and power for educational decision making falling within the Lander (States) which causes a lot of heterogeneity in educational policies (Davoli & Entorf, 2018; Wößmann, 2007). This system was retained after the German Reunification in 1990. This period marked a change in the educational system of Germany because East Germany adopted the federal structure of West Germany (Kotthoff, 2011). After the reunification, there were discussions about reformations in the educational system, but steps were not taken till Germany's less than average results in TIMSS and PISA were revealed which led to a state of PISA shock in 2000 that introduced an era of sweeping reforms in the German educational system (Davoli & Entorf, 2018; Kotthoff, 2011; Waldow, 2009). The PISA shock refers to the reaction of stakeholders in education to less than satisfactory results in PISA (Davoli & Entorf, 2018; Kotthoff, 2011; Waldow, 2009). Although the PISA shock legitimized a lot of the reforms that took place, Waldow (2009) points out that a lot of these reforms were underway before the PISA results were published in 2000 (Davoli & Entorf, 2018). Prior to the PISA shock, Germany had abstained from international comparative assessments from the 1970s to the 1990s because they believed that important aspects of education could not be measured quantitatively (Bos & Postlethwaite, 2002; Waldow, 2009).

The PISA shock revealed that German students performed below average when compared to students from other OECD countries. It also revealed that the gap between the highest achieving student and lowest achieving student was wide. The gap in performance between students with or without migratory backgrounds was wide and this exposed the inequality in educational access, opportunity and outcomes for students especially based on socio-economic status and migration status (Davoli & Entorf, 2018; Waldow, 2009). The reforms that succeeded the shock led to a shift in focus to outcomes-based education, competence orientation, external assessment and evidence-based pedagogic practice (Ertl, 2006).

After 2012, there has been a significant improvement in the scores of German students. German students are performing above OECD average in math, reading and science and the impact of socio-economic status on student outcomes has reduced (Davoli & Entorf, 2018). German students are becoming more “resilient” and “this means that despite their disadvantaged socio-economic background, they score among the top 25% of students around the world” (Davoli & Entorf, 2018, p. 4) and the percentage of resilient students has gone up by nine points (Davoli & Entorf, 2018). Although there has been persistent improvement in student performance, students of a migratory background still lag when compared to their native counterparts and the gap between both student groups remains above the OECD average (Davoli & Entorf, 2018). This gap exists due to the fact that the German educational system was built around homogeneity without an official policy to accommodate immigrants which has led to problems (Auernheimer, 2005; Sliwka, 2010). Although Germany is taking steps in the right direction to build a heterogeneous system of education that takes advantage of diversity and the experiences of the students, more effort would have to be put in to ensure that students of migrant backgrounds can succeed and the achievement gap can be closed (Sliwka, 2010).

While this paper does not disaggregate the data based on migratory status to discover if there are digital inequality issues between students of migratory or native backgrounds, this paper looks at digital inequality broadly among fourth grade German students and the exposition above provides a glimpse into the social categories that exist within the German society.

Although this research focuses on lack of access to digital resources in the home, it would be remiss not to address digitization in German schools. A survey of 15,000 people by Gewerkschaft Erziehung und Wissenschaft (GEW) study found that German schools were ill-equipped to prepare students for the digital world (Education International, 2018). According to Education International (2018), the concerns that need to be addressed before a proper digitization plan can be fruitful are provision and maintenance of the digital equipment for both teachers and students, education and support for teachers, data privacy and protection, autonomy from media groups and the acknowledgement of the value of pedagogy over digital equipment (Education International, 2018). Based on the report, more funding would be necessary to get German school systems to an ideal place for digitization (Education International, 2018). According to a report by Bertelsmann Foundation, Germany must invest about €3 billion annually to remain competitive in the digital education environment (Schuster, 2017) in comparison to the €5 billion from the digital pact and €3.5 billion for school improvement (Education International, 2018), which is a one-time investment. Funding remains a big part of ensuring that the digital education action plan succeeds in Germany.

2.1.2. European Commission Digital Education Action Plan and Germany's Involvement. On January 17th, 2018, the European Commission launched the Digital Education Action Plan as a follow up to the November 2017 Gothenburg Summit where the Parliament, the Council and the Commission discussed the reduction of socio-economic inequalities and the development of a stronger Europe through education and training (European Commission, 2018a; European Commission, 2018b). The action plan comprises of three priorities and each priority sets out actions and measures to facilitate the implementation of the action plan by the member states (European Commission, 2018a; European Commission, 2018b) and totally, there are 11 actions that should be taken to reach a level of acceptable digitization. The priorities are:

- Making better use of digital technology for teaching and learning;
- Developing the digital competences and skills needed for living and working in an age of digital transformation; and
- Improving education through better data analysis and foresight.

(European Commission, 2018a, p. 4).

Making better use of digital technology for teaching and learning. The first action under this priority focuses on providing high broadband internet to schools through creating awareness about European Union (EU) funding schemes and developing a voucher scheme (European Commission, 2018a). The second action offers support to schools by offering European schools the possibility of using SELFIE which is a free, online self-reflection tool on the use of digital technologies and launching a mentoring scheme to build a support network for teachers to collaborate and improve the mainstreaming of technology-based teaching practices (European Commission, 2018a). The third action focuses on the adoption of digitally signed qualifications which will be housed in the Europass platform and this would facilitate the authentication and delivery process of diplomas and certificates to future employers and for cross-national purposes (European Commission, 2018a).

Developing the digital competences and skills needed for living and working in an age of digital transformation. The fourth action is the creation of a higher education hub which will be an EU-wide online platform for higher education institutions that enables them to improve the quality of instruction and facilitate and support internationalization and cross-country collaboration among European higher education institutions (European Commission, 2018a). The fifth action focuses on the creation and development of open science skills and digital competences in higher education as a means to address societal and technological issues (European Commission, 2018a). The sixth action aims to involve more primary, secondary and vocational schools in EU code week which is a grassroots movement that promotes coding, computational thinking and creative use of digital technology (European Commission, 2018a).

The seventh action concerns itself with cybersecurity with the initiative of conducting a cyber awareness campaign surrounding online safety and media literacy that targets students, parents and teachers. The second initiative in the seventh action is a teacher training program on the best ways to teach cybersecurity to students (European Commission, 2018a). The eighth action is gender specific and it focuses on closing the gender gap in digital competences by encouraging and helping girls in primary and secondary schools to develop digital skills and consider careers in technical and entrepreneurial fields (European Commission, 2018a).

Improving education through better data analysis and foresight. The ninth action focuses on monitoring and evaluation and the collection of data on the mainstreaming of digital technology in school. This will be done in collaboration with the OECD as there will be a development of a new module on PISA that targets the use of technology in education (European Commission, 2018a). The tenth action focuses on running pilots of artificial intelligence and learning analytics in education for predictive purposes (European Commission, 2018a). The eleventh action is a strategic foresight initiative that would focus on identifying future trends and challenges that might plague the current educational model and would provide recommendations to tackle these challenges.

The plan outlines measures that the commission along with the member states will accomplish by the end of 2020 as steps towards the European Education Area which is in line with the recommendations on Common Values and Key Competences. The action plan is part of the European cooperation in education and training (ET 2020) (European Commission, 2018a).

Germany became a member and was a founding country of the European Union (formerly known as the European Economic Community, 1957- 1993; and the European Community, 1993-2009) on January 1, 1958 and as a member state of the European Union, is subject to the commission's initiatives and policy recommendations. In response to the action plan, Germany's chancellor Angela Merkel said that Germany needed to embrace technological change despite the discomfort that it might bring (Ellyatt, 2018). This shows a willingness on the executive part of the government to buy into the digital education action plan, notwithstanding the groups that are at risk of getting excluded.

2.2. Key Concepts

2.2.1. Definition of digital literacy, digital illiteracy and digital inequality. Digital literacy as a term has often been confused and used interchangeably with terms such as "internet savvy" and "computer literacy" (Bawden, 2008). Gilster (1997) provided a conceptual understanding of the word "digital literacy" even though it was not the first time the phrase had been used (Bawden, 2001). Gilster's (1997) definition of digital literacy proposed a practical and mindful approach to digital and media consumption that went beyond the use of digital resources to find information but also encouraged the practice of applying the gathered information to real life situations. However, Gilster (1997) did not explicitly list out the skills or competencies that comprised digital literacy (Bawden, 2008). Although Gilster (1997), in his work, invited users of digital resources to be mindful and inquisitive about the completeness and reliability of the information gathered through digital resources (Bawden, 2001), an action which he termed "knowledge assembly" (Gilster, 1997, p. 9), he did not provide a conceptual explanation for critical consumption of digital information. He also gave a broad description of digital literacy that leaves the concept open to interpretation which many reviewers have critiqued.

Pangrazio (2016) proposed the beginning of a new critical digital literacy framework which is a parameter of Freire's (1970) critical pedagogy. Critical digital literacy invites digital media creators and users to be intentional about the consumption of digital information while also understanding and critiquing broader systemic, political, economic and societal inequities (Pangrazio, 2016). This is an ideological movement that proposes that although technical mastery of digital technology is relevant to building economic prowess, critical personal reflection is important for the transformation of the individual and society (Pangrazio, 2016). The idea posits that when this is introduced in an educational setting, it leads to learners who, after critically consuming digital information, can produce "critical and practical knowledge of digital text" (Pangrazio, 2016, p. 166).

With both concepts introduced by Gilster (1997) and Pangrazio (2016), the author synthesized and proposed a working definition of digital literacy that fits within the context of this study. Digital literacy refers to the set of skills and competencies that an individual has gained throughout his lifetime that enables him to gather digital information, critically assess it and intentionally apply it to real-life situations while considering and acknowledging the broader societal issues. Conversely, digital illiteracy would be the lack of skills and competencies that hinder an individual from gathering, critically assessing and applying digital information to improve his quality of life.

The forerunner to research in digital inequality is research on the digital divide. The digital divide refers to the disparities between people with and without access to digital technology (Norris, 2001). Researchers DiMaggio and Hargittai (2001) urged current researchers to move from research on the digital divide to research on digital inequality. Digital inequality is defined as the disparity in usage, participation, skills, information gathering and use, and competencies that characterize the digital era (DiMaggio & Hargittai, 2001; Hargittai & Hinnant, 2008; Hsieh, Rai &, Keil, 2008; Iske et al., 2008; Robinson et al., 2015). DiMaggio & Hargittai (2001), in their research, proposed five dimensions to digital inequality which are:

a. The technological devices which people use to access the internet.
b. The "autonomy" that users have- Do they use it from home? Is their use monitored? Do they have to compete for time online?
c. Skill.
d. Social support.
e. Purposes of using the internet.

Although the operational variables of this research might lead the reader to assume that it focuses on the digital divide (access) rather than digital inequality, the researcher urges you to understand that focusing on access is the first dimension of digital inequality. The second dimension of digital inequality will be addressed by the variables that the study measures. Dimensions three to five are beyond the scope of this study but this would be an area of further research for the same fourth-grade population. This could prove useful in helping to track how digital inequality builds and using a regression design, the researcher would be able to predict future digital capital that the students may or may not acquire if changes are not made.

Hargittai and Hinnant (2008), in their study of the Web usage of 270 adults across the United States of America aged 18-26, found that users with more education and resources used the internet for more “capital-enhancing activities” (p, 617) and that this was responsible for an increase in human, social, cultural and financial capital. Theirs’ is not the only research that has investigated upward mobility in comparison to internet usage and activities. Iske, Klein, Kutscher, and Otto (2008) in their study of the internet usage behaviors of young people between the ages of 14 and 23 in Germany found that digital inequality was reflective of the wider societal inequalities and this affected the ways young people used the internet and even more specifically, highlighted the disparities in the way the same services were used.

Robinson, Wiborg, and Schulz (2018) in a survey of 1,015 American students in a Californian high school with a majority disadvantaged population found that high academic achievement had a positive relationship to duration of digital experience and academically useful computing even when students’ curricular and class placements were considered. This means that systemic deconstruction of digital inequality might have an impact on improving student achievement, thereby closing the achievement gap.

There are researchers on the other end of the spectrum who advocate for breaking down systemic barriers before technology is brought into the classroom. Gorski (2009) in his research stated that in a review of research done, technology had been shown to exacerbate inequities in some societies, contrary to its' perception as an equalizer. He posited that systemic inequities and societal factors that affected students' access and outcomes ought to be addressed before technology is introduced into the classroom. Ono and Tsai (2008) are not as radical in their study, although there is the consensus that digital inequality mimics societal inequalities. This research does not stand firmly with either point of view but rather, strives to strike a balance between an already emerged capitalist economy that is rife with inequality and trying to ensure that marginalized students have equal opportunities to succeed. While it is idealistic to believe that all systemic inequities can be broken down before technology can be brought into the classroom, this research holds the belief that technology, if handled incorrectly, will continue the cycle of inequality that is currently at play.

2.2.2. The European Commission, Soft Power and Educational Policy Making. Since the end of World War II, international organizations have played a major role in economic and political processes of different countries, mostly through soft power (Abbott & Snidal, 2000). The European Commission in no exception. Walkenhorst (2005) examined the Europeanization of the German educational system. Europeanization is defined as the extent to which European integration has caused change at the domestic level (Walkenhorst, 2005). The author examined how Europeanization has affected the educational sector and policy making at all three levels of education. The author claimed that the changing processes in Germany was as a result of globalization and Europeanization so as to retain a global competitive edge. In the research, the author found that despite the limited legal power of the European Commission, there were direct effects from the European Commission on the German educational system. The research concluded by identifying processes of Europeanization as a horizontal process as opposed to a top-down process. Europeanization as a top-down process defines a clear boundary at the European Commission level where policies are created, and the process which member states are pressured to adopt and implement these policies at local levels (Radaelli, 2003). On the other hand, Europeanization at a horizontal level is a process where member states are not pressured to adopt the policies recommended by the European Commission but rather adoption happens because member states have been socialized to believe that these policies are the best practice (Radaelli, 2003). Another factor that influences the horizontal process is consumerism. The demands of consumers and the markets frame the European Commission's policies as best practices and this framing ensures that member states adopt these policies in order to gain legitimacy before their citizens (Radaelli, 2003). Germany's adoption of European policies is a result of Germany's desire to have its citizens identify as part of a larger European identity through education (Walkenhorst, 2005).

Trampusch (2009) in her work compared how Europeanization had manifested itself in the policies of Vocational Education and Training (VET) in Austria and Germany. The author identified two distinct forms of Europeanization which are in the form of reform policies in Germany and in the form of domestic institutional change that is not explicitly identified in reform policies. The author referenced that the Bologna Process had instituted widespread reform efforts in domestic institutions and this is an example of the soft power that the European Union (EU) wields over her member states. The research identified that the European Union's VET policies were present in the reform efforts of both countries but there seemed to be a divergence in the directions that both efforts took (Trampusch, 2009). The author concluded by outlining that there might be divergent attempts at Europeanization that do not necessarily preclude the power of the EU.

Vukasovic (2013) focused on the change in education in European countries and how Europeanization could account for the change. The author provided a clear definition and framework for the concept of Europeanization using rationalist and sociological institutionalism and identified two perspectives for the Europeanization of education. The first perspective looked at Europeanization through external incentives. For educational institutions to adopt the policies, the benefits have to outweigh the inconveniences of adopting the policies. This would mean that the policies would be explicit in order to serve as prerequisites for the benefits and the larger the benefits, the higher the motivation to adopt the policies (Vukasovic, 2013).

The second perspective is Europeanization through social learning and this perspective represents the normative and legitimized nature that European policies take that enable state actors to adopt them because they have been socialized to see these policies as appropriate for their needs (Vukasovic, 2013). Much like Walkenhorst (2005) stated, there is also an identity aspect to the adoption of European Union policies. If the member states believe that the adoption will grant them an opportunity to identify as part of the European organization and gain legitimacy because of the alignment, there is a higher possibility that the policies will be adopted (Vukasovic, 2013).

The author used the discussions surrounding Quality Assurance (QA) as evidence for the framework. The author found that Europeanization through social learning was more evident in the adoption and adaptation of the European QA initiatives at member state levels. The author concluded by observing that although legitimacy and resonance are considered important factors in Europeanization through social learning, further research needs to be conducted at the micro level to explore how well the perspective could explain Europeanization (Vukasovic, 2013).

This body of literature provides a rationale for Germany's needs to adopt initiatives that have been recommended by the European Commission although the necessary infrastructure is unavailable. It also provides a representation of the soft power that an international organization such as the European Commission wields on a country like Germany in the field of education.

2.2.3. Digital Literacy and its link to Capability. Digital literacy refers to the skills and capabilities to survive and thrive in the information age (Eshet-Alkalai, 2004). Eshet-Alkalai (2004) proposed a framework for the skills that digital literacy ought to encompass. They are:

i. Photo visual literacy;
ii. Reproduction literacy;
iii. Information literacy;
iv. Branching literacy;
v. Socio-emotional literacy

(Eshet-Alkalai, 2004, p. 94).

According to the literature, photo-visual literacy refers to the ability of "using vision to think" (Mullet & Sano, 1995; Shneiderman, 1998; Tuft, 1990). The graphic user interface enables users to speak a common language using effective photo-visual communication

(Eshet-Alkalai, 2004, p. 95). Reproduction literacy refers to the ability of creating new information and meaning from already existing information (Eshet-Alkalai, 2004). Information literacy refers to the skills that enable an individual critically assess and consume information in an educated manner (Eshet-Alkalai, 2004). Branching literacy involves hypermedia and encourages consumers to engage in non-linear thinking (Eshet-Alkalai, 2004). Branching literacy presents consumers with the ability and freedom to construct knowledge from non-linear sources of information and different domains of knowledge (Eshet-Alkalai, 2004). Socio-emotional literacy enables consumers avoid traps in the cyberspace and inducts them into a set of social and emotional skills that are necessary to survive in cyberspace (Eshet-Alkalai, 2004). This body of literature shows that digitization of an education system exceeds providing technological equipment, although that is a necessary step. However, if students do not have access to technological equipment at home, it becomes difficult for them to develop these skills that have been outlined above.

The link between digital literacy and capability building transcends student achievement in the classroom and affects participation at the society level. Bakker and de Vreese (2011) in their study of the intersection between political participation and internet use among young people, surveyed 2,409 youth from the ages of 16 to 24 in the Netherlands and found that various forms of internet usage were positively related to political participation. The research found that although the relationship between traditional forms of media and participation was positive, the relationship was weak. The researchers also found a positive relationship between non-informational uses of the internet such as online communication and visits to non-news websites and different forms of political participation (Bakker & de Vreese, 2011).

The implication of this in an era of digital inequality is that some individuals would lack the capability to be fully politically active because they cannot afford the same opportunities to be digitally literate. This means that individuals who do not have access to digital resources or are unable to be digitally literate are at risk of being successively excluded from political participation because they are unable to access the necessary information to gather knowledge and make informed decisions. They are also unable to engage in online discussions and building of social networks which Bakker and de Vreese (2011) show in their study is positively related to most forms of political participation (Bakker & de Vreese, 2011). This is a form of exclusion from social activities.

Goldman, Booker and McDermott (2008) in their research studied how the mix of social, cultural and digital technologies affect youth participation. In their paper, technology is described as a social tool that is invariably connected to other social processes and institutions. To encompass the conceptual framework of both social technology and cultural technology, technology is defined as, “first, the body of knowledge appropriate to the development of such skills and applications and, second, a body of knowledge and conditions for the practical use and application of a range of devices” (Goldman, Booker & McDermott, 2008, p. 185). Therefore, “social technologies are tools that organize social activities” and cultural technologies are “formal tools that organize processes for communication in specific settings” (p. 185).

Using two case studies, the authors found that a mix of digital, social and cultural technologies produced inspirational levels of youth participation that can herald a new age of participatory culture through new media (Goldman, Booker & McDermott, 2008). The three technologies served as platforms for representation that enabled the voices of youth to be represented in public discourse. The authors identified unequal access to digital resources as a barrier to this revolutionary type of youth participation. This research shows a clear link between the cultural and social aspects of participation and digital technology. Without proper access to digital technology, the voices of youth in the political arena is often shrouded. With the emergence of new media and media literacy, youth are developing capabilities that ensure that they are critical consumers of information and creating content that is representative of their identity and their presence at the national level on discussions of democracy and civic participation (Goldman, Booker & McDermott, 2008). Without access to these digital resources, the voices of youth are threatened with the possibility of suppressing them as there is no platform that serves as a vehicle for their message (Goldman, Booker & McDermott, 2008). This shows that digital inequality is a threat to civic engagement, political participation and the democratic process.

This research adds to the literature in this field because it focuses on Germany which is a population and context that is not often considered in societal/ digital inequality research. Majority of the research in inequality focus on the United States context and even though the researchers encourage the readers to generalize the results to a large part of the developed world, it would be prudent to consider that both the United States and Germany are different in their historical backgrounds and current economic and social structures. Although research such as that of Iske et al. (2008) focused on the German context, this research focuses on a different population that is not addressed within their research. This research also serves as a working document for policy makers to understand that access to digital resources in school is not enough. Students must also have access to these resources at home, social support and the necessary skills to use these resources to foster upward mobility.

2.3. Theoretical Perspective

2.3.1. Social Exclusion. The term "social exclusion" was coined in 1974 and is credited to René Lenoir (Sen, 2000) who was the French government's Secretary of State on Social Action in the Chirac government. After the social and political uprising of May 1968 in France, there was a focus on social cohesion and the development of a social provision system (Mathieson et al., 2008; Silver, 1994) and exclusion was identified as a social problem as there were people within the system who were not socially protected (Silver, 1994). Salaried employments were viewed as the background for social citizenship and when Lenoir referred to *les exclus* (the excluded), he was referring to the members of the groups that were unable to get jobs and whose social citizenship and insurance were threatened (Mathieson et al., 2008; Silver, 1994). Lenoir identified members of the following groups as socially excluded and estimated that they made up one tenth of France's population: "mentally and physically handicapped, suicidal people, aged invalids, abused children, substance abusers, delinquents, single parents, multi-problem households, marginal, asocial persons, and other social 'misfits'" (Sen, 2000, Silver, 1994).

Silver (1995) further widened the group from the literature and identified further provisions from which people could be excluded.

> A livelihood; secure, permanent employment; earnings; property, credit, or land; housing; minimal or prevailing consumption levels; education, skills, and cultural capital; the welfare state; citizenship and legal equality; democratic participation;

> public goods; the nation or the dominant race; family and sociability; humanity, respect, fulfilment and understanding.
>
> (Silver, 1995, p. 60).

The study is using a social exclusion theoretical perspective as proposed by Amartya Sen. The idea of social exclusion is rooted in the literature and research on poverty and deprivation (Sen, 2000). Amartya Sen looks at social exclusion from a capability deprivation approach (Sen, 1992). This approach highlights the lack of equal opportunity and the capability deprivation that certain groups who are living impoverished lives suffer (Sen, 1992). According to Sen (1992), social exclusion refers to the denial of capabilities "of being integrated into the community, participating in the community and enjoying social bases of self-respect" (Klasen, 1998, p. 2).

Social exclusion has multiple meanings and it has often been used interchangeably with poverty and unemployment. Although both poverty and unemployment intersect with social exclusion, the conceptual understanding of social exclusion exceeds poverty and unemployment (Klasen, 1998; Silver, 1994). The conceptual definition of social exclusion for this study is couched in rights-based language and capability deprivation.

Room (1995) defined social exclusion as the "denial or non-realisation of civil, political and social rights of citizenship" (Klasen, 1998, p. 1) and this resonates with Sen's capability deprivation approach (Sen, 2000). Sen (2000) cautions against viewing social exclusion in only terms of shortage of income but rather through the observation of impoverished lives as this enables one to understand that while income influences the quality of life, it is not the only determinant of an impoverished life. The advantages of taking a rights-based and capability approach to social exclusion is that it identifies the inability of an individual to participate in and be respected by mainstream society as a rights violation (Klasen, 1998, p. 2). As an approach, it does not demand uniform outcomes but rather advocates for equal opportunities for all citizens and residents to all aspects of citizenship (Klasen, 1998, p. 2). For example, a distinction of this is a migrant community that is not allowed to participate in all aspects of society as opposed to a migrant community who has equal access to all the same protections and provisions as other citizens, and they may not wish to participate in mainstream society although their rights to do so are available and protected. The former is social exclusion and the latter is not (Klasen, 1998, p. 2).

This approach also recognizes the differences in people's ability to use their opportunities. For some marginalized groups, additional concessions and extra efforts would need to be made by the society in order to ensure equality of access and capability for them to close the gap. It would require equity which would necessitate that some groups be given preferential treatment over equality which points to an equal starting point for everyone which is not sufficient to ensure equal capabilities (Klasen, 1998, p. 2).

This rights-based and capability deprivation approach is ideal for this study because it views digital inequality as a hindrance to full participation in the economic, social, political and civic processes of the society. Goldman, Booker and McDermott (2008) found in their study that an interaction between social, cultural and digital technologies provided a platform for youth political participation and Bakker and de Vreese (2011) found positive relationships between forms on internet usage and political participation. This provides evidence that digital inequality is a threat to youth engagement in the democratic process. Digital inequality also affects an individual’s ability to engage in online and digital capital enhancing activities that affect upward social mobility (Hargittai & Hinnant, 2008; Park, 2012). In line with this approach, this approach does not advocate for the forced integration of groups that might not want to be included in the digital environment, however, it does advocate for the provision of equal opportunities for all students to have at home access to the necessary digital resources with the knowledge that the government would need to make concessions to provide these resources to groups that might not be able to afford it personally.

2.3.2. Social Exclusion and Digital Inequality. Park (2012) in her research discussed the relationship between digital media literacy and social exclusion. The author explained that "information poverty" (p. 94) was indicative of social exclusion and pointed out that without access to the internet and large banks of information, people would not have access to the same type of information to accomplish various tasks. The author went deeper into the analysis by pointing out that providing access to digital resources was simply a first step in the journey of ensuring that access and use of digital resources promoted social inclusion. She identified digital media literacy and the ability to create which is a dimension of digital media literacy as closely linked with the ability to participate. She concluded by identifying provision of home access to digital technologies as a step towards alleviating issues of social exclusion.

In this research, digital inequality can be conceptualized as capability deprivation for the individuals who lack the necessary resources, tools, skills and support (Sen, 2000). The inability of some students to access digital resources at home to gather knowledge or even connect on social media is capability deprivation that leads to social exclusion (Sen, 2000). In the technologically advanced world, lack of these digital skills carries dire consequences that go beyond being digitally illiterate as exclusion at that level could lead to deprivation at other levels that could potentially affect the quality of life of students. In their research, Pagani, Argentin, Gui, & Stanca (2016) found that digital skills had a positive impact on educational outcomes and the positive effects were more pronounced for students from low income families and students with low academic achievement rates. The implication of this is that if students continuously lack access to digital resources and the necessary support, achievement gaps will continue to exist and as the knowledge economy keeps growing, the gaps might even widen. In order to address these problems, the research will answer the question: How does access to and use of technology at home relate to and predict student performance in mathematics as measured by TIMSS 2015?

To answer the question, the researcher has designed a quantitative study with these sub questions and their corresponding hypotheses:

1. Is access to personal computers and tablets at home significantly related student outcomes on TIMSS?
    a. Access to personal computers and tablets at home is significantly related to student mathematics outcomes on TIMSS.
2. Internet access at home is significantly related to student mathematics outcomes on TIMSS.
    a. Internet access at home is significantly related to student mathematics outcomes on TIMSS.
3. Is socio-economic status a significant predictor of students' mathematics outcomes on TIMSS?

a. Socio-economic status as measured by parents' education level, parents' occupational level and employment status, and digital material resources are significant in predicting students' mathematics outcomes on TIMSS.

Chapter 3- Methodology

This research presents a quantitative study of Germany's adoption of the European Commission's Digital Education Action Plan through an analysis of TIMSS data from student background questionnaires and student achievement in the TIMSS mathematics assessment. In this case, the analysis makes a case for the phenomenon of social exclusion in the German context as a result of students' lack of home access to digital resources.

A quantitative analysis is most appropriate here because the study only focuses on examining the relationship between home access to digital resources and student outcomes and understanding how significant socio-economic status as measured by parents' education level, parents' occupational level and employment status, and digital material resources are in predicting students' mathematics outcomes on TIMSS. Although this is not an experimental study that can draw causal inferences, this research is sufficient to make conclusive statements about student performances on TIMSS when compared to the access or lack of access to digital resources. This methodology also sets the stage for understanding how digital inequality is related to student performance and it is therefore capable of answering the research question: How does access to and use of technology at home relate to and predict student performance in mathematics as measured by TIMSS 2015?

In order to answer this question, the researcher has designed sub-questions and hypotheses that would guide the data analyses. They are:

1. Is access to personal computers and tablets at home significantly related student outcomes on TIMSS?
    a. Access to personal computers and tablets at home is significantly related to student mathematics outcomes on TIMSS.
2. Internet access at home is significantly related to student mathematics outcomes on TIMSS.
    a. Internet access at home is significantly related to student mathematics outcomes on TIMSS.
3. Is socio-economic status a significant predictor of students' mathematics outcomes on TIMSS?
    a. Socio-economic status as measured by parents' education level, parents' occupational level and employment status, and digital material resources are significant in predicting students' mathematics outcomes on TIMSS.

This section begins by giving a description of the participants that are used for this study and the site of the study. It then continues by giving a description of TIMSS, its mathematics assessment framework and the background questionnaires that are used for data collection. The research design, procedures and the data analysis process that are used for the research are explained.

3.1. Participants

The sample for this study was taken from the 2015 Trends in International Mathematics and Science Study (TIMSS), which is a comprehensive international comparative test conducted by the International Association for the Evaluation of Educational Achievement (IEA) and given at the fourth and eighth grades to students in participating countries. In the most recent assessment conducted, there were 57 participating countries and 7 benchmarking participants with a total of more than 580,000 students. TIMSS used a two-stage random sampling design where a random sample of schools was chosen, and one or more intact classes were chosen from the sampled schools at the second stage (Joncas & Foy, 2011; Schiller, Khmelkov & Wang, 2002). Each participating country was responsible for applying the sampling method and obtaining a sample that was representative of their national population (Joncas & Foy, 2011).

This study focused on Germany and the participants for this study were fourth grade German male and female students who participated in the TIMSS 2015 assessment. Fourth grade students were chosen because this is the terminal class of compulsory primary school with the students being an average of at least 9.5 to 10 years old (Joncas & Foy, 2011). In the German context, education at this level is compulsory. It is also important to note that Germany only participated in the fourth-grade TIMSS assessment in 2015. For this analysis, the total sample of German students who participated in the assessment was 3948.

The data were gathered from background questionnaires given to participants of the test and it is made publicly available on the TIMSS database. There was less than minimal risk to the students as their data and identifying information has been anonymized by IEA. There was no need for IRB approval because the study was done using an existing data set without the researcher approaching participants for new data.

3.2. Site

This study was conducted in Germany by the IEA. Germany partook in TIMSS 2015 and it started partaking in TIMSS in 1995 (Schwippert, 2007). Fourth grade was chosen for analysis because this is the only student group that participated in TIMSS 2015. Germany is chosen as an ideal country to study digital inequality because despite its large economy and position as the 4th country in the Gross Domestic Product (GDP) rankings, it still lags in technological advancements when compared to countries with the same development index (Naudé & Nagler, 2017).

This study also considers the European Commission's Digital Education Action Plan and Germany, as a member of the European Union has adopted the plan and this makes it an ideal context to study. Germany as a country has also improved in their rankings on international comparative tests on all fronts except that of the achievement gap between students with migrant backgrounds and students without migrant backgrounds. Although this study does not disaggregate the data based on migrant status, it does look through a lens of inequality and exclusion and considers students who are of migrant backgrounds as a disadvantaged group who are at higher risk of being socially excluded (Park, 2012; Park, 2017).

Germany is also chosen because an investment of €5 billion from the digital pact has been slated for the spearheading of digitization of education (Education International, 2018), however, there are no plans and actions to close the digital divide that exists between the students with at home access to digital resources and those that lack access. It becomes important to understand the influence of digital technology on education and how catering to school needs without making provision for continued access at home can further marginalize already marginalized groups.

3.3. Measures

3.3.1. The TIMSS Assessment. Since 1995, the Trends in International Mathematics and Science Study (TIMSS) organized by the International Association for the Evaluation of

Educational Achievement (IEA) has measured student achievement in mathematics and science in countries across the world (Martin, 1996). The aim of TIMSS is to measure student achievement to understand the “nature and extent of student achievement and the context in which it occurs” (Martin, 1996, p. 3). The goal is to identify manipulable factors that affect student achievement so that they can be targeted by policy reforms (Martin, 1996). Educational researchers, policy makers and stakeholders in education have used TIMSS to understand student achievement in mathematics and science and to make decisions concerning education systems (Evans, 2015).

TIMSS has been administered every four years from 1995 till most currently in 2015 and the data is used to examine and understand overall student achievement in mathematics and science in a comparative context- between countries and in-country between student groups (Evans, 2015). Participation in TIMSS provides countries with data for cross-national comparison that enables them to monitor student achievement and adjust policies to meet student needs (Evans, 2015). This study uses data from TIMSS 2015 which is the sixth assessment in the TIMSS series (Martin, Mullins & Foy, 2015).

3.3.2. The Mathematics Assessment Framework for Fourth Grade. The mathematics assessment is broken down into two dimensions which are content and cognitive dimensions (Martin, Mullins & Foy, 2015). The content dimension is further broken down into domains which are number, geometric shapes and measures, and data display and the cognitive dimension is further broken down into domains which are knowing, applying, and reasoning (Grønmo et al. 2015; Martin, Mullins & Foy, 2015). The content domain is the subject matter that is assessed, and the cognitive domain is the thinking process that is assessed (Grønmo et al. 2015).

Table 3.1. TIMSS 4th Grade Mathematics Dimensions and Domains

Content Dimension	Percentages
Number	50%
Geometric shapes and measures	35%
Data display	15%
Cognitive Dimension	Percentages
Knowing	40%
Applying	40%
Reasoning	20%

3.4. Research Design

3.4.1. Dependent variable: student outcomes as measured by TIMSS. The dependent variable is student outcomes operationalized as Mathematics achievement which is measured by TIMSS. The total test scores of participants was coded using Item Response Theory (Schiller, Khmelkov & wang, 2002). The test scores have a standard mean of 500, a maximum score of 1000 and a standard deviation of 100 (Martin, Mullins & Foy, 2015; Schiller, Khmelkov & wang, 2002). The achievement scores for the students are termed as plausible values.

Plausible Values

To reduce student testing time so as not to overtax students, they are only given one test booklet with a combination of blocks of items. TIMSS groups test items into item blocks that have about 10-14 items in each block. The distribution across the content and cognitive domain are matched as closely as possible to the overall test item pool. Totally, there are 14 blocks for mathematics achievement testing (Martin, Mullins & Foy, 2015). This means that not all students are given the same test items (Evans, 2015). In the booklet, students are given two blocks of mathematics items to answer.

Because all students did not attempt all 14 blocks of the mathematics achievement testing, plausible values are calculated for each student as if they attempted all 14 blocks (Evans, 2015). Plausible values are assigned to students based on their response patterns and survey data (Evans, 2015). Each student is assigned plausible values and they are not meant to represent the student's individual score (Evans, 2015). This method is beneficial because it technically assigns more questions to student without taxing them with long examination periods (Evans, 2015). However, because these are estimated values, there is a measurement error but this is mitigated through the calculation and assignment of five plausible values (Evans, 2015). Therefore, this makes it important to run your analysis of TIMSS data using all five plausible values as using any less than that would increase the standard error of the achievement means (Evans, 2015).

3.4.2. Independent variables: At home access to computers, tablets and internet. The first hypothesis was tested by coding the response of students to the background question ASBG05A- "Do you have any of these things at your home? A computer or tablet of your own". The student responses was coded as Yes= 1 and No=2 just as TIMSS has it coded in the database. For students who were not administered this question or omitted it, the responses will be coded with a dummy variable that will indicate the missing value. It should also be noted that there is a subsequent question in the background questionnaire that asks students about the availability of shared computers and tablets. This research only focuses on students' access to their own personal devices because it is concerned with autonomy as a dimension of digital inequality (DiMaggio & Hargittai, 2001).

The second hypothesis was tested by coding the response of students to the background question ASBG05E- “Do you have any of these things at your home? Internet connection?” The student responses were coded as Yes= 1 and No=2 just as TIMSS has it coded in the database. For students who were not administered this question or omitted it, the responses will be coded with a dummy variable that will indicate the missing value.

Both questions are dichotomous variables and categorical variables.

3.4.3. Predictor Variables. The predictor variables to be used in the regression analysis are outlined in table 3.2.

Table 3.2. Description of predictor variables.

Name	Description	Response Categories
ASBG05A	gen\home possess\computer tablet own	2
ASBG05E	gen\home possess\internet connection	2
ASDHEDUP	Parents' Highest Education Level	6
ASDHOCCP	Parents' Highest Occupation Level	7
ASBH15	gen\digital information devices	5

All five predictor variables have been conceptualized as signifiers of socio-economic status as TIMSS does not collect direct socio-economic background data from participants. There is precedent for using each of these measures as a signifier of socio-economic status. Todman et al. (2009) use lack of home access to internet access and computer as indicators of economic disadvantage and Harding et al. (2009) use internet connection at home as an indicator of socio-economic status as well. Education level and occupational level are also correlated to income level and they have historically been used as indicators of socio-economic position (Galobardes et al., 2006).

For parents' educational level, it is a categorical variable that has been broken down to six categories which are:

1. University or Higher
2. Post-secondary but not university
3. Upper Secondary
4. Lower Secondary
5. Some Primary, Lower Secondary or No School
6. Not Applicable

For parents' occupational level, it is a categorical variable that has been broken down to seven categories which are:

1. Professional
2. Small Business Owner
3. Clerical
4. Skilled Worker
5. General Laborer
6. Never Worked for Pay
7. Not Applicable

For digital information devices in the home, according to the background questionnaire, the digital devices that ought to be included in the count are computers, tablets, smartphones, smart TVs, and e-readers. This is a categorical variable that has been broken down to five categories which are:

1. None
2. 1-3 devices
3. 4-6 devices
4. 7-10 devices
5. More than 10 devices

3.4.4. Reliability and Validity

TIMSS is designed to provide reliable and valid results of trends in student achievement in countries around the world through a rigorous sampling method of participating countries to ensure that the sample is representative of the population (Joncas & Foy, 2011). A stratified method is used to ensure proportional distribution that would improve the sample, thereby making the survey responses reliable (Joncas & Foy, 2011; for more on the reliability and validity of TIMSS, see Joncas & Foy, 2011).

For a study to be valid, the components that are being studied must be valid. TIMSS ensures validity of the assessment by creating a scoring rubric that is written, reviewed and revised by the national research coordinators of all participating education systems. Each country's national research coordinator is responsible for the data entry process for their country after which the IEA Data Processing Center reviews it further and cleans it. All countries are provided with their data almanacs and reliability statistics. This allows countries to review their data to ensure validity (Foy et al., 2016; NCES, *n.d.*). The researcher, in conducting this study made the following assumptions about the background questionnaire and responses as provided by TIMSS:

a. The students responded truthfully to the background questionnaires.

b. The data provided by TIMSS on student achievement is accurate.

c. The sample is a true representative of the population. TIMSS provides their sampling methods in their documents (Joncas & Foy, 2011).

The statistical validity is provided by the quantitative design of the study that will use an independent samples *t* test. A possible threat to external validity is that generalization that is made across constructs. For the purpose of this study, measuring digital inequality has been reduced to two questions on a background questionnaire that does not take into account student uses of digital resources but only focuses on the availability. For this reason, the study cannot make generalizations about digital inequality with confidence.

3.5. Procedures

As stated earlier, data for this study is provided by TIMSS and it has been gathered from the background questionnaires that are given to participants in the exams.

Background Questionnaires. Extensive background information about student home life, learning environment, knowledge, content, and quality of information in the curricula is collected from the questionnaires that are distributed to students, parents/guardians, teachers, and school principals. The data is made publicly available on the TIMSS database (Joncas & Foy, 2011). The data for this study is provided by the student questionnaire. Each student that participated in TIMSS 2015 completed the questionnaire (Martin, Mullins & Foy, 2015). This questionnaire asked for basic demographic information as well as specific information regarding their learning climate and attitudes towards mathematics and science (Martin, Mullins & Foy, 2015). Although the background questionnaire was given to both fourth and eighth grade students, there were variations and it was made language appropriate for each level (Martin, Mullins & Foy, 2015). The student questionnaire took about 15-30 minutes to complete (Martin, Mullins & Foy, 2015). In the background questionnaire given to students at the fourth-grade level, specific questions about at home internet access and access to computers and tablets were included (Joncas & Foy, 2011).

The duration of the study was four calendar months that included the coding of data, data analyses and the writing up of the results, discussion and subsequent policy recommendations. This research presents a quantitative case study for the adoption of the European Commission Digital Education Action Plan by Germany using publicly available data from TIMSS database. As identified earlier, the independent variable was at home access to the internet, computers and tablets and the dependent variable was student outcomes, specifically in mathematics as measured by TIMSS. The study was done using an independent samples *t* test to answer the research question and provide support for each hypothesis.

3.6. Analysis

This was a quantitative research using raw TIMSS dataset. The analysis was done using an independent samples *t*-test. In order to run an independent samples *t*-test, there are assumptions that must be met which are: Observations from both samples are independent of each other, the two populations that the sample is selected from must be normal and there must be equal variances from the samples selected (Gravetter & Wallnau, 2011). The groups and variables for analysis meet these assumptions and this is the reason for the use of this method.

The raw TIMSS dataset was downloaded from IEA TIMSS 2015 website. The dataset is presented in a large aggregated format and with the use of the merge module in the IEA IDB Analyzer, the student achievement scores (plausible values) for mathematics, the variable for home possession of internet connection and possession of personal computer and tablet at home were disaggregated and merged into one data file analyzable by SPSS. In order to carry out the analyses, the following were also hypothesized in the study:

Hypothesis 1: Access to personal computers and tablets at home is significantly related to student mathematics outcomes on TIMSS.

Using a two-tailed independent samples *t*-test with α at .05 on SPSS, the researcher ran the data analysis using all five overall plausible values for mathematics achievement with the statistical hypothesis.

The null hypothesis was retained when $p \geq .05$. If the p value is less than .05, this means that there is less than 5% chance that the results occurred due to chance and a greater than 95% chance that the results did not occur due to chance or other confounding variables and the null hypothesis was rejected. If the null hypothesis was rejected, the effect size using Cohen's *d* was reported. An independent samples *t* test is ideal to test this hypothesis because both groups are independent of each other and a mean comparison is necessary to determine if there is a significant difference in student mathematics achievement.

Hypothesis 2: Internet access at home is significantly related to student mathematics outcomes on TIMSS.

Using a two-tailed independent samples *t*-test with α at .05 on SPSS, the researcher ran the data analysis using all five overall plausible values for mathematics achievement with the statistical hypothesis.

The null hypothesis was retained when $p \geq .05$. If the *p* value is less than .05, this means that there is less than 5% chance that the results occurred due to chance and a greater than 95% chance that the results did not occur due to chance or other confounding variables and the null hypothesis was rejected. If the null hypothesis was rejected, the effect size using Cohen's *d* was reported. An independent samples *t* test is ideal to test this hypothesis because both groups are independent of each other and a mean comparison is necessary to determine if there is a significant difference in student mathematics achievement.

Hypothesis 3: Socio-economic status as measured by parents' education level, parents' occupational level and employment status, and digital material resources are significant in predicting students' mathematics outcomes on TIMSS.

Using student outcomes in mathematics and parents' education level, parents' occupational level and employment status, and digital material resources as independent variables (predictors), a multiple regression analysis with α at .05 was run on. To run a regression analysis, the International Association for the Evaluation of Educational Achievement (IEA) International Database (IDB) Analyzer (IEA, 2013) must be used in conjunction with SPSS because the unique nature of the large scale assessments in the inclusion of five plausible values must be taken into consideration to achieve unbiased results. The researcher ran the data analysis using all five overall plausible values for mathematics achievement with the statistical hypothesis in the IDB data analyzer. The researcher began by using the merge module of the

IDB analyzer to merge the necessary variables into a single file readable by SPSS. This merged file was then loaded into the analysis module of the IDB analyzer and the appropriate analysis was chosen taking into consideration the TIMSS student weights and deleting the missing data listwise in the IDB analyzer. Each variable was entered into the respective sections in the software and an SPSS syntax which can be run in the SPSS software was created and this syntax was used to run a multiple regression and the regression coefficients and standardized *t* values and coefficients are reported in the SPSS output.

The null hypothesis was retained when $p \geq .05$. If the *p* value is less than .05, this means that there is less than 5% chance that the results occurred due to chance and a greater than 95% chance that the results did not occur due to chance or other confounding variables and the null hypothesis was rejected. A regression analysis was appropriate to address this hypothesis because the researcher is considering how significant the independent variables mentioned earlier are in predicting students' mathematics achievement. A multiple regression specifically was used because the analysis consisted of multiple independent variables and one dependent variable, albeit at five levels. In order to come to the conclusion of the predicted mathematics achievement outcomes based on the independent variable, the regression equation below is used:

$$\hat{y}_i = b_0 + b_1 X_i$$

where b_0 is the predicted value for the outcome when X = 0 and b_1 is the predicted change in the outcome for a one-unit increase in X.

The results for the analyses are presented in the next chapter.

Chapter 4- Results

This research began by asking a broad question: How does access to and use of technology at home relate to and predict student performance in mathematics as measured by TIMSS 2015? The broad question was addressed in a series of sub-questions and hypotheses which are:

1. Is access to personal computers and tablets at home significantly related student outcomes on TIMSS?
    a. Access to personal computers and tablets at home is significantly related to student mathematics outcomes on TIMSS.
2. Internet access at home is significantly related to student mathematics outcomes on TIMSS.
    a. Internet access at home is significantly related to student mathematics outcomes on TIMSS.
3. Is socio-economic status a significant predictor of students' mathematics outcomes on TIMSS?
    a. Socio-economic status as measured by parents' education level, parents' occupational level and employment status, and digital material resources are significant in predicting students' mathematics outcomes on TIMSS.

Using Germany's fourth grade TIMSS data on mathematics achievement and student's home possession of computers, tablets and internet connection, parents' educational and occupational levels and number of digital information devices at home as independent variables, this research examined the relationship of student home access to digital resources to their mathematics achievement. This research used an independent samples *t* test to compare the means across the two groups- Possession of your own personal computer and tablet at home (Yes- 1, No-2) and possession of internet access at home (Yes- 1, No-2) and went on further to use the other independent variables as predictors to understand the relationship that socio-economic status has with student achievement through the use of a multiple regression. This section begins by reporting the descriptive statistics for each variable that was used in the analyses. One measure of central tendency and one measure of variability was reported for each continuous dependent variable and because the independent variables are categorical and in some cases dichotomous, the proportions were reported. The section then concludes by presenting the data analysis that was run for each hypothesis and the results that were produced by the SPSS output.

4.1. Descriptive Statistics

4.1.1. Independent Variables

As seen in the table in appendix A, the independent variable of home access to computer and tablet had 3285 valid responses and 663 missing responses. 57.2% of the respondents replied yes and 42.8% of the respondents replied no. This gives this question a response rate of 83%.

As seen in the table in appendix B, the independent variable of internet access at home had 3269 valid responses and 679 missing responses. 77.5% of the respondents replied yes and 22.5% of the respondents replied no. This gives this question a response rate of approximately 83%.

4.1.2. Predictor Variables

As seen in the table in appendix C, the predictor variable of parents' highest education level had 2437 valid responses and 1511 missing responses. 22.2% of the respondents replied that they had a university or higher education, 32.6% responded that they had post-secondary but not university, 9% had upper secondary education, 27.1% had lower secondary education, 8% had some primary, lower secondary or no school and 1.1% of the respondents replied not applicable. This gives this question a response rate of 62%.

As seen in the table in appendix D, the predictor variable of parents' highest occupation level had 2010 valid responses and 1938 missing responses. 10.5% of the respondents replied that they were professionals, 6% responded that they were small business owners, 25% were clerical, 5.8% were skilled workers, 1.5% were general laborers, 0.5% never worked for pay and 1.5% replied not applicable. This gives this question a response rate of 51%.

As seen in the table in appendix E, the predictor variable of digital information devices in the home had 2441 valid responses and 1507 missing responses. 0.2% of the respondents replied that they had none, 11.1% responded that they had 1-3 devices, 28.6% had 4-6 devices, 16.5% had 7-10 devices, and 5.4% had more than 10 devices. This gives this question a response rate of 62%.

4.1.3. Dependent Variable

As shown in appendix F., there are five plausible values for mathematics achievement. For this variable, *n*= 3948.

- The first plausible value has *M*=522.47, *SD*=64.88 with a skewness of -0.13 and a kurtosis of -0.08 which means that the distribution is approximately symmetric.
- The second plausible value has *M*=522.10, *SD*=65.57 with a skewness of -0.14 and a kurtosis of 0.05 which means that the distribution is approximately symmetric.
- The third plausible value has *M*=522.35, *SD*=63.88 with a skewness of -0.10 and a kurtosis of -0.10 which means that the distribution is approximately symmetric.
- The fourth plausible value has *M*=521.63, *SD*=64.69 with a skewness of -0.14 and a kurtosis of 0.07 which means that the distribution is approximately symmetric.

- The fifth plausible value has *M*=521.54, *SD*=65.23 with a skewness of -0.15 and a kurtosis of 0.10 which means that the distribution is approximately symmetric.

4.2. Statistical Analyses

- Hypothesis 1: Access to personal computers and tablets at home is significantly related to student mathematics outcomes on TIMSS..

  Using a two-tailed independent samples *t*-test with α at .05 on SPSS, the data analysis was run with the statistical hypothesis to measure the mean difference between both independent groups (Yes VS. No).

<u>*Results*</u>

- In the first plausible value for mathematics, there was a significant mean difference in outcomes between students who have access to personal computers and tablets at home (*M*= 521.08, *SD*= 64.74) and students who do not have access to personal computers and tablets at home (*M*= 534.71, *SD*= 65.06), $t_{(3283)}$= -5.96, $p < .001$, *d*= -0.21, with students without home access scoring higher than students with home access.
- In the second plausible value for mathematics, there was a significant mean difference in outcomes between students who have access to personal computers and tablets at home (*M*= 519.25, *SD*= 65.38) and students who do not have access to personal computers and tablets at home (*M*= 535.60, *SD*= 65.55), $t_{(3283)}$= -7.08, $p < .001$, *d*= -0.25, with students without home access scoring higher than students with home access.
- In the third plausible value for mathematics, there was a significant mean difference in outcomes between students who have access to personal computers and tablets at home (*M*= 520.59, *SD*= 62.56) and students who do not have access to personal computers and

tablets at home (*M*= 534.06, *SD*= 65.46), $t_{(3283)}$= -5.99, $p < .001$, *d*= -0.21, with students without home access scoring higher than students with home access.

- In the fourth plausible value for mathematics, there was a significant mean difference in outcomes between students who have access to personal computers and tablets at home (*M*= 520.87, *SD*= 64.48) and students who do not have access to personal computers and tablets at home (*M*= 532.35, *SD*= 64.78), $t_{(3283)}$= -5.04, $p < .001$, *d*= -0.18, with students without home access scoring higher than students with home access.
- In the fifth plausible value for mathematics, there was a significant mean difference in outcomes between students who have access to personal computers and tablets at home (*M*= 519.22, *SD*= 64.57) and students who do not have access to personal computers and tablets at home (*M*= 534.83, *SD*= 66.00), $t_{(3283)}$= -6.79, $p < .001$, *d*= -0.24, with students without home access scoring higher than students with home access.

Levene's test for homogeneity of variance was not significant for all plausible values, $p > .05$, therefore, the assumption for homogeneity of variance is met for this analysis.

Based on these results, we reject the null hypothesis and conclude that there is a significant mean difference in the outcomes between students who have access to personal computers and tablets at home and students who do not have access to personal computers and tablets at home.

- Hypothesis 2: Internet access at home is significantly related to student mathematics outcomes on TIMSS.

Using a two-tailed independent samples *t*-test with α at .05 on SPSS, the data analysis was run with the statistical hypothesis to measure the mean difference between both independent groups (Yes VS. No).

Results

- In the first plausible value for mathematics, there was a significant mean difference in outcomes between students who have internet access at home (*M*= 529.80, *SD*= 64.55) and students who do not have access to the internet at home (*M*= 518.27, *SD*= 65.89), $t_{(3267)}$= 4.25, $p < .001$, *d*= 0.18, with students with internet access at home scoring higher than students without internet access at home.
- In the second plausible value for mathematics, there was a significant mean difference in outcomes between students who have internet access at home (*M*= 529.16, *SD*= 65.21) and students who do not have access to the internet at home (*M*= 517.29, *SD*= 66.50), $t_{(3267)}$= 4.33, $p < .001$, *d*= 0.18, with students with internet access at home scoring higher than students without internet access at home.
- In the third plausible value for mathematics, there was a significant mean difference in outcomes between students who have internet access at home (*M*= 529.44, *SD*= 63.78) and students who do not have access to the internet at home (*M*= 516.95, *SD*= 64.03), $t_{(3267)}$= 4.68, $p < .001$, *d*= 0.20, with students with internet access at home scoring higher than students without internet access at home.
- In the fourth plausible value for mathematics, there was a significant mean difference in outcomes between students who have internet access at home (*M*= 529.04, *SD*= 64.37) and students who do not have access to the internet at home (*M*= 515.45, *SD*= 64.21), $t_{(3267)}$= 5.05, $p < .001$, *d*= 0.21, with students with internet access at home scoring higher than students without internet access at home.

- In the fifth plausible value for mathematics, there was a significant mean difference in outcomes between students who have internet access at home (M= 528.69, SD= 64.95) and students who do not have access to the internet at home (M= 517.16, SD= 66.19), $t_{(3267)}$= 4.23, $p < .001$, d= 0.18, with students with internet access at home scoring higher than students without internet access at home.

Levene's test for homogeneity of variance was not significant for all plausible values, $p > .05$, therefore, the assumption for homogeneity of variance is met for this analysis.

Based on these results, we reject the null hypothesis and conclude that there is a significant mean difference in the outcomes between students who have access to the internet at home and students who do not have access to the internet at home.

- Hypothesis 3: Socio-economic status as measured by parents' education level, parents' occupational level and employment status, and digital material resources are significant in predicting students' mathematics outcomes on TIMSS.

Using student outcomes in mathematics and parents' education level, parents' occupational level and employment status, and digital material resources as independent variables (predictors), a multiple regression analysis with α at .05 was run to determine how significant these independent variables are in predicting students' mathematics outcomes.

<u>Results</u>

The results of the regression analysis showed that the predictors explained 15% of the variance ($R^2 = .15$).

- For parents' educational level, the group 1- University or Higher was used as a reference for the model. The constant for the model was 571.33, *t* value= 6.80, $p < 0.05$.

Table 4.1. Multiple regression results from parents' educational level

Predictor variables	Unstandardized β weight	Standardized β weight	*t*-value
Post secondary but not university	-11.99	-.09	-2.01*
Upper secondary	-15.76	-.07	-2.21*
Lower secondary	-32.55	-.23	-5.84*
Some prim., lower sec. or no school	-56.00	-.24	-7.32*
Not applicable	-60.09	-.10	-2.71*

Note. * - Statistically significant *t* values at $p < 0.05$ level.

Based on the analysis, the predictor variable showed that students with parents who had lower than a" university degree" performed lower on the TIMSS mathematics assessment with all levels being statistically significant.

- For parents' occupational level, the group 1- Professional was used as a reference for the model. The constant for the model was 571.33, *t* value= 6.80, $p < 0.05$.

Table 4.2. Multiple regression results from parents' occupational level

Predictor variables	Unstandardized β weight	Standardized β weight	*t*-value
Small business owner	-21.28	-.11	-3.17*
Clerical	-18.58	-.14	-4.17*
Skilled worker	-33.10	-.16	-5.14*
General laborer	-29.18	-.08	-2.75*
Never worked for pay	-46.56	-.06	-2.88*
Not applicable	-25.22	-.07	-2.65*

Note. * - Statistically significant *t* values at $p < 0.05$ level.

Based on the analysis, the predictor variable showed that students with parents who had lower occupational levels than "professional" performed lower on the TIMSS mathematics assessment with all levels being statistically significant.

- For possession of own computer, tablet and internet connection at home, the group 1- Yes was used as a reference for the model. The constant for the model was 571.33, *t* value= 6.80, $p < 0.05$.

Table 4.3. Multiple regression results from possession of personal computer, tablets and internet at home

Predictor variables	Unstandardized β weight	Standardized β weight	*t*-value
Own computers and tablets (No)	14.81	.11	3.77*
Internet (No)	-15.03	-.10	-4.14*

Note. * - Statistically significant *t* values at $p < 0.05$ level.

Based on the analysis, the predictor variables showed that students who did not have access to their own personal computers and tablets at home performed higher on the TIMSS mathematics assessment and students who did not have access to internet at home performed lower on the TIMSS mathematics assessment with all levels being statistically significant.

- For number of digital information devices in the home, the group 1- None was used as a reference for the model. The constant for the model was 571.33, *t* value= 6.80, $p < 0.05$.

Table 4.4. Multiple regression results from number of digital information devices at home

Predictor variables	Unstandardized β weight	Standardized β weight	*t*-value

1-3 devices	-8.39	-.05	-.10
4-6 devices	-1.27	-.01	-.20
7-10 devices	.84	.01	.01
More than 10 devices	1.16	.01	.01

Note. * - Statistically significant *t* values at $p < 0.05$ level.

Based on the analysis, the predictor variable showed that students with more than 10 devices at home performed better than students in the other groups on the TIMSS mathematics assessment, however, no levels are statistically significant.

In summary, based on the analyses for the first two hypotheses, the results showed that students who do not have access to computers and tablets at home scored higher across all five plausible values and students who have access to internet at home scored higher across all five plausible values. The analyses for the third hypothesis showed that parents educational level and occupational level and home possession of computers and internet access were all significant in predicting students' scores on TIMSS mathematics achievement.

These results and its implications are discussed in the following chapter.

Chapter 5- Discussion

This section begins with a summary of the results to answer the broad research question of how access to and use of technology at home relate to and predict student performance in mathematics as measured by TIMSS 2015. The section then goes on to discuss the results of the analyses. The first section in the discussion addresses how digital inequality ties to home access to personal computers and tablets and its implications for being socially included. The next section tackles digital inequality and its ties to home access to the internet and its implications for social exclusion. The third section addresses parents' educational and occupational Level and its ties to social exclusion. The discussion then progresses by framing digital literacy as a capability which when lacking, leads to social exclusion. This is followed by a discussion of the limitations of the study and linking it to further research. The research concludes by making policy recommendations.

5. 1. Summary of Results

Based on the analysis for the first hypothesis, the results showed that there is a significant mean difference in the outcomes between students who have access to personal computers and tablets at home and students who do not have access to personal computers and tablets at home. Students who do not have access to computers and tablets at home scored higher across all five plausible values.

Based on the analysis for the second hypothesis, the results showed that there is a significant mean difference in the outcomes between students who have access to the internet at home and students who do not have access to the internet at home. Students who have access to internet at home scored higher across all five plausible values.

Based on the analysis for the third analysis, the results showed that parents' educational level, parents' occupational level, access to computers and tablets at home and access to the internet at home were all significant predictors of student achievement. Students with parents' educational level at university degree or higher performed higher than all other groups with scores decreasing as parents' educational level reduced. Students with parents' occupational level at professional performed higher than all other groups with scores decreasing as parents' occupational level reduced. Students with access to the internet at home performed higher than students without access. Students without access to personal computers and tablets performed higher than students who had access. Number of digital resources in the home was used as a predictor and although there was a positive relationship between a higher number of digital devices and student achievement, these results were insignificant.

These results answer the hypothesis that there is a significant difference in performance between student groups who have home access and students who do not have home access to the same digital resources. The results also show that there is a relationship between at home access to digital resources such as the internet, computers and tablets, parental socio-economic status and student performance in the TIMSS mathematics assessment.

5.2. Discussion

This section addresses how home access to digital resources, parental occupation levels and educational levels all intersect to affect digital social inclusion. It also looks at this issue from a capability approach steeped in rights-based language.

5.2.1. Digital Inequality, Home Access to Personal Computers and Tablets and Social Exclusion

Use of personal computers and tablets has been tied to improved student achievement (Robinson et al., 2018). However, the results from the analysis showed that use of personal computers and tablets are negatively related to student outcomes in mathematics achievement measured by TIMSS. This is consistent with Robinson, Wiborg, and Schulz's (2018) study that found that both leisure computing and smartphone usage has a negative relationship with high academic achievement and that high academic achievement has a positive relationship to duration of digital experience and academically useful computing. This research does not investigate usage patterns of personal computers and tablets of fourth grade German students and a usage pattern of leisure computing could explain the negative relationship between home access to computers and tablets and student mathematics achievement.

This points to the need for the German state ministries of education to go beyond provision of computers and move to help students develop the skills to use computers for capital enhancing activities (Hargittai & Hinnant, 2008; Park, 2012) as individuals who have more education and support systems know how to use the digital resources to their advantage (Hargittai & Hinnant, 2008). Lack of these skills and education point toward a trend of social exclusion if individuals are unable to properly participate in the digital environment as they are deprived of this capability and this can be conceptualized as an impoverished life (Sen, 1992).

An impoverished life in this context does not exclusively refer to income insufficiency, although this is a hinderance to gaining necessary digital skills for capital enhancing activities, “information poverty” as identified by Park (2012, p. 94) adds to the detriment of an impoverished life. Information poverty is an indicator of social exclusion (Park, 2012). Information poverty is the inability to use and interpret digital information and resources and this widens the gap between the socially included and excluded (Park, 2012).

In this context, social exclusion within the rights-based approach would be that the individuals who have personal computers and tablets but lack the necessary skills and capabilities to properly engage and integrate into the digital community or to use the digital resources to their benefits are at risk of not realizing their rights of social, civic and political citizenship to its full potential (Klasen, 1998).

Provision of skills which in this context refers to digital media literacy is consistent with Park (2012) who identified that provision of access to digital resources is simply a first step in the journey of ensuring that access and use of digital resources promotes social inclusion. She identified digital media literacy and the ability to create which is a dimension of digital media literacy as closely linked with the ability to participate. Participation in this research ranges from participation on social media to participation in the civic and democratic processes of a society. If students lack the skills of knowledge gathering using tablets and personal computers, it becomes impossible for them to use these digital resources to enhance their learning which is a possibility in this research that would explain the reason for students with home access performing lower than students without access.

Use of these resources for anything other than useful computing causes distractions and they limit the learning process. Parental/ adult supervision of digital resource use, especially at the fourth-grade level would be useful in keeping the students focused on capital-enhancing activities. This is consistent with Wong’s (2010) findings that more parental supervision of digital activities such as playing an active role and being involved in children's online activities and having more discussions of the online experiences as well as the use of an authoritative parenting style all had satisfactory results in influencing children’s behavior. However, this is limited to better educated parents as lower-educated parents are not able to fully understand and participate in the digital activities of their children past closely monitoring their activities because they are unable to properly engage them in capital-enhancing activities (Wong, 2010).

This result is consistent with Hargittai and Hinnant (2008), who found that digital users with more education and resources used the internet for more “capital-enhancing activities” (p, 617). Monitoring patterns of use of digital resources can be better achieved when students share these resources either with their parents/ guardians or older siblings who are able to provide guidance on reaping the benefits of digital resources for learning purposes, however this would interfere with the autonomy of the students.

It is also pertinent to add that although this research only used data on possession of personal computers and tablets, another question that addresses the use of shared computers and tablets are also included in the background questionnaire by TIMSS. This could also account for the results as students who answered ‘no’ to the background question on possession of personal computers and tablets might in fact have home access to these same resources but do not possess the same amount of autonomy as students who possess personal computers and tablets. This research did not consider the performance of students who share personal computers and tablets against students who have their own personal computers and tablets. This research investigated the role that autonomy plays in improving student achievement as proposed by DiMaggio and Hargittai (2001) who identified lack of autonomy in the use of digital resources as a dimension of digital inequality.

Therefore, at home access to personal computers and tablets may have a positive relationship to mathematics achievement as measured by TIMSS but autonomy in possession and use has not shown any positive relationship with student achievement. According to the results, in the case of Germany’s fourth grade students, autonomy does not benefit them academically and this could be due to a lack of skills as identified earlier which is the third dimension of digital inequality as identified by DiMaggio and Hargittai (2001). This is an area of further research.

5.2.2. Digital Inequality, Home Access to the Internet and Social Exclusion

Use of the internet has been positively related to various forms of participation and achievement (Bakker & de Vreese, 2011; Goldman, Booker & McDermott, 2008). The results of this study are consistent with the findings of a positive relationship between internet usage and participation and achievement. Students who do not have home access to the internet are at risk of being socially excluded because they are unable to participate fully in the online community.

Lack of home access to the internet is viewed as capability deprivation in this research as students who lack the necessary resources, tools, skills and support to engage online are deprived of the opportunity to fully participate (Sen, 2000). The inability of some students to access digital resources at home to gather knowledge or even connect on social media is capability deprivation that leads to social exclusion (Sen, 2000).

In the technologically advanced world, lack of digital skills carries dire consequences that go beyond being digitally illiterate as deprivation at that level could lead to deprivation at other levels that could potentially affect the quality of life of students, thus leading to social exclusion. Research has shown that access, use and development of digital skills have an even bigger positive impact on student achievement, especially for students who come from low income families or low academic achievement rates (Pagani et al., 2016). The amount of information that is housed online that people use to make daily decisions would be impossible without access to the internet. This poses a problem for students who are not connected to the internet as they are deprived of the same information that has the potential to improve their decision-making or their quality of life. The implication of this is that if students continuously lack access to digital resources and the necessary support, achievement gaps will continue to exist and as the knowledge economy keeps growing, the gaps will widen.

To further understand the link between lack of home access to digital resources and social exclusion, we need to look to inequality at the socio-economic status line. Computer access and internet access have been used as indicators of economic disadvantage (Harding et al., 2009; Todman et al., 2009) as lack of access is usually tied to the socio-economic status of the family and students who do not have access are excluded from technology (Park, 2012). Research has shown that digital inequality mirrors societal inequality (Iske et al., 2008; Ono & Tsai, 2008), therefore tackling digital inequality must be undertaken with the understanding of contextual factors that led to this gap in the first place.

5.2.3. Parents' Educational and Occupational Level and Social Exclusion

Socio-economic status has always affected education in myriad ways and research has shown this (Bornstein, & Bradley, 2003). This research did not only undertake to point out a relationship between socio-economic status and student performance, but it went a step further to investigate how the intersection between parents' educational level, occupational level and income impact social inclusion in the digital environment (Boocock, 1972). Income affects the possibility of a family being able to provide digital resources in the home for their children (Boocock, 1972). This is the viewpoint that this research took.

The results of this study are consistent with research in the field that show a relationship between parents' educational and occupational status and student achievement (Boocock, 1972; Bornstein & Bradley, 2003; Okpala, Okpala, & Smith, 2001). Children from families with parents that have lower educational levels are at a disadvantage as higher parental educational levels have been correlated to higher student achievement (Gooding, 2001). This leaves room for students to be deprived of the academic support that a higher educated parent can provide.

In the realm of digital inequality, lower educated parents might be unable to properly engage in conversations with their children about their digital and online activities because they lack the capacity (Wong, 2010). This affects monitoring on the part of the parents to ensure that their children are using digital resources for capital-enhancing activities (Wong, 2010). Without monitoring, we could see a decline in student achievement even with the necessary digital resources because they become time wasters (Vigdor, Ladd & Martinez, 2014). This all ties into social exclusion.

If parents are lower educated and unable to properly engage with their children digitally, it becomes problematic as students do not reap the benefits of technological advancements (Wong, 2010). If parents are uncomfortable with engaging digitally, this has implications for assignments that students are expected to carry out using digital resources. This would mean that parents would be unable to assist their children with their homework or provide guidance. This is problematic because research shows that children with parents who are more engaged in their academic activities perform better (Lareau, 2000; 2003). This lays the groundwork for social exclusion as students continuously perform lower as a result of factors that are out of their control, thus reducing both their educational opportunities and opportunities for higher earning power (Kao & Thompson, 2003; Waller & Hase, 2004). From a capability standpoint, it would mean that these students would have been denied of the capability to fully harness their potential because structural inequality would have deprived them of the enabling environment that is necessary for the opportunity to thrive academically.

Parents' occupational level most often depends on their educational level and with lower educational levels often come lower occupational levels and income is affected by both educational and occupational levels (Wolla & Sullivan, 2017). With a lower occupational level comes less income to provide the necessary digital resources that students require to take advantage of the opportunities that are available in the digital community (Boocock, 1972). Often, when family income is less than expenses, there are cases of one or both parents taking on extra employment to meet the family's needs. This impacts the amount of time that parents have to spend with their children on academic activities. This has implications as research has shown that higher student achievement is positively correlated with higher parental involvement in the educational activities of their children (Lareau, 2000; 2003). This research shows that parental occupational level is related to student achievement in mathematics and as parental occupational level went lower, student mathematics achievement went lower as well. The implication is social exclusion because students cannot access the same digital resources as their higher socioeconomic status counterparts as a result of lower family income levels. This all ties into social exclusion as digital inequality at the fourth grade level transcends that period in time and affects students' human capital, social capital and cultural capital development (Kao & Thompson, 2003; Waller & Hase, 2004)

This research also used number of digital devices in the home as a predictor and the higher the number of devices in the home, the higher the student achievement, however the results were not significant. This could also be because as was stated earlier, if students are not instructed on the appropriate way to use digital resources for capital enhancing activities, the resources become time wasters. This is also a dimension of digital inequality that was discussed earlier in this chapter.

The next section addresses the capability and rights-based approach to digital inequality, literacy and social exclusion.

5.3. Digital Literacy, Capability and Social Exclusion

Lack of home access to digital resources leads to a state of “digital bind” (Robinson et al., 2018) which connotes a situation where students are expected to use digital resources to carry out their schoolwork, but these resources are unavailable to them either at home or in school, thus leading to disparities in access and ultimately an achievement gap between advantaged and disadvantaged students. This is even more dire for students from disadvantaged backgrounds as their academic performances are already negatively affected by factors beyond their control such as socio-economic status, parental educational levels, parental occupational levels, lack of support systems and lack of access to digital resources or the necessary skills to properly engage these resources only compound the problems. Taking into consideration cases of digital bind, it becomes almost impossible for disadvantaged students to perform at par with their advantaged counterparts.

For human capital development, this has implications for their academic performance which would ultimately affect their earning potential. Higher educational achievement often leads to a greater availability of educational opportunities and educational attainment affects labor options and earning power (Cole, 2019; Ellison, Steinfield, & Lampe, 2007; Kao & Thompson, 2003; Waller & Hase, 2004). Therefore, the effects of digital inequality at the fourth-grade level transcends the school environment and has the potential to affect future human capital. Deprivation at the fourth-grade level can mean a diminished earning capability as students would be unable to properly harness digital resources to carry out capital enhancing activities. In the current technology dependent world, without digital skills, it even becomes difficult to apply for jobs as the previously paper-dependent process has moved online with jobs being advertised on job advertisement and recruitment sites and applications for positions being a one-click activity over the internet. Universities, institutions and organizations are slowing phasing or have completely phased out paper applications and documentation with a large part of this information being housed in a digital environment (the Cloud) and with a focus on sustainable environment practices, replacement of paper-based processes with online processes ensure that digital skills are necessary for engagement. This is evidence of how lack of digital capability can be detrimental to an individual who needs to access these resources (Iske et al., 2008).

For social capital development, students without the necessary digital resources and skills are unable to engage in the online community. Simple actions such as connecting on social media have impacts on student's development of their habitus from improved online and offline civic and political participatory behaviors (Ellison et al., 2007) to bridging social capital and improving psychological well being (Gil de Zúñiga, Jung, & Valenzuela, 2012) and to engaging academically to build an academic community of practice (Hung, & Yuen, 2010). These are all capabilities that are undermined by a lack of access to digital resources and skills.

For cultural capital development, students who do not have the skills and resources to engage online lack the knowledge, skills and behaviors as well as the material objects (computers, tablets and the internet) to demonstrate digital competence in the online community (Cole, 2019). This has implications for their upward mobility as there are codes of conduct that are specifically useful to properly engage in the online community and without understanding those codes, students are at risk of being excluded both online and offline as online practices often transcend into the offline environment (Goldman, Booker & McDermott, 2008).

From a political and civic engagement perspective, information and knowledge gathering from the digital community is hampered when the students lack both digital resources and skills. This is a threat to the democratic process as a mix of digital, social and cultural technologies has been shown to produce high levels of youth participation which shows a new dimension of youth participatory culture through new media (Goldman, Booker & McDermott, 2008). Digital platforms serve as spaces where youth voices can be represented in public discourse. Unequal access to digital resources is a barrier to this revolutionary type of youth participation. AN individual without proper access to digital technology has the potential of having his voice suppressed in the political arena. With the emergence of new media and media literacy, youth are developing capabilities that ensure that they are critical consumers of information and creating content that is representative of their identity and their presence at the national level on discussions of democracy and civic participation (Goldman, Booker & McDermott, 2008) and an individual who does not enjoy these opportunities is incapable of fully participating civically.

Even in social justice movements, online participation is critical. There are scenarios where social justice movements which started online moved offline. This took place in Guatemala as Facebook was used as a medium to spark up online social movements to hold perpetrators of violence accountable. The users' protest-related and motivational comments helped organize protests that called for justice and an end to violence (Harlow, 2011). Such revolutionary moves would have been greatly diminished or impossible without the online platform that served as a starting point for the movement.

This section outlined the necessity for steps to be taken to mitigate the effects of digital inequality on school aged students as the effects transcend their academic career and move into affecting every aspect of their lives.

5.4. Limitations

This research is limited by its nature of being a non-experimental quantitative study only. It cannot make causal inferences concerning the influence that home access to digital resources would have on student achievement. Because of the nature of this research, confounding variables are not accounted for in the analysis and this also affects the findings of the research. This research also uses a sample of only fourth grade German students, therefore the generalizability of the research to populations outside the fourth-grade demographic should be undertaken with caution. A focus on access alone to digital resources cannot allow for a concrete claim of social exclusion without investigating usage patterns of the same fourth grade students while taking into consideration student groups who have shared access and lack autonomy, students who have personal devices and enjoy autonomy and students who lack complete access to the same digital resources. This would provide a more buoyant result as to the influence of autonomy and usage patterns on student achievement. This study was undertaken in this manner as a result of time constraints and a deeper delve into the issues of autonomy and usage patterns would have been impossible to achieve within the set time frame as there are language barriers and access issues to the research sample. These limitations provide directions for further research which are discussed in detail in subsection 5.6 of this chapter.

5.5. Policy Recommendations

This research bears implications for the adoption of the Digital Education Action Plan. Policy level and institutional imperatives to digitize education need to be adopted cautiously as there is a potential of exacerbating already existing inequality within the school system and the wider society. A policy recommendation would be to carry out a pilot program of incorporating technology into the school system. It would be ideal to implement this pilot program in at least one school in each Land (state) and each of the schools should have a diverse population from a variety of backgrounds and student groups to understand how the digitization policy manifests itself across different student groups. This provides an opportunity to formatively assess the policy implementation on a small scale so that necessary changes can be made and the margin of error during the large-scale policy implementation can be reduced. It would also provide an opportunity for the school administration and teachers to scaffold students through the transition process as a pilot study already reveals areas of concern that need to be addressed in order to fully benefit from the process of digitization.

In line with the Gewerkschaft Erziehung und Wissenschaft (GEW) study findings, some concerns need to be addressed before a full-scale digitization plan can take place. These concerns that need to be addressed are provision and maintenance of the digital equipment for both teachers and students, education and support for teachers, data privacy and protection, autonomy from media groups and the acknowledgement of the value of pedagogy over digital equipment (Education International, 2018). Based on the report as well, more funding would be necessary to get German school systems to an ideal place for digitization (Education International, 2018).

To address issues of home access might be beyond the scope of the state ministries of education, however, subsidy programs that would aid families to buy and install digital equipment in their home would go a long way in closing the current digital gap. This is in line with the rights-based and capability approach to social inclusion which requires that for some marginalized groups, additional concessions and extra efforts would need to be made by the society in order to ensure equality of access and capability for them to close the gap. This would require an approach of equity which would necessitate that some disadvantaged groups be given preferential treatment over equality which points to an equal starting point for everyone, which is not enough to ensure equal capabilities at this stage (Klasen, 1998, p. 2). It is also necessary to address issues of home monitoring and supervision when students engage in the digital community. This would require that parents remain constantly informed and maybe even trained in ideal monitoring skills that would enable them to provide a layer of security for their children.

It would also be ideal to collect data and feedback for the first five years of the digitization plan from all the stakeholders in education (teachers, parents, students and educational administration). This data provides formative information that can be used to properly assess the effectiveness of the program in achieving its proposed goals and ensuring that no student group is excluded from the process.

5.6. Recommendations for Future Research

Further research directions would be to conduct a qualitative study that investigates usage patterns of the same sample while taking into consideration student groups who have shared access and lack autonomy, students who have personal devices and enjoy autonomy and students who lack complete access to the same digital resources. This would provide a more buoyant result as to the influence of autonomy and usage patterns on student achievement.

It would also be useful to qualitatively investigate the reasons for the results that showed that students who had home access to their personal computers and tablets did not outperform students who lacked at home personal access to the same resources. It would also be useful to explicitly investigate the intersection of migrant status, parents' socio-economic status and the ability to afford digital resources and gain digital skills to improve capital enhancing activities which foster upward mobility.

5.7. Conclusion

This research began by asking the broad question: How does access to and use of technology at home relate to and predict student performance in mathematics as measured by TIMSS 2015? The broad question was addressed in a series of sub-questions and hypotheses using T-tests and regression analysis to determine if there was a relationship and its significance level. The research found that there is a relationship between access to and use of technology at home and student performance in mathematics and the research further discovered that parental occupational level and educational level which are often indicators and determinants of socio-economic status (Galobardes et al., 2006) significantly predicted student achievement and number of digital devices at home was a predictor as well but it was statistically insignificant. These findings have implications for how the face of education is changing to include technology to prepare students for the knowledge based economy. As national systems of education evolve to include the technological advancements brought on by globalization, attention must be paid so that vulnerable student groups are not left behind. Achievement gaps caused by digital inequality only compound issues of low educational attainment and this has the potential to exacerbate poverty, inequality and social exclusion.

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APPENDICES

Appendix A

Possession of own computer/ tablet at home frequency table

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	1879	47.6	57.2	57.2
	No	1406	35.6	42.8	100.0
	Total	3285	83.2	100.0	
Missing	Omitted or invalid	77	2.0		
	System	586	14.8		
	Total	663	16.8		
Total		3948	100.0		

Appendix B

Possession of internet access at home frequency table

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	2532	64.1	77.5	77.5
	No	737	18.7	22.5	100.0
	Total	3269	82.8	100.0	
Missing	Omitted or invalid	93	2.4		
	System	586	14.8		
	Total	679	17.2		
Total		3948	100.0		

Appendix C

Parents' highest education level frequency table

Parents' Highest Education Level					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	University or Higher	540	13.7	22.2	22.2
	Post-secondary but not University	795	20.1	32.6	54.8
	Upper Secondary	219	5.5	9.0	63.8
	Lower Secondary	661	16.7	27.1	90.9
	Some Primary, Lower Secondary or No School	196	5.0	8.0	98.9
	Not Applicable	26	.7	1.1	100.0
	Total	2437	61.7	100.0	
Missing	Omitted or invalid	1511	38.3		
Total		3948	100.0		

Appendix D

Parents’ highest occupation level frequency table

Parents' Highest Occupation Level					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Professional	416	10.5	20.7	20.7
	Small Business Owner	238	6.0	11.8	32.5
	Clerical	986	25.0	49.1	81.6
	Skilled Worker	230	5.8	11.4	93.0
	General Laborer	61	1.5	3.0	96.1
	Never Worked for Pay	20	.5	1.0	97.1
	Not Applicable	59	1.5	2.9	100.0
	Total	2010	50.9	100.0	
Missing	Omitted or invalid	1938	49.1		
Total		3948	100.0		

Appendix E

Digital information devices in the home frequency table

GEN\DIGITAL INFORMATION DEVICES					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	7	.2	.3	.3
	1-3 devices	438	11.1	17.9	18.2
	4-6 devices	1129	28.6	46.3	64.5
	7-10 devices	653	16.5	26.8	91.2
	More than 10 devices	214	5.4	8.8	100.0
	Total	2441	61.8	100.0	
Missing	Omitted or invalid	29	.7		
	System	1478	37.4		
	Total	1507	38.2		
Total		3948	100.0		

Appendix F

Mathematics achievement scores frequency

		1ST PLAUSIBLE VALUE MATHEMATICS	2ND PLAUSIBLE VALUE MATHEMATICS	3RD PLAUSIBLE VALUE MATHEMATICS	4TH PLAUSIBLE VALUE MATHEMATICS	5TH PLAUSIBLE VALUE MATHEMATICS
N	Valid	3948	3948	3948	3948	3948
	Missing	0	0	0	0	0
Mean		522.4722	522.1039	522.3523	521.6265	521.5432
Median		524.7714	524.0024	523.9047	523.5631	522.9644
Mode		463.97[a]	475.21	468.06	520.26[a]	422.36[a]
Std. Deviation		64.87718	65.57011	63.87571	64.69429	65.22539
Variance		4209.049	4299.440	4080.107	4185.351	4254.351
Skewness		-.133	-.145	-.103	-.140	-.153
Std. Error of Skewness		.039	.039	.039	.039	.039
Kurtosis		-.083	.052	-.102	.067	.098
Std. Error of Kurtosis		.078	.078	.078	.078	.078

a. Multiple modes exist. The smallest value is shown

Appendix G

Independent T-test for possession of own computer/ tablet at home and its relationship to student outcomes.

Group Statistics

	GEN\HOME POSSESS\COMPUTER TABLET OWN	N	Mean	Std. Deviation	Std. Error Mean
1ST PLAUSIBLE VALUE MATHEMATICS	Yes	1879	521.0849	64.73949	1.49350
	No	1406	534.7073	65.05630	1.73499
2ND PLAUSIBLE VALUE MATHEMATICS	Yes	1879	519.2511	65.37637	1.50819
	No	1406	535.5978	65.55234	1.74822
3RD PLAUSIBLE VALUE MATHEMATICS	Yes	1879	520.5893	62.56455	1.44333
	No	1406	534.0639	65.45854	1.74572
4TH PLAUSIBLE VALUE MATHEMATICS	Yes	1879	520.8692	64.47762	1.48746
	No	1406	532.3521	64.77874	1.72759
5TH PLAUSIBLE VALUE MATHEMATICS	Yes	1879	519.2160	64.56696	1.48952
	No	1406	534.8297	66.00259	1.76023

Appendix G (contd.)

Independent T-test for possession of own computer/ tablet at home and its relationship to student outcomes.

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
1ST PLAUSIBLE VALUE MATHEMATICS	Equal variances assumed	.382	.537	-5.955	3283	.000	-13.62235	2.28766	-18.10773	-9.13697
2ND PLAUSIBLE VALUE MATHEMATICS	Equal variances assumed	.184	.668	-7.083	3283	.000	-16.34679	2.30798	-20.87203	-11.82156
3RD PLAUSIBLE VALUE MATHEMATICS	Equal variances assumed	3.558	.059	-5.988	3283	.000	-13.47459	2.25041	-17.88695	-9.06224
4TH PLAUSIBLE VALUE MATHEMATICS	Equal variances assumed	.254	.614	-5.040	3283	.000	-11.48292	2.27818	-15.94973	-7.01611
5TH PLAUSIBLE VALUE MATHEMATICS	Equal variances assumed	2.122	.145	-6.793	3283	.000	-15.61365	2.29859	-20.12046	-11.10685

Appendix H

Independent T-test for internet access at home and its relationship to student outcomes

Group Statistics

	GEN\HOME POSSESS\INTERNET CONNECTION	N	Mean	Std. Deviation	Std. Error Mean
1ST PLAUSIBLE VALUE MATHEMATICS	Yes	2532	529.7970	64.55263	1.28287
	No	737	518.2683	65.89242	2.42718
2ND PLAUSIBLE VALUE MATHEMATICS	Yes	2532	529.1583	65.21329	1.29600
	No	737	517.2928	66.50068	2.44958
3RD PLAUSIBLE VALUE MATHEMATICS	Yes	2532	529.4371	63.77541	1.26742
	No	737	516.9471	64.02757	2.35849
4TH PLAUSIBLE VALUE MATHEMATICS	Yes	2532	529.0363	64.36671	1.27917
	No	737	515.4525	64.20510	2.36503
5TH PLAUSIBLE VALUE MATHEMATICS	Yes	2532	528.6943	64.95121	1.29079
	No	737	517.1590	66.18586	2.43799

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
1ST PLAUSIBLE VALUE MATHEMATICS	Equal variances assumed	1.529	.216	4.247	3267	.000	11.52871	2.71455	6.20632	16.85111
2ND PLAUSIBLE VALUE MATHEMATICS	Equal variances assumed	.251	.617	4.328	3267	.000	11.86551	2.74170	6.48989	17.24113
3RD PLAUSIBLE VALUE MATHEMATICS	Equal variances assumed	.052	.819	4.675	3267	.000	12.49000	2.67167	7.25168	17.72831
4TH PLAUSIBLE VALUE MATHEMATICS	Equal variances assumed	.004	.947	5.045	3267	.000	13.58385	2.69251	8.30466	18.86303

5TH PLAUSIBLE VALUE MATHEMATICS	Equal variances assumed	.040	.842	4.225	3267	.000	11.53534	2.73023	6.18221	16.88847