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Enabling Productivity Improvement in Education through the Translation of the Overall Equipment Effectiveness Framework to Support Quantitative Classroom Analysis

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Abstract

This study aimed to support productivity improvement in schools through the development of an analytical template and model with which to collect and process quantitative classroom observation data. As the name implies, the Time on Task Analytical (TOTA) template and model focus on quantifying and analysing Time on Task losses in the school classroom and is based on the Lean Management productivity metric of Overall Equipment Effectiveness (OEE). The amount of time spent on task has a strong correlation to learner achievement, especially in literacy and maths. Additionally, a Lean Management approach was followed during the engagement of education stakeholders to test whether the approach could energise the sector towards productivity improvement.

The research was done in two phases: a model and template design phase and a model testing phase. The development of the model was done by triangulating the existing and proven theoretical base, namely OEE, with terminology and definitions from the target domain of education and then testing and refining the structural model through the coding of qualitative classroom data reflecting the semantics and reality of a school day. The refined model was then further tested by using it to create descriptive analytics from quantitative classroom observation data. A diverse group of 52 education stakeholders were then asked to assess the novelty and validity of such an analysis through a structured questionnaire.

The TOTA model was found to be novel as well as accurate, complete, free from conflict as defined by Shanks et al. (2003) and was received favourably by the stakeholders in terms of its individual impact, perceived organisational impact, perceived usefulness and intention to use as defined by Brown and Jayakody (2008). Of the 52 education stakeholders, 90.3% indicated that the data analysis provided a new perspective to the study of productivity in the classroom. A total of 94.2% of the participants also indicated that the presentation of the data analysis had stimulated them to think of improvement ideas. A large private schools' group in South Africa are in discussion with the researcher to roll out the use of the TOTA model as part of a 'blue-light time' project starting in 2022 that will focus on increasing learning moments in the classroom through teacher involvement in the improvement effort.

With quantitative classroom studies being scarce (Wragg, 2011, Apter et al., 2020), the TOTA model contributes a novel and valid way of building this body of knowledge. Furthermore, the TOTA model provides a novel and valid method of systematically and analytically assessing where productivity losses take place where education productivity is influenced the most: the classroom. Combining Scientific Management with Human Relations theory, the TOTA model, coupled with a Lean Management approach of engaging with education stakeholders provides a fresh tool with which to address the problem of education's declining productivity in the place where it is impacted most: the school classroom.

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Table of Contents

List of Tables

Table of Figures

List of Abbreviations

EBIT	Engineering, Built Environment, and Information Technology
ICT	Information and Communications Technology
IE	Industrial Engineering or Industrial Engineer
IISE	Institute of Industrial and Systems Engineering
OECD	Organisation for Economic Co-operation and Development
OEE	Overall Equipment Effectiveness
OEOR	Overall Equipment Operating Rate
SPSS	Statistical Package for the Social Sciences
TOC	Theory of Constraints
ToT	Time on Task
TOTA	Time on Task Analysis
TPM	Total Productive Maintenance
UP	University of Pretoria

1 INTRODUCTION

"Education is the quintessential upstream industry" (Hoxby, 2004).

Schools and universities feed the economy. They supply all other sectors of the economy with one common resource: educated labour. It is concerning to then note that where most industries have seen a rapid and consistent increase in productivity over four decades (Creighton, 2016), the pedagogues, economists and policy makers agree that the education sector's productivity has been steadily declining (Walberg, 1984, Levin, 1997, Hoxby, 1999, Ahlgrim, 2010, Scafidi, 2016, Creighton, 2016). To quantify: the mining, agricultural, retail and information sectors had an average annual rate of productivity improvement of between 1% and 1.5% between 1987 and 2014 whereas, in contrast, the services sector experienced an annual decline in productivity in those same years. This nett decline within the services sector can be attributed to only some of its industries, namely education, legal services, and hospitals as the hospitality, administration, and computer systems industries have, in fact, experienced an increase in productivity. Education services specifically experienced an average productivity decline of 0.65% per annum (Creighton, 2016).

To explain this phenomenon, Hoxby (1999) postulates that education is a non-traded market, which reduces competition, but also eventually leads to a reduction in productivity and the attraction of less productive resources. She proposes that these challenges be addressed by implementing pay for performance and relaxing schools policies to allow competition by free school choice (Hoxby, 2003).

Gundlach et al. (2001) explain the declining productivity trend by highlighting the fact that schooling has remained labour intensive, instead of experiencing the same productivity gains brought on by computerisation and automation in other economic sectors. The productivity metric most dominant in literature, and generally used at policy level, is that of learner achievement on standardised tests per dollar spent (Hoxby, 2003, Ahlgrim, 2010, Anderson, 2011, Lafortune et al., 2018, Verstegen and King, 1998, Walberg and Fowler Jr, 1987). Gundlach et al. (2001) investigated and normalised the effect that input inflation could have had on this metric, from three different perspectives, but still found that education productivity had declined, especially in countries affiliated with the Organisation for Economic Co-operation and Development (OECD), but also in other countries such as the United States of America.

Another perspective regarding why education productivity has not kept up with productivity gains in other sectors, is that there is generally low consensus in schools and the education establishment in general about who the customer is and what the needs of this customer are (Antony et al., 2012). Schools tend to have more than one type of customer: learners, guardians, governing bodies, shareholders, tertiary institutions, governmental departments, and the workplace in general. Some of these customers, such as the learners and their guardians, may even differ in terms of their needs. For example, some guardians expect high academic standards; whereas others expect a balanced approach between academics and extra-curricular activities, or opportunities to develop the social skills of the learners.

There is however consensus in the literature regarding the problem of declining productivity in schools, not just recently, but for several consecutive decades. In a workplace that is placing an increasing demand on both cognitive and non-cognitive skills that are to be developed by the school system (Ubalde and Alarcón, 2020, Abrassart, 2013, Brunello and Schlotter, 2010, Salpeter, 2003, Kay and Greenhill, 2011, Mann and Huddleston, 2017), the economy cannot afford for the education sector to fall behind in its delivery of these skills.

This paper investigates whether a novel and valid contribution can be made to the study and improvement of productivity in schools. The background to the research problem and its significance is described next.

1.1 Research Background

Background research was conducted to better understand the education environment, how productivity is measured and influenced as well as to ascertain the extent of Industrial Engineering involvement in the field.

THE CHALLENGES OF MEASURING EDUCATION PRODUCTIVITY

Productivity is generically calculated by the formula output divided by input. Although the formula is simple, the application and interpretation of the formula in various environments and under various circumstances is not (Del Gatto et al., 2011). Darra (2006) built a useful, simple conceptual bridge worth keeping in mind with the statement "in education inputs are principally represented by teaching, outcomes by learning."

Some variations to the dominant metric of learner achievement on standardised tests divided by dollars spent exist such as that proposed by Ahlgrim (2010): the number of learners achieving a set academic standard for every USD$100 000 of government educational funding spent on a district. This variation therefore diverges slightly but stays within the concept of learner achievement being used as output and funding as the input.

Another school of thought regarding the measurement of productivity in schools takes the view that the measurement is more complex than simply an aggregated output divided by an aggregated input. This school of thought proposes an indexed measure consisting of multiple factors (Hollingsworth and Ybarra, 2006, Walberg, 1984, Bryk et al., 1997, Essid et al., 2014). These scholars propose that a productivity measurement should consider an index of input and/or output factors. The index-based versions of productivity measurement are all comprised differently, depending on which factors they focus on influencing. The frequently cited indexed approach proposed by Walberg (1984) considers the influence of aptitude, instruction and environment, further broken down into nine different factors: Ability or prior achievement on standardised tests; age or development of learner; motivation or self-concept; the amount of time on task; the quality of instruction; the home environment, the classroom social group environment; the peer group; and the use of extra-curricular time. In contrast, the patented formula of Hollingsworth and Ybarra (2006) contain four variables: Student achievement to defined standards; alignment of curriculum; instructional effectiveness and time on task. These cited examples showcase the variations that exist in these indexed metrics, which is both a strength, the flexibility of the analytical approach, and a weakness, the lack of conceptual consistency between the indexes.

There were thus two main productivity measurement approaches found in the literature: one aggregated and the other more analytical. This research sides with the analytical school of thinking as the aim is to improve productivity, and to do that it would be most useful to understand, and quantify, the factors influencing it.

DECIPHERING THE FACTORS THAT INFLUENCE EDUCATIONAL PRODUCTIVITY

An explorative, quasi-systematic literature review, described in detail in section 2.1, revealed that the literature on factors influencing educational productivity is vast and ranges from factors that originate at policy level, in the home environment, at learner genetic level and within the school environment itself. It was decided to exclude factors that lie outside the reach of the researcher's field of study, Industrial Engineering, such as learner aptitude, development and self-concept, the home environment, the peer group, extra-curricular scheduling, socio-economic status etc. The factors included in this study focused on the factors within the control of the teacher and the school principal.

From the research, two factors emerged to be consistently trumping others in terms of their impact on productivity: the quality of teaching and the amount of time the learner spends 'on task'.

In a comparative study done by Sanders et al. (1997), the effect that an individual teacher can have on a student's learning, dwarfed other factors such as class size, learner achievement level, school system and grouping of learners according to aptitude. Another study placed twins in different classes and highlighted the positive correlation between teacher experience and learner achievement (Gerritsen et al., 2017). In a study aimed at capturing the traits of what constitutes an effective teacher, such a teacher was defined as one who would "foster the development of higher order thinking skills, promote creative thinking, embrace rigorous content, meet the individualised needs of their students, and incorporate real-life applications in their classrooms" (Cohen-Vogel et al., 2016).

Perhaps surprisingly, factors such as class size, financial expenditure per student and the type of governance (private or public) have relatively little impact on learning (Walberg, 1984, Ahlgrim, 2010, Dillon et al., 2002, Eberts and Stone, 1988, Hoxby, 2003). The length of a school period or school day also did not have a significant effect on learner achievement (Stallings et al., 1979, Stallings et al., 1975), but time on task, the effective use of allocated academic time, was found to have a positive correlation with learner achievement, especially in literacy and numeracy (Stallings, 1980, Fisher et al., 1978, Gettinger and Seibert, 2002, Prater, 1992).

The factors discussed here were frequently found in the literature review, but usually measured relative to a select number of other variables, making it difficult to assert that one factor is dominant as it was not compared to all factors. Although not exhaustive, the patterns found in the literature review indicated where productivity improvement are to be focused: The place where the input of teaching is converted into the output of learning, the school classroom.

Due to their training, Industrial Engineers are better equipped to contribute to maximising Time on Task than they are to enhance the quality of pedagogic instruction. For this reason, the researcher chose Time on Task as the productivity factor in scope for this research.

Improving productivity in the classroom will ultimately depend on teachers and principals, who will be the stakeholders implementing the required improvement changes. As this research aims to enable productivity improvement, the research design would need to be informed by literature on how to best engage with these critical stakeholders to effect change.

HOW CHANGE IS BEST EFFECTED IN EDUCATION

Although education shares many of the change management challenges found in most environments (Horsley and Kaser, 1999), some stood out as relatively unique to and pronounced in the education sector. These included:

1. A lack of urgency and coherence around improvement exists in schools as a result of a lack of awareness about who the customers are, and what their specific needs are (Antony et al., 2012).
2. Being a non-traded market, public education is not as competitive as other sectors, attracting less productive resources and with less incentive to improve (Hoxby, 1999, Hoxby, 2003).
3. The allocation of pupils to schools by school district administrations creates a situation where customer satisfaction is not a priority (Wohlstetter et al., 2008).
4. The power dynamics within schools, both amongst personnel as well as within the classroom were mentioned several times and seemed to be more pronounced than in normal corporate politics (Sarason, 1990, Horsley and Kaser, 1999, Flumerfelt and Green, 2013, Elmore, 2004).

Considering these unique challenges to effecting change in education, Elmore (2004) makes the following suggestion: “One does not ‘control’ school improvement processes so much as one guides them and provides direction for them, since most of the knowledge required for improvement must inevitably reside in the people who deliver instruction not in the people who manage them”. Flumerfelt and Green (2013) suggest the use of continuous improvement as a method to guide and create a culture of organisational learning. Several other researchers agree with a participatory approach to implementing change (Cohen-Vogel et al., 2016, Elmore and McLaughlin, 1988, English and Hill, 1994, Forman et al., 2017, Fullan, 2012, Horsley and Kaser, 1999, Senge, 1995)

Lean Management theory evolved from Scientific Management in post-World War II Japan as a more delicate and democratic approach to the powerful analytical methods propagated by Scientific Management (Tsutsui, 2001). Lean Management therefore has a high regard for the people at all levels of the focus domain and involves them in the improvement effort (Liker and Convis, 2012, Womack and Jones, 1997). Considering the change management challenges mentioned in the education literature, Lean Management offers a participatory improvement approach without sacrificing systematic, analytical, and scientific methods. Lean Management was thus selected as an appropriate theoretical framework for this research. Not only does the Lean Management approach address the eventual change management challenges, but also provides a unique perspective to the study of productivity.

TOWARDS 'BLUE LIGHT TIME' – A LEAN MANAGEMENT APPROACH

As an applied science, Lean Management studies the flow of work, or more specifically, the conversion of value through a system (Womack and Jones, 1997). The economy of this conversion, its productivity, is the focus of this research philosophy (Gaudet and Bergeron, 2016). In the book Lean Thinking, Womack and Jones (1997) define value as the transformation of the utility of form, state, place or ownership. It is thus only during transformation of a utility that value is added.

The researcher proposes that, in education, the form or state of a learner's neural pathways are transformed. New concepts are deposited, categorised and hard-wired. It is thus only in the moments that these transformations take place that value is truly added, and a valuable output is created.

The researcher received an illustration of value creation anecdotally but was unable to locate the source of this effective illustration in literature. The illustration is this: when an arc welder's welding rod touches the metal it is welding, it emits the blue-tinted ultra-violet (UV) light, which could be damaging to the eyes. Using the definition of value addition as the transformation of form, it is only in those moments that the form of the metal is being transformed, in other words when the welding takes place, that value is created. The "blue light moments" are thus the only value creating moments. When the welder repositions the metal or fits a new welding rod and the blue light stops, no value is being added to the metal.

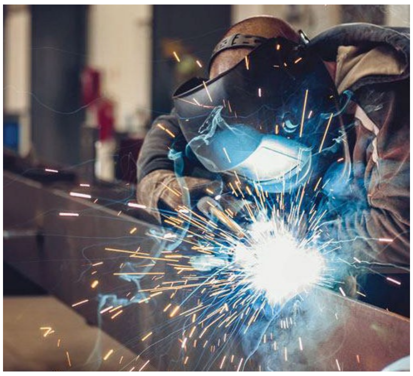

Figure 1: Blue UV light – arc welding

Building on the researcher's proposal regarding what constitutes value addition in education, the blue light moments are thus those moments where the learner's brain or neural pathways are transformed in line with what constitutes value. All other moments are therefore either waste or necessary set-up activities that prepare the learner for more blue light time.

These educational blue light moments take place during time on task activities, in other words in those moments when the learner is receiving instruction or engaging in learning activities. All time on task, however, does not constitute blue light moments. To be able to distinguish this, one would most likely require brain scans to discern. Optimising time on task does, however, take the productivity improvement effort one step closer to enable blue light time for the learner. How time on task could be studied effectively in the classroom was thus the next challenge to be solved.

STUDYING TIME ON TASK IN THE CLASSROOM

It was significant to note that, based on the more than 200 articles screened and more than 70 reviewed in depth during the explorative literature review, it was observed that the existing body of knowledge seems to focus mostly on high-level studies with data gathered at district or national level. A very small number of articles (less than five of the 200 screened initially) were practical efforts by an Industrial Engineer (IE) to improve productivity in a single school. Not in any of these cases were the improvement efforts focused inside the classroom, but rather on the support services such as infrastructure management and administration. There was, however, literature on both qualitative and quantitative classroom observation studies done by education researchers (Apter et al., 2020), but especially quantitative classroom observation studies are rare (Wragg, 2011). These reviews thus identified a potential gap in the research: Contributing to systematic quantitative classroom observation studies using IE theory which has, to date, been scarcely applied in the field, and not in the classroom at all.

Work study is a classic IE technique with its roots in Scientific Management and is “the systematic examination of the methods of carrying on activities so as to improve the effective use of resources and to set up standards of performance for the activities being carried out” (Kanawaty, 1992). In education, the work study equivalent is called systematic quantitative classroom observations (Wragg, 2011). Conducting quantitative studies in the classroom is thus not new, but the analysis of such data through the lens of an IE using Lean Management theory, could however be a novel and valid contribution to the productivity improvement effort in education.

As a systematic, quantitative observational method, work study is a good entry point for the IE as the time spent collecting quantitative data at the place where the actual work is done, is also a productive way of familiarising the IE with an unfamiliar improvement environment. The act of making numerous observations over a period also allows the IE to pick up productivity patterns within the work being observed, assisting in the identification of further IE techniques to be applied in the pursuit of productivity improvement within the unexplored environment. In this study, classroom observation data will be referred to interchangeably as work study data or quantitative classroom observation data.

The literature review on Time on Task helped the researcher to identify a model within a subsection of Lean Management theory, namely Total Productive Maintenance or TPM, which could prove useful as an analytical framework with which to study quantitative classroom data: Overall Equipment Effectiveness or OEE, as described by Hansen (2002). The literature on Time on Task referred to concepts such as ‘allocated academic time’ and ‘teacher loading time’ (Gettinger and Seibert, 2002, Fisher et al., 1978, Carroll, 1989, Federman, 2019), which corresponded conceptually to some of the terms used in OEE.

A literature review revealed that OEE is a widely used metric in manufacturing and mining, lauded for its analytical approach to the measurement of productivity in a way that enables the improvement thereof (De Ron and Rooda, 2006, Hansen, 2002, Muchiri and Pintelon, 2008). With its focus on how a machine spends its available time, it provides a framework with which to analyse how teachers and learners spend their time. It was thus decided to experiment with the use of OEE within the context of studying Time on Task in the school classroom to see if this could provide a novel and valid perspective to the study of productivity in the classroom.

1.2 Research Problem and Scope

The research up to this point has indicated that the productivity of the education sector has been declining for decades. Being the feeder industry to all other sectors in the economy, this is a concerning trend, especially given the changing workplace landscape. Excluding factors that lie outside the control of school management, the two factors that impact productivity the most are the quality of teaching and time spent on task. The latter factor was selected as the focus of the research due to the researcher's background of Industrial Engineering, which is well equipped to solve problems of time utilisation.

The research also identified the problem of the education sector's widely cited resistance to change with scholars recommending a more participatory approach when effecting change in schools. Lean Management, as a combination of Scientific Management and Human Resources was chosen as the theoretical framework with which to approach the problem at hand in a systematic, analytical but also participatory manner.

Within Lean Management, the model of OEE was identified as a potentially useful productivity metric with which to quantify and prioritise time on task losses in the classroom. This research would thus focus on the development and testing of a conceptually translated version of OEE for use in the classroom. The aim of such a model would be to enable productivity improvement in schools.

1.3 Research Questions and Methodology

Based on the background of the research problem outlined, the research question was articulated as follows:

Does Lean Management theory, and in particular the use of OEE as analytical framework for quantitative classroom observation studies, provide a novel and valid perspective with which to enable productivity improvement in schools?

The research was conducted in two main phases: a design phase and a testing and refinement phase (Figure 2). Chapter 3 describes the research methodology and design in detail, but it is summarised here to provide a high-level view of the approach followed in this dissertation.

PRELIMINARY LITERATURE REVIEW

The preliminary literature review already described in the introductory sections of this Chapter identified Time on Task as the productivity factor in focus and Lean Management as a potential improvement approach with which to engage a sector notoriously difficult to change. Within Lean Management, OEE was identified as a model which could be used as a conceptual base with which to identify Time on Task losses. Once identified, Lean Management could then potentially be used to exploit improvement opportunities.

PHASE 1: DEVELOPMENT OF THE TIME ON TASK ANALYSIS (TOTA) MODEL

Before OEE was selected as the theoretical framework to be used, literature was screened for alternative frameworks, but OEE was found to be the most suitable (section 2.3). The OEE framework was then conceptually translated through reviewing educational literature (section 2.4) for conceptual synonyms to the elements that make up the OEE framework. The result was a conceptual analytical model, named the Time on Task Analysis Model, or the TOTA model, described in section 3.1.

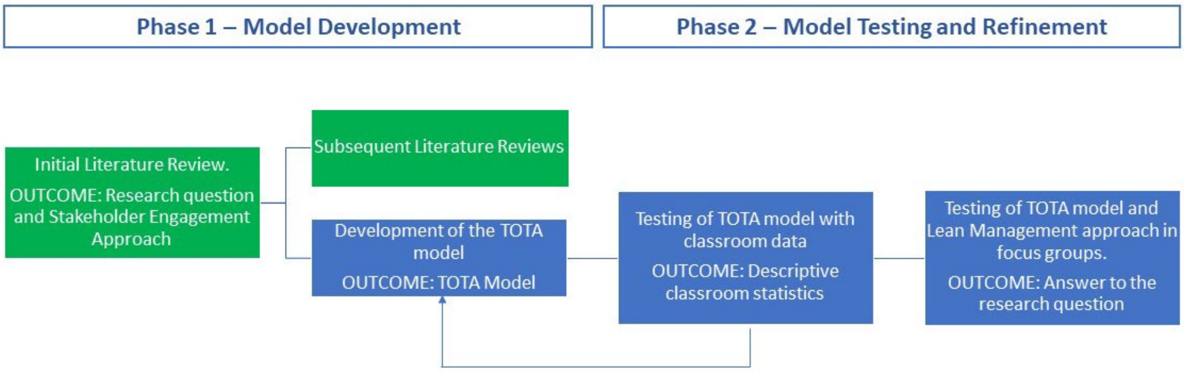

Figure 2: Research Phases

PHASE 2: TESTING AND REFINEMENT OF THE TOTA MODEL USING CLASSROOM DATA

Once the TOTA model was developed, it was tested using actual classroom data. Secondary classroom observation data was made available by a private primary school, which had commissioned the researcher in a private capacity to collect quantitative and qualitative data during a classroom observation project focused on the Intermediate Senior phase of the school in early 2020. The data set contained 450 lines of activities undertaken during 44 school periods, covering various subjects and teaching styles. The duration of those activities, as well as plenty field note observations were also contained in the data set. With its detailed observations and field notes, it provided a rich source of data to be analysed using the new TOTA framework to test its validity.

The work of Shanks et al. (2003) and Brown and Jayakody (2008) was combined to guide the validity testing of the model. Using an ontological approach, Shanks et al. (2003) reason that the validation of a conceptual model involves testing its faithful representation of the domain it is intended to represent. It is regarded as faithful when the model is accurate, complete, and conflict-free through the perspective of the domain stakeholders.

In this research, the accuracy of the conceptual model was tested in the focus groups by engaging 52 stakeholders in the focal domain of education. The completeness and freedom from conflict attributes were tested through the coding of the semantics found in the qualitative data of the classroom observations. The qualitative classroom data was coded line by line using a template created from the TOTA framework to test whether the semantics of the target domain were adequately and correctly described by the model, and whether the model was structurally sound. The structure of the framework was confirmed to be accurate, complete, and free from conceptual conflict with the semantics of the target domain. This testing phase allowed some refinement to be done at the detail level of the model where the definitions could be strengthened with more examples from the data. The model was however found to valid based on the validity attributes as defined by (Shanks et al., 2003).

Once the model had been tested against the semantics of the target domain, using the qualitative part of the data set, the model was further tested by using the model to process the quantitative data in the data set. The descriptive analytics produced by the conceptual model would be the showcase of semantics and analytical ability of the model to then finally be tested through the perspectives of the stakeholders in the target domain.

Brown and Jayakody (2008) added the following validity attributes to the ones required by Shanks et al. (2003) when testing systems such as those developed in Information Technology: individual impact, perceived organisational impact, perceived usefulness and intention to use. These additional four attributes were added for testing by the target stakeholders.

The descriptive statistics produced by the model were presented to five different focus groups, consisting of 52 education stakeholders to test the novelty and validity of the TOTA model in classroom data analysis to enable productivity improvement. The analysis produced by the model was perceived to be both novel and valid by the stakeholders of the target domain.

To test the selection of Lean Management as theoretical framework for the study, the focus groups were also introduced to the Lean Management principle of value creation as defined by (Womack and Jones, 1997) and specifically to how this translates into the classroom as the ultimate output measure of the productivity equation. The structured questionnaire completed after the presentation of the principles and data analysis included questions testing the Lean principle of involving all levels of employees in improvement efforts. The enthusiastic responses to these questions confirmed the choice of a Lean Management theory as guiding theoretical framework for the research and beyond.

1.4 Expected Contribution

The concept of blue light time is a powerful one that resonates as an illustration of true value-adding processes. Enabling more blue light moments in a school day will thus make schools more productive. Blue light moments, those moments of transformation in the learner's neural pathways might not be easy to measure yet, but optimising time on task for the learner might be a step towards the enabling of such blue light moments. This research aims to enable the measurement of time, as well as the diagnosis and prioritisation of time on task losses during a school day in a potentially novel and valid way. It also aims to test the participative approach of Lean Management theory to engage with and energise education stakeholders.

Quantitative classroom studies are not ubiquitous (Wragg, 2011), and where they do exist, they focus on a wide variety of phenomena in the classroom, ranging from gender interaction to how many open-ended questions were asked, or what method of instruction was used etc. Only a small number of studies focus on how time was spent in the school day (Apter et al., 2020). This study aims to introduce a new framework with which to extract and interpret quantitative classroom data to diagnose time on task losses. The diagnostic framework will thus enable the quantification and prioritisation of improvement opportunities.

Lean Management theory is also tested as an improvement approach with which to engage with and energise education stakeholders towards productivity improvement.

In this research, the Overall Equipment Effectiveness model was conceptually translated for use in the classroom. Secondary classroom observation data was then used to test the validity of the proposed model and the resulting analysis was presented to 52 education stakeholders in five different focus groups. The focus group participants were then asked to complete a structured survey to test the research questions. The outcomes of this research were the following:

1. Development of an analytical model and template for quantitative classroom observations focused on measuring and diagnosing time on task losses.
2. Descriptive analytics of classroom data using the developed model.
3. Analysis of the novelty and validity of the developed model.
4. Testing of effectiveness of using Lean Management principles to engage and energise education stakeholders towards improvement.

How these research objectives were achieved, is summarised in the next section.

1.5 Dissertation Structure

This introductory chapter has described the research problem, articulated the research question, and outlined the approach.

Chapter 2 contains the details of the literature reviews done to lay a sound academic foundation for this research by providing the link between the research objectives and existing literature. The chapter covers the definitions of key concepts applied; a critical review and synthesis of existing literature of the topics covered and the identification of gaps in the existing literature that are worth exploring in research.

Chapter 3 provides a detailed description of how the research was approached, describing the research methodology and techniques used, as well as the research ethics clearance process followed.

Chapter 4 contains the research outcomes of the various phases, with Chapter 5 closing this paper with a critical reflection on the research findings and proposed follow-up research. Chapter 5 also contains a review of the limitations of the research. How the literature review was approached and used to inform and shape this research, is detailed next.

2 LITERATURE REVIEW

Literature was reviewed before and throughout this study to add to the development of the research at the various phases. This chapter starts off with the approach used for the preliminary literature review, the synthesis of which has been described in sections 1.1 and 1.2 in providing the background and motivation for the study. The preliminary literature review led to the development of the research question described in section 1.3.

Three more phases of literature review were conducted during the research to ensure a solid academic base for the research and to link the research to existing literature. Once Lean Management theory was identified as a potential framework for this research, a review was done to establish its basic principles, the definitions of key concepts and to critically review it as a framework for this research. This review is described in section 2.2.

As Overall Equipment Effectiveness (OEE) was being considered as a possible framework, the literature was screened for alternative approaches. When OEE was selected, a review of its key concepts was done and is described in section 2.3.

Once the work began to conceptually translate OEE into what was to become the Time on Task Analysis (TOTA) Model, education literature had to be reviewed to identify terminology that could be used in the TOTA model. This review is described in section 2.4.

2.1 Preliminary Literature Review Leading to Research Questions

The preliminary study, already synthesised in the introductory section of this paper, was conducted to explore what was perceived to be a gap in the research and led to the definition of the research question.

PURPOSE OF THE REVIEW

The preliminary literature study was two-pronged. Firstly, the researcher wanted to gain an understanding of the field of study to:

- Determine productivity trends within education
- Understand how productivity is measured within education
- Identify the factors influencing productivity
- Identify challenges affecting improvement efforts in education.

The aims of the second part of the preliminary literature review were to:

- Establish to what extent Industrial Engineers (IEs) have contributed to the study of productivity in education
- Establish the nature of this involvement.

The purpose of the review was to identify gaps in the field of study, articulate the research question and inform the research methodology to be used.

REVIEW APPROACH SELECTED

To be able to screen literature as widely as possible to both find evidence of the involvement of IEs, as well as to orientate the researcher as to the key concepts surrounding productivity in education, the eight step approach as proposed by Okoli and Schabram (2010) was followed.

The articulated purposes of the literature review were analysed in a search term matrix (Bezuidenhout, 2019) to identify a comprehensive list of search terms. A total of 39 search terms were used (see Table 13 in Appendix A) and delivered 236 articles to be screened further.

To go about the screening process in a systematic way, the PRISMA approach as developed by Moher et al. (2009) was used for the screening of the initial 236 articles that had been identified. After screening for duplicates, scope, relevance, and quality, 46 articles were identified to contain relevant content of high quality. The inclusion and exclusion criteria are shown in Table 1.

Table 1: Assessment Criteria Used for Screening of Literature

	Inclusion Criteria	Exclusion Criteria
Focus	Secondary or primary schools unless the article is generic enough to be applied to primary and secondary education.	Industry focus Sociological focus Macro-economic focus Public policy focus
Format and Age	Post 1980	Pre-1980 unless cited post 1995. Unreadable format. Language unclear or difficult to follow. Poor academic writing such as lack of in-text citations, plagiarism, unsubstantiated claims.
Scope	Operations management in schools. Input factors that would influence education output.	Tertiary – e.g., productivity of business school research Narrow scope – such as minority groups or learning disabilities or gender specific focus Side scope – such as the effect of unionisation on teacher productivity
Geographical	All countries	Where the geography has unique cultural implications.

The PRISMA flow diagram in Figure 3 provides a visual representation of the screening process. A total of 236 articles were screened initially. This number greatly increased, easily doubled, during the study as an iterative approach was followed during the later phases of the research, which in turn produced new insights with which to further define and refine the research. For example, during the initial data extraction phase of the preliminary literature review, another 24 relevant articles were discovered in the referenced literature and added to the database, bringing the total number of articles studied during the preliminary phase to 70.

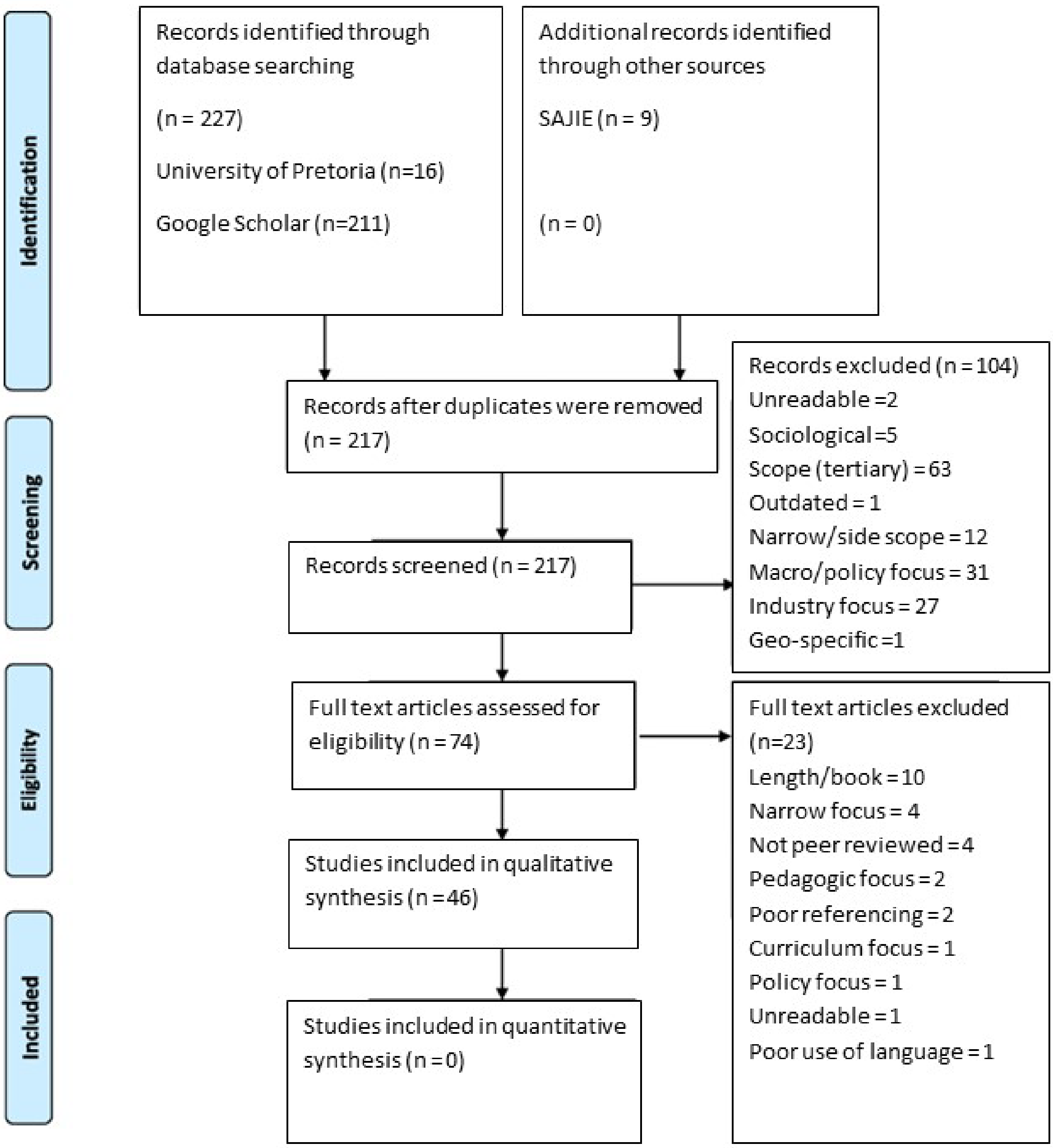

Figure 3: PRISMA Screening Process Flow Diagram (Moher et al., 2009)

SYNTHESIS OF THE LITERATURE REVIEWED – PRODUCTIVITY IN EDUCATION

The synthesis of the literature reviewed during this part of the research has been used in Chapter 1 to create the context of, and motivation for, the research and will not be repeated here, but summarised in its review outcome.

REVIEW OUTCOME

This outcome of this preliminary review was a deeper and broader understanding of the research environment, an identified gap in research and research approach as well as a theoretical framework to be used.

The research question was articulated as follows:

Does Lean Management theory, and in particular the use of OEE as analytical framework for quantitative classroom observation studies provide a novel and valid perspective with which to enable productivity improvement in schools?

The cautionary tales found in the literature on managing change in education, along with the identification of Time on Time as the productivity factor in scope for this research led to the selection of Lean Management as theoretical framework. To gain a sound academic base, a literature review was conducted on the subject and is described next.

2.2 Theoretical Framework

Lean Management has become a fashionable approach in business and the public sector alike, but in this mass adoption has, in many instances, become diluted and eroded (McCann et al., 2015). Delving into credible, published research on the theory provides both a prudent ballast as well as a stimulating source from which the research can be conducted.

REVIEW APPROACH

A narrative and theoretical literature review approach was used to identify and synthesise some of the seminal works in the field of Lean Management to fulfil the purpose of the review outlined in the introductory paragraph of this section.

Lean Management is also associated with search terms like kaizen, continuous improvement, Toyota Production System, Lean Six Sigma and Agile. The initial literature screening showed that the most literature exists on Lean Management and Lean Six Sigma. The other search terms were also used to identify seminal inputs into the thinking, but the term Lean Management was chosen to represent the body of knowledge described.

SYNTHESIS OF THE LITERATURE

The theoretical framework and its key concepts will first be described after which it will be critically assessed for goodness of fit to this research.

- *APPLICABLE FUNDAMENTAL CONCEPTS OF LEAN MANAGEMENT*

As an applied science, Lean Management studies the flow of work through a system, thus the conversion of value through a system. The economy of this conversion, its productivity, is the focus of this research. In order to improve flow, inefficiencies, or wastes, are studied and reduced through rigorous tools and techniques, which are usually experimental in nature as part of the continuous improvement philosophy (Gaudet and Bergeron, 2016).

With its emphasis on respecting the problem-solving inputs of the individuals at the place of value-addition, Lean Management in this regard, is part of the school of thought known as Social Constructivism, where knowledge is shaped by multiple actors, regarded as equals. This characteristic of Lean Management thus forms an intersection with the domain of Collaborative Science (Gaudet and Bergeron, 2016). With its view of all individuals within the organisation as amateur scientists, empowering them to experiment with flow and waste as the objects of study, it also shares similarities with the emerging field of Citizen Science. According to Riesch and Potter (2014), Citizen Science recognises the win-win scenario, where scientists (in organisations, the Industrial Engineers) get help from the public (in organisations, the general workforce) and where the participants (in organisations, the employees) gain an engagement experience (in Lean Management, kaizen) that involves them in real and meaningful scientific research (the study of flow). The collaborative approach was found to provide a solution for the difficulties faced in effecting change in education as discussed in the preliminary literature review.

In summary, Lean Management focuses on the continuous improvement of three dimensions:

- Waste reduction
- Value enhancement
- People involvement (Bicheno and Holweg, 2000).

This research aims to enable productivity improvement through the development of an analytical framework, based on a Lean Management tool called OEE. The developed analytical framework will be used to analyse quantitative classroom observation data to quantify and identify Time on Task losses, which will become themes for improvement. In Industrial Engineering, the equivalent of quantitative classroom observations is work study. Work study is a technique of Scientific Management (Baumgart and Neuhauser, 2009) and Scientific Management is also one of the roots of Lean Management (Tsutsui, 2001).

Scientific Management was adopted in manufacturing in pre-War Japan and after World War II the approach evolved through the incorporation of the Human Relations approach to address the key criticism of Taylorism, the dehumanisation of the worker, but also to address challenges facing industry such as the unionisation of the workforce (Tsutsui, 2001). Although the Human Relations movement was argued to be the antithesis to Taylorism among American academia, the Japanese application thereof, within the context of the Scientific Management training of the industrial engineers within the Japanese industry, such as Toyota's Taiichi Ohno, resulted in a more complementary interpretation of the two approaches (Waring, 2016). It is this interpretation of Lean Management: the combination of the strengths of Scientific Management with the strengths of the Collaborative Sciences, made necessary through the work done in Human Relations Science, that is used as theoretical framework for this study and influenced the research design of this study.

- JUSTIFICATION FOR THEORETICAL FRAMEWORK

The interpretation of Lean Management as Scientific Management enhanced through Human Relations theory, was considered an appropriate theoretical framework for this study for the following four reasons:

Firstly, with education being part of the Social Sciences, the selection of a Scientific Management tool as the basis from which to examine the productivity problem in schools, was deemed to be the most likely novel approach to the study of productivity in the classroom. Highlighting the overlap in Scientific Management and the principles of Lean Management, observation and objective data collection at the source are both part of the Scientific Management approach and the Lean Management principle of Genshi Genbutsu, where the problem is studied first-hand at the place where the value-adding work takes place (Bicheno and Holweg, 2000). Trained in the Scientific Management school of thought as a young engineer in pre-War Japan (Cameron and Pertuze, 2009), Taiichi Ohno, the father of the Toyota Production System, was known for making young engineers stand in a demarcated "Ohno Circle" within the workplace for extended periods of time in order to learn to study the problem first hand (Liker and Convis, 2012).

Secondly, although not unique to the education sphere, the adoption of change has been proven to be notoriously difficult in schools (Fullan, 2012, Sarason, 1996, Senge, 1995). This indicates the need for a more delicate and democratic approach to change, which is the reasoning behind the selection of Lean Management as interpreted here, and thus also explains the rejection of Scientific Management in its original form as it would not be effective in addressing the change management challenge.

Thirdly, Lean Management theory covers a wide range of aspects of operations management and improvement, equipping the Industrial Engineer with a diverse range of tools and techniques with which to explore an environment that does not yet have a predictable Industrial Engineering approach. This characteristic of Lean Management therefore provides flexibility and range.

Fourthly, the analysed view of Lean Management as made up of the components of Scientific Management and Human Relations Science/Collaboration Science provided a way of presenting a thorough analysis of work study data (Scientific Management) to the stakeholders who would be collaborating in the effecting of the change within their environment (Collaborative Science), thus simultaneously collecting their input on the novelty and validity of the quantitative classroom data analytical framework, but also creating some form of buy-in to further research and cooperation. A pure Scientific Management approach might have the Industrial Engineer do the analysis and make the deductions and recommendations more independently resulting in the poor adoption by a difficult change environment. A pure Collaborative Science approach might put too much weight on qualitative input, forsaking the strength that empirical techniques bring to the debate. The research design thus focused on combining quantitative and qualitative research to make the research as usable as possible for the greater goal of the research: Improving productivity in schools.

- *VALIDATION OF THE THEORETICAL FRAMEWORK*

An indication that the choice of Lean Management as overarching theoretical framework was appropriate, was that the testing of the developed framework with actual classroom data confirmed the validity of the choice of using OEE, a Lean Management tool, as a theoretical framework. OEE is a diagnostic productivity metric that forms part of Total Productive Maintenance (TPM), which in turn became part of the Lean Manufacturing approach in the 1950s Japan (Hansen, 2002). The developed model was found to be valid, proving logical consistency in the selection of the theoretical framework (Fereday and Muir-Cochrane, 2006).

A further indication that Lean Management theory provided a good basis for approaching the problem of productivity in schools was the positive response that teachers specifically showed to the presentation of the work study data analysis (Chapter 4.3), showing that the people involvement principle of Lean Management, provided a good point of departure for the study of, and potentially the improvement of, productivity in schools.

- *LIMITATIONS OF THE THEORETICAL FRAMEWORK*

This section will start with a disclaimer: Lean Management proved valuable as a theoretical framework for this study as it contains many useful principles which could be used to ensure that the study contributes valuable research given the constraints and challenges of the environment. Interpreting the use of the theoretical principles, as it is done here, should not be interpreted as an endorsement to be used in practice. Lean Management is easily misplaced as a solution when it is in actual fact only successful when implemented in a systematic, holistic way that focuses on the long term establishment of a continuous improvement culture, driven by the leadership of the company (Liker and Convis, 2012).

Secondly, with its roots in manufacturing, lean management theory has to be conceptually translated into other environments, including that of the classroom (Cusumano, 1994, James-Moore and Gibbons, 1997). This is an exciting intellectual challenge, but one that can easily translate basic principles in either a too shallow or too far-fetched manner. It is thus the responsibility of the researcher to be aware of these two risks and follow a rigorous approach to prevent these dangers.

A further limitation is also potentially controversial: In manufacturing, the value-adding work is done by machines and humans. In education it is done by teachers and learner (and computers to a growing extent). Applying the diagnostic metric of OEE to a classroom, also implies that the learners are conceptually like machines, a potentially offensive concept to some if read out of context. The researcher must therefore be sensitive to the language used and ensure that, where necessary, the conceptual bridges between the two environments are well built.

Lastly, being an applied science, the first principles of Lean Management theory, are often interpreted and applied within complicated contexts such as that of companies, with their entrenched organisational cultures and legacy systems. This, amongst other criticisms, leads some critics to question the validity of the theory (Samuel, 2013). When applying Lean Management as theoretical framework, it is imperative to understand the first principles of the theory before application and translation. Several factors add to the challenge of extracting these first principles. Firstly, the fact that much of Lean Management evolved from Japanese Management, deeply entrenched in the Japanese culture, and thinking, translation of the concepts between languages and cultural contexts created an opportunity for the misinterpretation of these first principles. Secondly, the fact that the theory has been evolving for more than a century, makes it difficult to find a singular, consistent source of the first principles.

REVIEW OUTCOME

The literature review assisted in highlighting the synergies to be gained by designing the research around the components of Scientific Management and Collaborative Science. While ensuring that the research question was answered, the approach followed also enabled the identification of further research in directions that could be significant to the problem of productivity in schools.

The Lean Management tool of OEE has been mentioned several times in this paper thus far. The metric will be discussed in more detail next.

2.3 Analytical Productivity Metrics

The concept of 'blue-light time' was explained in Chapter 1 as a useful illustration for the concept of value-addition in a system. Time on Task was selected as the classroom productivity factor that would bring the productivity improvement thinking closer to blue light time. A Lean Management metric, called OEE was chosen as a conceptual framework for the analysis of classroom data due to its analytical power to quantify and identify time losses (Dal et al., 2000, Muchiri and Pintelon, 2008). This literature review also screened for alternative and potentially more suitable metrics, but OEE emerged as the metric with potentially the most novel and valid contribution.

REVIEW PURPOSE AND APPROACH

A literature review was done to:

1. Ensure that the theory of OEE is accurately understood
2. Screen for other metrics using the multiplier principle found in OEE to ascertain whether there is a similar metric available in or more closely related to the field of education.

An iterative, narrative review approach was followed whereby literature reviewed often led new search terms to explore. Academics in the field of economics, management sciences and education were also consulted to screen for alternatives and to point the researcher towards new search terms.

SYNTHESIS OF THE LITERATURE REVIEWED - OEE

In 1988, Nakajima introduced a novel quantitative metric for the measurement of productivity, namely OEE (De Ron and Rooda, 2006, Jonsson and Lesshammar, 1999, Muchiri and Pintelon, 2008). The metric was used within the context of Total Productive Maintenance (TPM), a branch of Lean Management, to increase the productivity of machines and equipment (Andersson and Bellgran, 2015).

OEE expresses the productivity of a machine as a function of an availability, performance, and quality rate (Dal et al., 2000, Muchiri and Pintelon, 2008). The various productivity losses measured by OEE are shown in Figure 4 and referred to as 'the six big losses'.

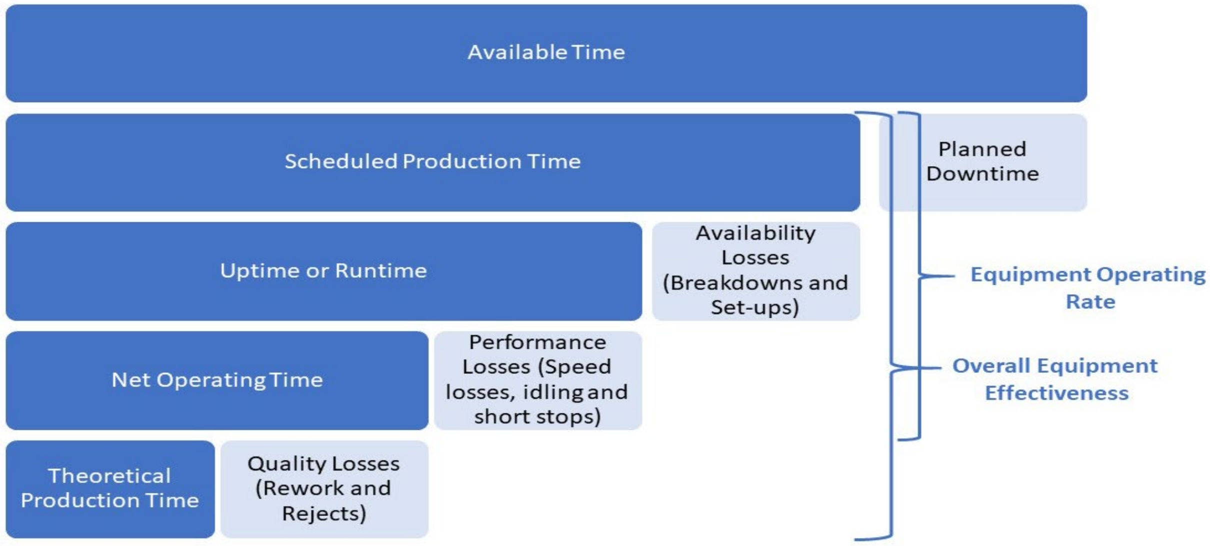

Figure 4: Perspectives of Performance Integrated into OEE (Muchiri and Pintelon, 2008).

The strength of the OEE metric lies partly in its multiplier effect, which prevents various productivity factors from being measured in isolation but highlights the compound effect that these factors have on productivity overall. To illustrate this point, the formula for OEE, as described in the seminal work of Hansen (2002), is:

$$OEE = Availability\ Rate\ x\ Performance\ Rate\ x\ Quality\ Rate$$

Where Operating Time is denoted by *OT*, Loading Time by *LT*, Net Operating Time by OT_n and Valuable Operating Time by OT_v, the expanded form of OEE is expressed as:

$$OEE = \frac{OT}{LT}\ x\ \frac{OT_n}{OT}\ x\ \frac{OT_v}{OT_n}$$

Therefore, essentially reducing to the compound effect:

$$OEE = \frac{OT_v}{LT}$$

Which correlates with the generic formula for productivity (*P*) of Output (*O*) divided by Input (*I*):

$$P = \frac{O}{I}$$

As mentioned, the compound effect of this metric is particularly advantageous to gain a synthesised view of the effect that different productivity factors have on overall productivity. OEE, is however, not only a productivity measure. It is also a powerful diagnostic tool in that it is able to pinpoint which of ‘the six big losses’ shown in Figure 4 contribute to a machine’s lower productivity rate.

Due to the researcher’s familiarity with the use of OEE in manufacturing and mining, the OEE analytical method was front-of-mind as a conceptual solution to the problem of measuring Time on Task in the classroom with its analytical method that could enable improvement. The concept of Time on Task however is the equivalent of Net Operating Time in the OEE formula and thus more closely resembles a truncated, lesser-known version of OEE called Overall Equipment Operating Rate (OEOR), which does not take into account the quality aspect included in OEE (Kobayashi, 1995). Figure 4 demonstrates the difference between OEE and OEOR. The secondary classroom observation data confirmed the choice of using the truncated version of OEE as it also did not include the quality of the learning that took place during Time on Task as this happens in the learner's mind and can therefore not be observed during a classroom work study. Work studies can however be set up to easily assess the availability and the performance of a group of learners, which is the two elements measure by OEOR. Section 4.1 provides more insight into how the truncated version of OEE provided insight into the interpretation of the data set.

To counter the researcher's bias towards OEE due to her experience in using OEE in industry, a subsequent literature review was conducted to find similar metrics being used within the education sector or a sector more closely related to that of education. To aid with the identification of search terms, informal discussions were held with acquaintances of the researcher who held senior positions in business and held PhD degrees in their individual fields. These individuals included an economist, a general manager, an educational academic with a large education corporate and an education academic at a tertiary institution. The principle of OEE was explained to these individuals, specifically pointing out the analytical powers of the metric, but none of the individuals were aware of a similar metric in their fields.

Two similar metrics were identified in the screening process – one in education and one in management accounting. The literature reviews for these metrics are described next:

A MODEL OF SCHOOL LEARNING

Articles published as recently as 2020 (Kraft and Monti-Nussbaum, 2020), still refer to the paper by Carroll (1963) as the seminal work on the allocation of time in the classroom. A Model of School Learning by (Carroll, 1963) described learning as being a function of available learning time, available teaching time and the quality of the teaching. This definition echoes the thinking behind OEE.

Carroll (1963) synthesised five factors that influence learning productivity into the following formula with the degree of learning denoted by DL, Time actually spent by T_a and Time needed by T_n:

$$DL = f(\frac{T_a}{T_n})$$

This function could be influence by three factors in the individual:

1. Aptitude or the amount of time needed to learn a task under optimal instructional conditions
2. Ability to understand instruction
3. Perseverance or the amount of time the learner is willing to engage actively in learning.

The factors external to the individual leaner are:

4. Opportunity or time allowed for learning
5. Quality of instruction or a measure of the degree to which instruction is presented so that it will not require additional time for mastery beyond that required in view of aptitude.

In a later article, Carroll (1989) discusses developments and expansions made based on his model, including that of Walberg (1984) discussed in section 2.1, but these expansions did not build on the formula per se, but rather on how to influence the variables. Although Carroll was the first to describe learning as a function of different variables, he ended up synthesising them into a reduced efficiency formula. OEE proposes the opposite of this: analysis rather than synthesis. As Aristotle is quoted by (Beaney, 2021):

"For a doctor does not deliberate whether he shall heal, nor an orator whether he shall convince… Having set the end, they consider how and by what means it is to be attained; and if it seems to be produced by several means they consider by which it is most easily and best produced."

As Aristotle so eloquently explained, the objective of this research is clear: improving productivity in schools. The task is to find out how to improve it. By using an analytical metric such as OEE, a diagnostic power can be harnessed by keeping the components of the productivity formula separate as long as possible in the calculation in order to identify specific productivity losses. Carroll's model thus lacks the analytical strengths of OEE and therefore OEE remained the theoretical basis for the analysis.

The other similar metric identified in the literature was in the field of management accounting, namely Du Pont Analysis.

DU PONT ANALYSIS

According to Jansen et al. (2012) Du Pont Analysis deconstructs the Return on Assets (ROA) ratio into two components useful in the analysis of profitability and changes in profitability of a firm. Jewell and Mankin (2011) found that the most frequently used formula for the calculation of Return on Assets (*ROA*) is that of Net Income (I_n) divided by Total Assets (A_t):

$$ROA = \frac{I_n}{A_t}$$

In Du Pont analysis, Jewell and Mankin (2011) deconstruct this ROA formula as follows, with Sales denoted by S, Total Assets by A_t and Profit by P:

$$ROA = \frac{S}{A_t} \, x \, \frac{P}{S}$$

Which essentially reduces the ROA to the product of the classical Asset Turnover Ratio (ATO) and the Profit Margin (PM).

Although the metric is similar in its use of deconstruction to analyse the state of a metric more accurately, the Du Pont Analysis does not offer a significant benefit over that of the more widely used and described OEE. It was thus decided to use OEE as theoretical basis with which to measure and analyse Time on Task losses in the classroom.

REVIEW OUTCOME

This literature review thus screened for more suitable, but similar, metrics to OEE, found only two possible alternatives, but they either did not have the same level of analytical strength, as in the case of the Model of School Learning, or did not have the same amount of detail or published literature as OEE, as in the case of Du Pont Analysis. OEE was thus confirmed as conceptual base to be used.

The next step of the model development required the conceptual translation of the truncated OEE framework for use in the classroom, which would require the study of the six OEE losses (Figure 4) and the identification of existing education terminology to be used in the development of the TOTA model. The next section describes the literature review conducted for this task.

2.4 Terminology for Use in Conceptual Translation

Once OEE was identified as the appropriate analytical framework to use, an in-depth literature review was conducted of the OEE metric itself, but also of terminology used in education.

The literature review described in section 2.3 also served to identify relevant literature to be used to provide a sound academic base for the in-depth study of the OEE framework. The seminal work of Hansen (2002) was to be used for an in-depth study of OEE, with the literature review of Muchiri and Pintelon (2008) and critical analyses of Dal et al. (2000) and De Ron and Rooda (2006) providing background information as input to the conceptual thinking to be done in the translation and application of the model. The first step was thus to study the components of OEE, to be able to provide a sound academic base from which the conceptual translation of the framework could be done.

Once the elements of OEE were defined, a literature review was to be done to find educational terminology and vocabulary that could be used to translate the OEE elements for use in the classroom. A search term matrix was used to identify possible synonyms for the OEE terms to screen literature for relevant terms. Identified terms were then reviewed using a narrative literature review approach in order to ascertain their goodness of fit for use in the proposed model.

SYNTHESIS OF THE LITERATURE REVIEWED – OEE TERMINOLOGY

The work of Hansen (2002) was used to define the components of OEE to be translated for use in the classroom. The definitions are given in Table 2.

Table 2: OEE Terms and Definitions

OEE terms to be translated	Definitions of terms as defined by Hansen (2002)
Loading Time	Also called Scheduled Time or Planned Production Time. The time that normal operations intend to make production. It includes all events that are common to meeting delivery schedules, such as product changeovers or transitions, set ups, information downloads, all production run time, and unplanned stoppages for equipment, people, quality, and testing.
Downtime	All unplanned machine downtime events should be categorised into the following categories: Downtime technical: Downtime due to any equipment failures affecting the machine or process, including periphery equipment (utilities, sprinklers, doors, humidifiers etc), equipment failure due to maintenance errors, and equipment-caused dirt or scratches.

	Downtime operational: downtime caused by not following procedures, operating outside of specifications, operator error, etc. Downtime quality: Downtime caused by non-conforming supplies and raw materials, process control problems, unplanned testing, non-manufacturable product, and dirt from the product or process.
Changeovers	Planned stop time which includes operational actions such as product changeovers, and size changes, as well as standard testing, planned material loading, and required documentation.
Operating Time	Also called Runtime or Uptime. The portion of loading time when the system is actually making product.
Net Operating Time	The portion of operating time when the system is working at full speed without any idling or short stops.
Speed Loss	The percentage reduction of OEE due to running the equipment slower than the ideal rate for the size or format or product family. It represents the difference between the theoretical time and the actual time to make the product or run the cycle.
Ideal rate	Also called ideal Cycle Time or Theoretical Rate or Ideal Speed Rate. The best rate or speed for key equipment or the flow line bottleneck, given a size or format of product.
Idling	Also called Stop Time Induced. The amount of time the line is down due to external or non-machine reasons such as lack of materials and supplies, people, information or due to unplanned meetings.
Quality Loss	Also called waste. The total waste rate of the normal process. This should include structural waste, incident waste, testing waste, and recall waste.

Although not all of its contribution can be captured here, the book Overall Equipment Effectiveness by Hansen (2002) was consulted throughout the development of the model for explanations and deeper insight into the interpretations and categorisations of specific losses to stimulate thinking and guide the conceptual translation work.

With the definitions in mind and the literature available as reference, the work of the conceptual translation could begin. The terminology identified in the literature review is described next.

SYNTHESIS OF THE LITERATURE REVIEWED – EDUCATION TERMINOLOGY

The first concept identified to be of possible use to the translation of OEE for use in the classroom, was that of Time On Task as first described by Stallings (1980), but also described earlier in the work of Carroll (1963) as the time spent "paying attention" or "trying to learn". Time on task, also known as engaged time, refers to the amount of time students spend attending to school-related tasks (Prater, 1992). This then describes the time that the learner is engaged in structured schoolwork (of unknown quality) in the time allocated as academic time. When related to the OEE terms, it closely relates to Net Operating Time, although the ideal speed element is not taken into consideration.

Allocated Academic Learning Time was also identified in the review as a term to be used in the OEE translation. Described by Carroll (1963) as "opportunity", the term was coined by Fisher et al. (1978) in a landmark study. The term describes the amount of planned time allocated to instructional activities and therefore represents the upper limit of in-class opportunities for students to be engaged in learning (Gettinger and Seibert, 2002). In the OEE terms demonstrated in Figure 4, Allocated Academic Learning Time is the Equivalent of Loading Time.

Downtime in education is called interruptions. The literature classified them as either external or internal interruptions. The term external interruptions describes those "intrusions from outside the classroom that are not under the direct control of classroom teachers" (Kraft and Monti-Nussbaum, 2020). Internal interruptions are caused by off-task student behaviour (Little & Akin-Little, 2008; McLeod, Fisher & Hoover, 2003). Unlike internal interruptions, many external interruptions are caused by school staff and are under the direct control of the school leadership. Commonly cited examples of external interruptions include announcements made through school intercom systems, calls to classroom phones, classroom "drive-bys" by school staff, a term used in education literature for unplanned informal meetings during class time between teachers (Kraft and Monti-Nussbaum, 2020), and student pull-outs.

Some terms discovered did not exactly correlate to that used in OEE. To avoid introducing confusion in literature, new terms were used where necessary. Table 3 provides a summary of terms identified and used.

Table 3: Education Terms Used in the Time on Task Analytical (TOTA) Model

OEE terms to be translated	Educational terms used
Loading Time	Allocated Academic Time
MINUS Availability Losses **Downtime** **Changeovers**	 Internal and external interruptions No single term found. Set-up time used. Some terms found: Teacher preparation time (Whiteley and Richard, 2012) Class changes
EQUALS Operating Time	No equivalent found. Available Academic Time used
MINUS Speed Losses	Learner-generated interruptions
EQUALS Net Operating Time	Time on Task
MINUS Defect Losses	Out of scope
Valuable Operating Time	Out of scope

REVIEW OUTCOME

The review's ultimate outcome was the refined analytical model discussed in section 4.1 but provided the vocabulary and conceptual groundwork for the development of the model.

2.5 Conclusion

The literature review was extensive as it covered many topics but greatly added to the development of the research at the various phases. The reviews also helped the researcher lay a sound academic foundation for the research by providing the link between the research objectives and existing literature. The review also assisted in identifying and confirming some gaps in the literature that could lead to further research, which is described in section 5.4.

The preliminary literature review, as well as that for the theoretical framework, provided the background needed to conceptualise the research methodology, which is described in Chapter 3.

3 RESEARCH METHODOLOGY

The research methodology and design used for this research are discussed in detail in this chapter and uses the research schematic shown in Figure 5 as navigational tool. The research comprised two phases:

Phase 1: The development of a model with which to measure and quantify Time on Task losses in the classroom. The model was called the Time on Task Analysis (TOTA) model. This phase also included the identification of a productivity improvement approach, namely the core principles found in Lean Management.

Phase 2: The testing and refinement of the TOTA model using secondary classroom observation data and focus group responses.

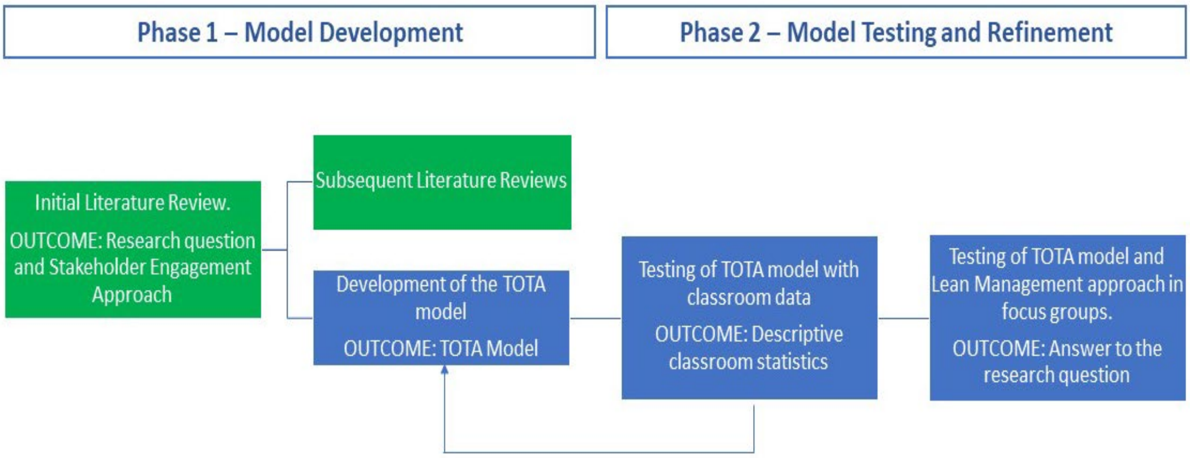

Figure 5: Research Schematic

RESEARCH ETHICS

The process of the Ethics Committee of the Faculty of Engineering, Built Environment, and Information Technology (EBIT) of the University of Pretoria (UP) was followed to ensure the research described here was conducted in line with the ethics protocol of the University. Ethics clearance was obtained on 17 April 2021 and data collection commenced on 23 June 2021.

The following actions were taken to comply to the ethics protocol:

- Company permission was obtained for the use of secondary data.
- Company permission was obtained to engage with the focus group participants as informants.
- A Non-Disclosure Agreement was signed with the company.
- Ethics clearance was required for the use of people as informants in the focus group surveys.
- Informed Consent was sought from each participant.
- Data was collected anonymously, handled confidentially, and stored securely.

3.1 Phase 1: Model Development

The preliminary and subsequent literature reviews described in Chapters 1 and 2 of this paper provided the groundwork for the conceptual thinking that needed to be done. Understanding the factors influencing productivity in education led to the selection of Time on Task as the targeted variable as well as the selection of Lean Management as a theoretical framework with which to engage with education stakeholders during the focus groups and beyond. It also formulated the research question as follows:

Does Lean Management theory, and in particular the use of Overall Equipment Effectiveness (OEE) as analytical framework for quantitative classroom observation studies provide a novel and valid perspective with which to enable productivity improvement in schools?

Once OEE was selected as the Lean Management tool to be used as conceptual framework for analysing Time on Task losses in quantitative classroom observations (process described in section 2.3), both OEE terminology and the equivalent terminology used in education were identified and defined through literature reviews (described in section 2.4).

The development of the model was thus done by triangulating (Figure 6) the existing and proven theoretical base, namely OEE, with terminology and definitions from the target domain of education and then testing the structural model through the coding of qualitative classroom data reflecting the semantics and reality of the target domain. The resulting framework, named the TOTA model is described as the outcome of this phase of the research and is presented in section 4.1.

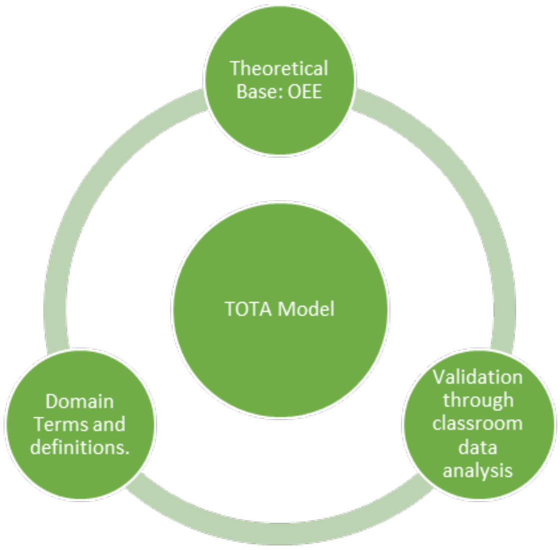

Figure 6: Triangulation during Model Development

At this stage of the paper, it is important to note that the TOTA model breaks the school day into six hierarchical levels of detail. The six losses of OEE appear in the fourth level, meaning that the losses were described in two more levels of detail categories. These hierarchical categories – the sub-categories and how they are grouped into the higher-level categories were to be tested in the next phase.

Once the model had been conceptualised from the reviewed literature, it was ready to be tested for validity and eventually also novelty. The research methodology of this second phase is described next under the following sub-headings:

- Model Testing Through Qualitative Classroom Data Analysis
- Model Testing Through Quantitative Classroom Data Analysis
- Model Testing Through Focus Groups
- Analysis of Focus Group Responses

MODEL TESTING

Two widely cited articles (Brown and Jayakody, 2008, Shanks et al., 2003) on the validation of conceptual models were used to design the testing of the conceptual model.

Using an ontological approach, Shanks et al. (2003) reason that the validation of a conceptual model involves testing its faithful representation of the domain it is intended to represent. It is regarded as faithful when the model is accurate, complete, and conflict-free through the perspective of the domain stakeholders. Table 4 contains the definitions of these attributes as defined by Shanks et al. (2003).

Table 4: Attributes of a Valid Model (Shanks et al., 2003)

Model Attribute	Attribute Definition
Accuracy	The model should accurately represent the semantics of the focal domain as perceived by the stakeholder(s) of the focal domain.
Completeness	The model should completely represent the semantics of the focal domain as perceived by the focal stakeholder(s)
Conflict-free	The semantics represented in different parts of the model should not contradict one another; and there should be no redundancy. To reduce the likelihood of conflicts arising if and when the model is subsequently updated the model should not contain redundant semantics.

In this research, the accuracy of the conceptual model was tested in the focus groups by engaging 52 stakeholders in the focal domain of education (section 3.4). The completeness and freedom from conflict attributes were tested through the qualitative coding of the 450 lines of classroom observations (section 3.2).

In a review of the work done in Information Systems design, Brown and Jayakody (2008) describe the evolution of the seminal model for validation testing developed by DeLone and McLean (1992). This review added the following attributes to the ones required by Shanks et al. (2003):

- Individual Impact
- Perceived Organisational Impact
- Perceived Usefulness
- Intention to use

These additional four attributes would also be testing the focus group setting (section 3.4).

3.2 Phase 2A: Model Testing Through Qualitative Classroom Data Analysis

Secondary classroom observation data was made available by a private primary school and contained 450 activities undertaken during 44 school periods and covered the following:

- Activity start time
- Activity duration
- Activity description

- Some field notes

A sample of the secondary data is shown in Table 5. As can be seen in the sample, observations were often done by the minute, evidence of the level of detail observed.

Table 5: Sample of Secondary Data Obtained

START		DURATION	DESCRIPTION OF ACTIVITY	FIELD NOTES
8	1	5	learners waiting outside, asked to take out diaries and pencil cases while Amy and Gregg clarify something for Gregg.	
8	6	4	Learners walk in and take out books	
8	10	2	Giving of assignment - MasterChef using preserve	
8	12	1	Revision - Global Competencies	
8	13	9	Going through steps of assignment (not MAKE preserve, USE preserve)	
8	22	1	learners seem saturated with detail 1 minute before all steps worked through	22 learners out of 25 attending
8	23	1	Teacher gives activity for learners while setting up laptop	17 learners working on activity out of
8	24	1	One learner goes to bathroom	
8	25	2	Teacher explains timetable change	learner arrives at door with document
8	27	1	Learners left to carry on	9 learners back to activity
8	28	2	learner arrives back from toilet break	
8	30	2	Teacher needs to call to order, moves learners around.	
8	32	-	Asks learners if they have good midterm	4 learners keep writing
8	32	1	Teacher announces 5 minutes to chat amongst themselves about midterm - learners line up	
8	33	1	Learners are asked to pack up	
8	34	1	Learners asked to stand and wait for all learners to finish packing up.	
8	35	1	learners dispersed	
8	36	1	Next class starts walking in	GRADE 7
8	37	1	Teacher needs to organise corridor outside	
8	38	2	Learners take out books	

The qualitative data, meaning the descriptions of the classroom activities, providing the semantics and structure of the focal domain (Shanks et al., 2003) was coded line by line into a template created from the developed TOTA model. The coding of each of the 450 classroom activities tested the completeness of the model and screened for conflict as defined in Table 4, by either finding that the activity (the semantics) easily slotted into the semantics of a developed category of the model or highlighting where the model needed further categorisation or detail.

The model structure was found to be accurate, complete, and conflict-free at the structural level, meaning the level at which higher level and medium level major losses were defined. The detail category definitions were strengthened through the streamlining of category names and the addition of more examples to some of the definitions. This enhanced user-friendliness and clarity of the model but did not challenge the validity of the structure.

The coding of the data was done in Microsoft Excel, which provided flexibility and visibility of the data. The manual handling of data as opposed to a more automated approach of using dedicated software was found to be important in the iterative process. Table 6 shows a sample of the coding work done.

Once the qualitative testing had confirmed the completeness and conflict-freedom of the model and had added to the robustness of the detail definitions and categorisations of the model, the model was further tested by using it to process the quantitative part of the data set.

Table 6: Sample of Early Phase of Model Testing and Refinement

Notes:			School day																																	
			Scheduled non-academic time							Scheduled academic time																										
			Events		Breaks					Availability losses																	Available academic time									
										Interruptions									Set-up								Opportunity losses		Time on Task							
										External					Internal				Logistics			Academic				Non-academic			Instruction		Group		Individual			
Activity Start Time Stamp	Duration	Activity Description	Routine	Non-routine	Snack breaks	Concentration breaks	Set-up: Teaching preparation	Meetings	Other	Administrative	"Drive-by"	Maintenance	Resource availability	Other	Discipline issues	Off-topic discussions	Other	Other	Class change-overs	In-class configuration	Other	Progress monitoring	Work instructions	Feedback	Other		Short stops (<20sec)	Speed losses/Idling	Revision	New	Class group work	Physical education	Workbook	Electronic	Assessment	
	361		0	0									5	0	11	0		0	57	40	0	1	14	0	0	0	0	59.0724638	5	0	27		36.2608696	67.75	0.41666667	0
	1	Line up outside class																	1																	
	1	Walk into class and greet																	1																	
	1	Sit down and take out books																		1																
	1	Listen to instructions																					1													
	2	Start activity																										2					0			
	27	Learners do maths workbook activity																										0					27			
	3	12 learners busy with school workbooks, 11 colour in, read																										1					2			
	3	Supervised class																										2					1			
	1	Supervised class																										1					0			
	6	Supervised class																										4					2			
	4	Supervised class																										3					1			
	5	Supervised class																										3					2			
	5	Supervised class																										4					1			
	0	Asked to pack up																	0																	
	1	Learners go to class																	1																	
	0	arrive at ENGLISH																	0																	
	3	walk in and settle down, lots of kids at tecaher																	3																	
	1	Asked to take out books																		1																
	2	Start listening about homework																					2													
	1	Pack away signed work																		1																
	1	Take out speeches																		1																
	2	Arrangements around sound for speeches																		2																
	2	Get classroom ready for speeches																		2																
	2	Speech 1 starts																										1.9167							0.0833	
	1	Speech 2 setup																		1																
	3	Speech 2 starts																										2.875							0.125	
	1	Speech 3 set up																		1																
	3	Speech 3 starts																										2.875							0.125	
	1	Speech 4 set up																		1																
	2	Speech 4 starts																										1.9167							0.0833	

Classroom activity descriptions

Hierarchical categories of the TOTA model

3.3 Phase 2B: Model Testing through Quantitative Classroom Data Analysis

This phase of the research delivered another round of testing using empirical classroom data, but also produced the descriptive analytics to be presented to the focus groups to demonstrate the TOTA model. These analytics served to showcase both the semantics and analytical ability of the TOTA model to stakeholders in the target domain who would then be asked to assess the validity attributes of Brown and Jayakody (2008), namely individual impact, perceived organisational impact, perceived usefulness and intention to use.

During the coding of the qualitative data in phase 2A as described in section 3.2, the quantitative data, the duration of each activity, had also been categorised in the TOTA Excel template shown in Table 6. From this template descriptive statistics could be created producing different levels of the hierarchical detail produced by the TOTA model.

This round of testing investigated whether the TOTA model could deliver a level of detail to be used in productivity improvement – in the width and depth of the hierarchical categories. These different levels of descriptive detail will become apparent in section 4.3 where the descriptive analytics are described in detail, but the following list shows some of the analysis made possible by the data and TOTA model:

- A breakdown of individual school days – both from teachers' and learners' perspectives - at the three levels of the TOTA model hierarchy:
    - A detailed view
    - A themed view
    - A broader themed view
- A breakdown of the consolidated data of observed school days, also at the three hierarchical levels
- A comparison of the different teaching days and styles observed, also at the three hierarchical levels
- A breakdown of one specific theme: available learning time

- A breakdown of another specific theme: set-up time
- The 'time on task' per different category of learning activity
- The productivity effect of interruptions on workbook activities
- Learning uptime during assessment
- Learning uptime during a supervised class.

The descriptive statistics produced during this phase were presented to the target domain stakeholders, who were then asked to comment on the model's accuracy (Shanks et al., 2003), as well as the model's individual impact, perceived organisational impact, perceived usefulness and intention to use (Brown and Jayakody, 2008).

Before moving on to the research methodology used in the focus group phase, a short discussion on the relative size of the data set used follows as part of the discussion on the quantitative analysis of this data for producing descriptive statistics.

SECONDARY DATA

In the literature review on education terminology, a systematic review article was found which summarises and describes some of the major quantitative classroom studies done to date. This allowed the researcher to compare the relative size of the secondary data set used in this research to what Apter et al. (2020) refers to as "mass studies" or "large studies". The data extracted from this systematic review is listed in Table 3 along with the sample size of the secondary data set.

From Table 3 it can be seen that, in terms of time observed, the secondary data set covers about 20% to 50% of what is termed as the mass studies of the past five decades (Apter et al., 2020). Although not the size of the major studies listed in the table, the secondary data is also not negligible. The purpose of this research was however not to conduct a classroom observation study, but to develop a model for the analysis of such studies.

The 1320 minutes observed had been made as a time-series study covering all activities from the start until the end of full school days. These observations thus also covered different subjects as well as different instructional methods. These time-series observations delivered a list of 450 school day activities, which provided enough detail with which the TOTA model could be tested and refined for use in further classroom observation studies.

Table 7: Comparison of Secondary Data Set to Mass Studies of Past Five Decades

Researcher	Research Year	Number of schools	Number of lessons observed	Total Time Observed	Number of Observers
Rutter	1979	12	402	2010	Multiple
Apter et al	1985 - 1992	71	141	6345	Multiple
Apter	2016	27	106	4770	Multiple
Apter	2016	1	122	5490	Multiple
Secondary Data	2020	1	44	1320	One

The studies mentioned in Table 7 were the mass studies of the past five decades, but classroom observation studies can be as small as two school periods, such as the widely cited research by Cobb et al. (1992), or even a single period, such as that, also widely cited, by Schoenfeld (1988).

Sample sizes in qualitative research are a point of ongoing debate (Saunders and Lewis, 2017, Boddy, 2016, Sim et al., 2018). Sim et al. (2018) state that "the decision over what constitutes an adequate sample size to meet a study's aims is one that is necessarily a process of ongoing interpretation by the researcher … It is an iterative, context-dependent decision made during the analytical process as the researcher begins to develop an increasingly comprehensive picture of the developed themes…".

The data set used in this research covered eight different teachers, using a combination of nine different instructional styles and methods at various points of the school day, to teach ten different groups of learners in seven different subjects. This provided a wide range of semantics and terminology to be accommodated by the model during the testing phase. Only 1.5% of the observations did not find a clear home in the TOTA model categorisations but were too ad hoc to justify the creation of any new TOTA categories. None of the TOTA model categories were not populated by the data set, meaning that the data set was varied enough to cover the 32 categories of the model.

The testing of the model had thus reached a level of saturation using the 450 activities and the research was able to advance to the next stage: presentation of the model to the target domain stakeholders.

3.4 Phase 2C: Model Testing Through Focus Groups

Five focus groups, consisting of 52 education specialists (Figure 7) were introduced to the Lean Management concept of value addition using the concept of blue light time, after which the descriptive analytics were presented to them.

After the presentation and discussion, the focus group participants were asked to complete a structured questionnaire to explore their perspectives on and reaction to the analysis. Due to the lockdown restrictions in place in July 2021, the focus groups were done virtually via Microsoft Teams, with respondents using Microsoft Forms to submit their responses to the questionnaire.

RESEARCH SAMPLE

The population studied during phase 2 was the group broadly defined as education stakeholders, consisting of teachers, principals, education academics, specialists, and corporate managers. The representation of the various groups is shown in Figure 6.

The presence of the various groups in the sample allowed for several cluster analyses to test whether the different groups within the larger sample have different perspectives on the research questions. Due to the prevalence of teachers within the sample group, the sample was divided into two clusters: Teachers and Other Education Stakeholders.

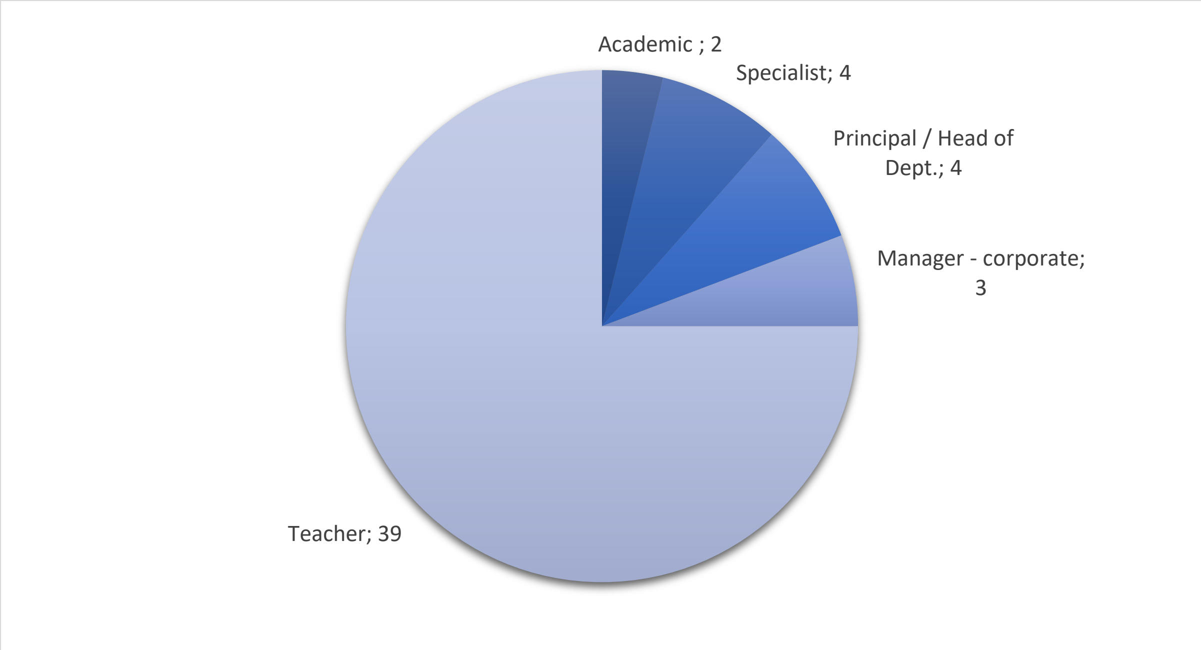

Figure 7: Breakdown of Research Sample

DATA COLLECTED

The online survey was filled in directly after the presentation of the descriptive analytics using Microsoft Teams Forms as a platform and took 11 minutes on average to complete (Figure 8). A structured discussion was then held within the group using the last few questions as input in to test the validity of the analysis.

The survey started with a cover letter containing information on the research, followed by a letter of consent which branched the survey after a Yes/No answer. The questions contained in the survey are shown in Table 8. The full survey is included in Appendix B.

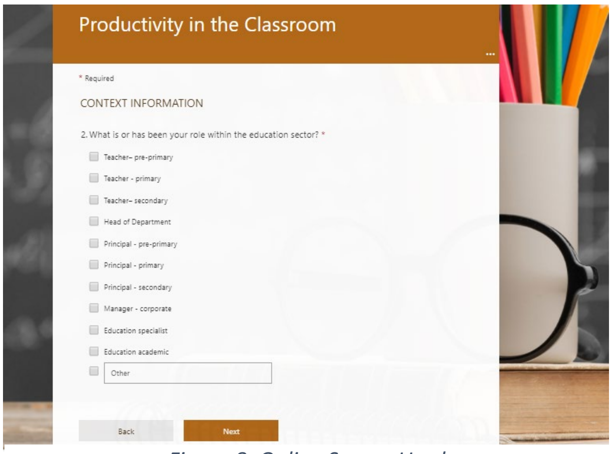

Figure 8: Online Survey Used

Table 8: Focus Group Survey Questions

	Question	Question Type
1	Informed Consent	Choice branch
2	What is or has been your role(s) within the education sector?	Choice
3	The presentation of the work study analysis provides a new perspective on how productivity can be studied in the classroom.	Likert scale
4	The presentation of the work study analysis helped me to look at productivity in the classroom in a new light.	Likert scale
5	I came up with improvement ideas <u>during</u> the presentation of the work study analysis.	Likert scale

6	I will be thinking of improvement ideas after the presentation of the work study analysis.	Likert scale
7	The school/s I am involved in can/could benefit from a classroom work study project.	Likert scale
8	Please rank the following options according to the impact that you think these options will have on productivity improvement in the classroom: - Teachers having been exposed to the findings of the work study. - School management having been exposed to the findings of the work study. - Education Policy makers having been exposed to the findings of the work study.	Ranked
9	Please rank the following options according to the impact that you think these options will have on productivity improvement in the classroom. - Teachers having been exposed to the findings of a classroom work study analysis - Teachers having been observed in the classroom during a work study analysis. - Techers having been part of a classroom productivity improvement workshop following a presentation on a classroom work study analysis.	Ranked
10	What are your main observations/realisations from the data presented?	Long text
11	What did you find surprising or new? I.e., what provided a new perspective?	Long text
12	What did you find unsurprising? I.e., what confirms an existing perspective?	Long text
13	How do you think these studies can be used to improve productivity in the classroom?	Long text
14	Which improvement opportunities become evident during the presentation of the data?	Long text
15	What causes productivity losses in the classroom? What prevents learning from being more productive?	Long text
16	Do you have any other observations or some experience that you would like to contribute? If so, please elaborate.	Long text

DEBRIEFING SURVEY WITH OBSERVED TEACHERS

A debriefing survey was completed by the three teachers who had volunteered to participate in the full-day part of the work study done in 2020, meaning that these teachers were shadowed during a complete school day to map “a day in the life of a teacher”.

Due to the Covid-19 restrictions, the format had to be online, and Microsoft Teams Forms was used as a platform to secure informed consent and host the survey. The survey questions are shown in Table 9.

As there were only three respondents, the debriefing survey did not need much analysis, and the responses were thus only used to inform some of the deductions and conclusions of the focus group responses. The methodology used to analyse the focus group data is described next.

Table 9: Debriefing Survey Questions

	Question	Question Type
1.	Informed Consent	Choice branch
2.	Did the study affect your productivity viz. the Hawthorne Effect?	Choice
3.	To what extent did the study affect your productivity during the work study?	Likert scale
	To what extent did the study affect your productivity after the work study?	Likert scale
4.	Did you identify any productivity improvement opportunities during the study?	Choice
5.	If so, please describe these improvement ideas.	Long text
6.	Did you identify any productivity improvement opportunities after the study?	Choice
7.	If so, please describe these improvement ideas.	Long text
8.	Are there any other observations or thoughts that you would like to add?	Long text

3.5 Phase 2D: Analysis of Focus Group Data

The focus groups were asked five questions that produced Likert Scale responses, and two questions that produced ranked responses (Table 8) thus both types of responses could be converted to quantitative data for statistical analysis. There were also seven voluntary long text questions which had produced 72 responses to be thematically coded and analysed.

The Likert scale responses were analysed descriptively and where appropriate also inferentially with paired samples t-tests exploring correlations between respondents' reactions. Statistical Package for the Social Sciences (SPSS) software was used for this quantitative analysis. The results are discussed in section 4.4.

A qualitative analysis was done on the long text questions of the focus group surveys (Table 8). Thematic analysis (Braun and Clarke, 2012, King and Brooks, 2018) was used to extract common themes, iteratively reviewing, and refining these themes as new sections of the qualitative data were analysed to provide more insight into the answering of the research question.

Table 10 shows a matrix of how the novelty and validity (Brown and Jayakody, 2008, DeLone and McLean, 1992, Shanks et al., 2003) of the Time on Task analysis were evaluated in the structured focus group questionnaire shown in Table 8.

The research was thus done in a development and a testing phase. The development of the model was done by triangulating a conceptual model (Overall Equipment Effectiveness) with the research and semantics of the target domain (education) and then testing it with data from the target domain.

Table 10: Novelty and Validation Attributes Tested in Survey

	Novelty	Accuracy	Individual impact	Perceived organisational impact	Perceived usefulness	Intention to use
Q1	Background Information					
Q2						
Q3	X			X		
Q4	X		X		X	
Q5			X		X	
Q6			X		X	
Q7				X	X	X
Q8		X		X		
Q9		X		X		
Q10		X	X		X	
Q11	X	X				
Q12	X	X				
Q13		X		X	X	X
Q14		X	X	X	X	
Q15		X				
Q16						

The model testing phase was done in three stages: The model was tested to see whether the semantics from the target domain are accurately, completely, and correctly addressed by the model. Once the validity of the model was established in this way, the model was also tested by processing the quantitative data from the classroom observations with the model's template to create a set of descriptive statistics with which to engage with the target domain stakeholders to test the novelty, as well as the individual impact, perceived organisational impact, perceived usefulness and intention to use (Brown and Jayakody, 2008) of the model. The model was found to be both novel and valid by the stakeholders of the target domain. The model, its template, the descriptive statistics as well as the focus group responses are discussed in Chapter 4.

4 RESEARCH OUTCOMES

The main outcome of the research is the answer to the research question, but a large part of the research contribution lies in the constructs produced during the research, namely the Time on Task Analysis TOTA model and template. The descriptive analytics produced by the research were also a research outcome, used in the focus group presentations, but also creating a basis for further classroom data to be added to build towards what Table 7 describes as a major study.

To recap the process followed to produce the research outcomes presented here, a quick summary will be given of the research to this point. A series of literature reviews identified a gap in the research, which culminated in the development of an analytical model called the TOTA model (section 4.1) to be used to support quantitative classroom data analysis with the aim of enabling productivity improvement.

This model was converted into the TOTA template (section 4.2) which was used to code secondary classroom data as part of validity testing of the model. This step was also useful in creating a more robust model by informing the detail definitions and categories. The refined model was then used to produce descriptive analytics of the secondary data (section 4.3), which was presented to the focus groups to test the validity and novelty of the model. The perspectives and reactions of the focus group participants to the analysis presentation were collected using a structured survey. The survey responses were quantitatively (section 4.4) and qualitatively (section 4.5) analysed to answer the research question.

4.1 The Time on Task Analysis (TOTA) Model

As explained in section 3.1, the TOTA model was based on the existing framework of Overall Equipment Effectiveness (OEE), found in the Reliability Management branch of Lean Management theory. Education literature informed the conceptual translation work that needed to be done to create the TOTA model for validity testing and ultimately for use in the school classroom.

The development of the model was thus done by triangulating an existing and proven theoretical base, namely OEE, with terminology and definitions from the target domain and then testing and refining the structural model through the coding of classroom data reflecting reality (Figure 6 in section 3.1).

Figures 9 and 10 show the structural overlap between the truncated version of the OEE model, called Equipment Operating Rate, and that of the TOTA model.

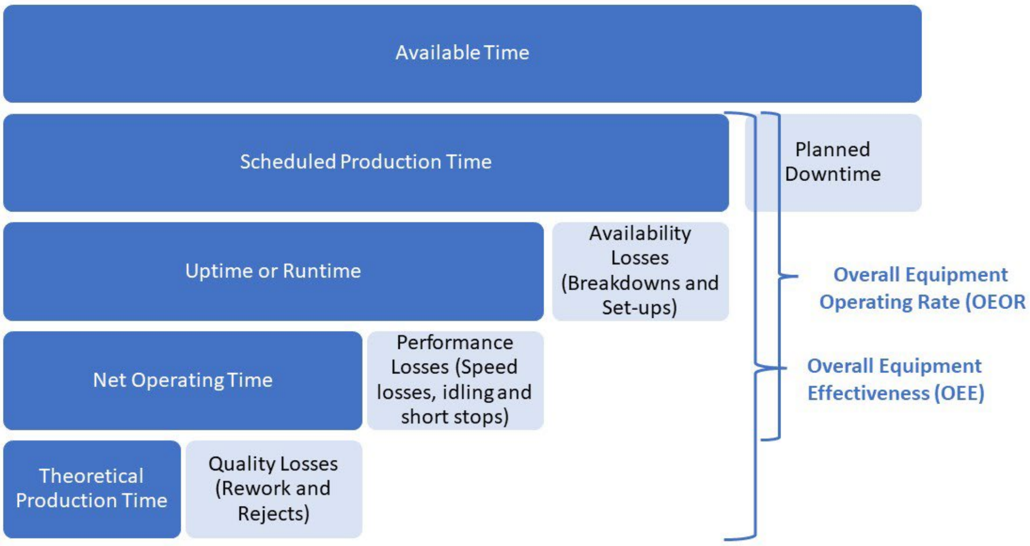

Figure 9: Overall Equipment Effectiveness Structure

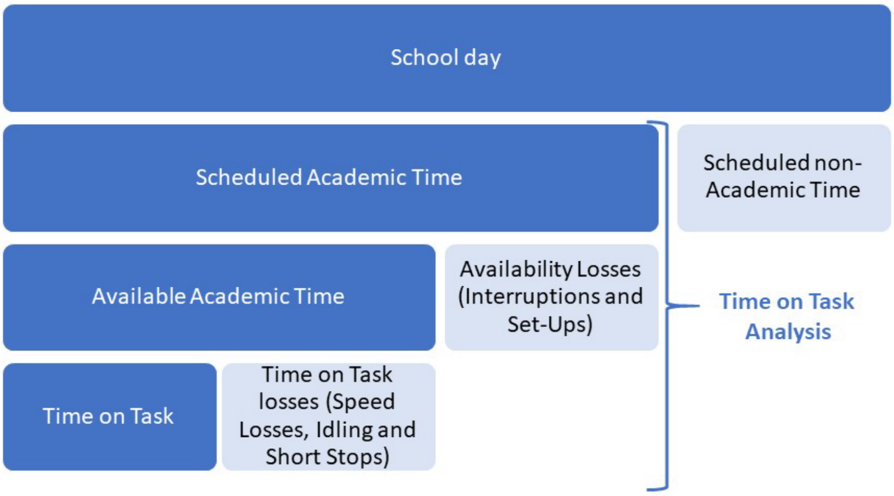

Figure 10: Time on Task Analysis Structure

As with OEE, the TOTA framework provides a means of identifying the biggest productivity losses on which to focus productivity improvement efforts. Figure 10 visualises the basic concept of the TOTA model: various efficiency losses (Availability and Time-on-Task losses) systematically reduce the available productive academic time. Breaking these loss categories into more detail, enables the quantification and identification of detail loss categories to be prioritised in production improvement efforts. A breakdown of the productivity losses analysed through the TOTA model is shown in Figure 11.

Colour-coding was used to identify the following three major categories of the school day:

- Green: Scheduled non-academic time
- Brown: Losses of scheduled academic time
- Blue (for blue-light time): Scheduled academic time (remaining after losses).

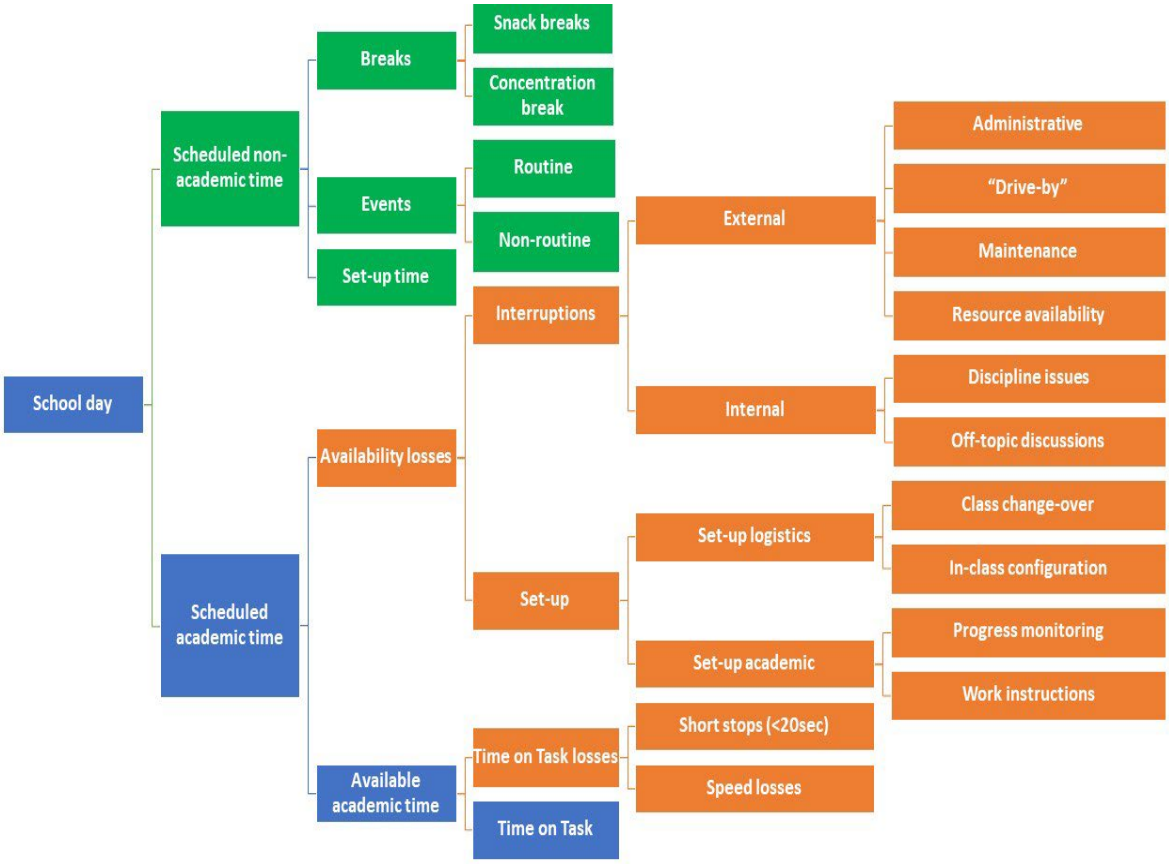

Figure 11: Time on Task Analytical (TOTA) Model

As can be seen from Figure 11, the TOTA model first separates scheduled academic and non-academic time. In OEE, scheduled downtime does not form part of the OEE calculation, as scheduled downtime is a utilisation issue, the control over which lies with management rather than the operations team responsible for the productivity of the machine being measured. Similarly, in the classroom, scheduled non-academic events such as school assemblies or school rosters requiring class changeovers, fall outside the control of the classroom teacher, responsible for optimising time on task otherwise. A 'green' loss category that might look like a mistake or duplication of 'brown' losses, is that of set-ups. As will be explained in the detail definitions of each loss category in section 4.2, the schedule set-up time is the optimal time reserved for set-up, for example a class changeover for which the ideal time has been set as 3 minutes. Any time taken more than the scheduled time, is considered an efficiency, not a utilisation, loss.

The scheduled academic time is separated into availability losses, such as interruptions and non-scheduled set-up-time, and available academic time. There is thus scheduled time, when learners are supposed to be taught in the classrooms, but some available losses such as interruptions and extra set-up time consume some this schedule academic time, leaving the category available academic time.

Some of this available academic time can now further be consumed by further productivity losses, such as time on task losses, which take place when learners are supposed to be on task but have lost concentration or are waiting for others to finish.

What remains after these time losses have been removed from the school day, is Time on Task. This would be the moments that were spent on a structured academic activity. This Time on Task (T_{oT}) could thus be a form of output measure for a productivity measure of the scheduled academic time (T_{SA}) as the input measure of the teacher and learner-controlled part of a school day. The productivity could be expressed as a Time on Task ratio (T_{oT}) as follows:

$$T_{oT}\ \% = \frac{T_{oT}}{T_{SA}}$$

The point of metrics such as OEE and the Time on Task ratio is not to determine that there are Time on Task losses, but rather where these losses occur and what should be done about them. That is their real contribution: the guiding of the improvement effort. The expanded, analytical form of the Time on Task ratio is thus of more interest to this research:

$$T_{oT}\ \% = \frac{T_{AA}}{T_{SA}}\ x\ \frac{T_{oT}}{T_{AA}}$$

Where T_{AA} denotes Available Academic Time.

The Availability (A) ratio of OEE is thus represented in the TOTA model as:

$$A = \frac{T_{AA}}{T_{SA}}$$

The Performance (P) ratio of OEE is represented (to a lesser extent) in the TOTA model as:

$$P = \frac{T_{oT}}{T_{AA}}$$

The phrase 'to a lesser extent' is used here since speed loss cannot as yet be individually measured per student. In the classroom observations it was visible when and how many learners were idle, but their speed of working could not be compared to their ideal speed, as OEE would want it to be measured (Hansen, 2002). Nevertheless, this Performance measure still brings the productivity analysis closer to Time on Task analysis.

The TOTA model thus focuses on time losses during the school day, but specifically focuses on those time losses that were intended to be academic time. These losses are not a result of policy decisions or management actions but are in the hands of the teachers and learners: they deal with what happens inside the school period and the school classroom.

By providing a teacher with an analysis of the school day, will firstly make the teacher aware of those losses that contribute the most to missed learning opportunities, and secondly, will help the teacher break down those losses into more detail to the point where improvement opportunities can be identified. Before the model can be implemented, it needed to be tested for validity.

MODEL VALIDATION

As described in detail in sections 3.1 to 3.5, the model was tested for validity by testing the following attributes: accuracy, completeness, conflict-freedom (Shanks et al., 2003) and individual impact, perceived organisational impact, perceived usefulness and intention to use (Brown and Jayakody, 2008, DeLone and McLean, 1992). To test accuracy, completeness and freedom from conceptual conflict, the qualitative data from 450 classroom observations from a private primary school were coded using the TOTA framework, which is described in the next two sections. For this purpose, the model was converted into an Excel template, which could also be used in the coding of future classroom observation studies.

The TOTA structure easily accommodated the classroom observations, thus satisfying the validity conditions of accuracy, completeness and conflict-freedom (Shanks et al., 2003). As discussed in section 3.3, only seven (or 1.5%) of the 450 activities were categorised as "other" as they did not fit into any of the 32 TOTA categories. Each of the four major loss categories of the TOTA model, contained such an "other" column, meaning that these seven observations could to some extent be categorised, albeit it under a higher-level productivity category. Only 1,5% of the 450 activities were thus not described by the model, but these activities were also too ad hoc, such as a swimming team send-off ceremony, to justify the creation of an additional TOTA category. Provision was made for such instances by the addition of the categories of "other" under each sub-group of the TOTA model.

With accuracy, completeness and freedom from conflict tested against the semantics and realities of the target domain, this left the attributes of individual impact, perceived organisational impact, perceived usefulness and intention to use (Brown and Jayakody, 2008, DeLone and McLean, 1992) still to be tested through the focus groups. The outcomes of testing these validity attributes are described in section 4.4.

LIMITATIONS OF THE MODEL

As Time on Task relates to the Net Operating Time of the OEE model and is also the point at which the proposed model stops, the model has in actual fact followed the model of Overall Equipment Operating Rate or OEOR, which measures the availability and performance of the machine, but not the quality produced, like OEE does (Hansen, 2002, Kobayashi, 1995). It would be valuable to be able to add a quality aspect to the model measuring whether the time on task is also producing effective learning. This is an opportunity for further research.

4.2 The Time on Task Analysis (TOTA) Template

During the literature review, some of the well-known templates that currently exist for systematic, quantitative classroom observations were found in a systematic review done by Apter et al. (2020) and include the approaches now known as OPTIC, TaMBIS and MICRO. These templates have a distinct pedagogic focus and do not focus so much on the time aspect, as does the TOTA model. For example, OPTIC focuses on how questions are handled in the classroom (Wheldall et al., 1986, Merrett and Wheldall, 1986), MICRO, developed from TaMBIS, looks at teacher-talk – how and to whom it is done, and how it influences Time on Task (Apter et al., 2020). This review thus identified a gap in the literature, namely the need to develop a classroom observation template specifically focused on different types of time losses during the school day.

The TOTA model discussed in section 4.1 was converted into the work study template shown in Table 11, containing all the categories of the TOTA model in the columns in the three hierarchical levels and columns to accommodate activity start time, duration, description, and field notes. The template will be described category by category through the definitions contained in this section.

The detail definitions of each of the TOTA categories, described in the sections that follow, were made more robust through the incorporation of some of the practical examples of losses contained in the classroom observation data set. For example, as will be seen in the definitions that follow, set-up time is explained by the provision of examples such as marking of test papers, or coordination amongst teachers regarding the interpretation of a set curriculum. Although the structural elements of the model were left intact, the detail descriptions increased in their depth through testing-refinement iterations of the coding process. These definitions are described next.

DEFINITIONS OF TEMPLATE CATEGORIES

Each of the template/model categories will be defined either by way of description or example. The seminal work on OEE by Hansen (2002) was continuously consulted in order to inform the translation of the loss categories into the classroom terminology. Where available, this was combined with terms and definitions found in educational literature.

School Day. The official school hours when learners are all required to attend and includes both scheduled academic time and scheduled non-academic time.

Scheduled Non-Academic Time. All minutes of the school day scheduled to not be used for academic activities. This may include:

- Scheduled breaks including scheduled snack breaks
- Scheduled concentration breaks. These are breaks between periods or tasks to enable sustained concentration during the scheduled academic time.
- Scheduled non-academic events such as routine events e.g., school assemblies, fire drills etc. and non-routine events e.g., health check days, traditions such as sports team send-offs, team building camps etc. These events may include any scheduled non-academic activity approved by the school management (based on their educational mandate). This mandate might, admittedly, not be a straightforward concept, but it is important for school management to understand firstly, who their customers are, and, secondly what their customers consider to be the valuable spending of school fees and time. Lean Management theory as explained by Womack and Jones (1997) is useful in understanding this fundamental of productivity improvement.
- Optimal set-up time. This category would include the optimal set-up time deemed necessary to do set-up activities, described under availability losses. Since set-up activities are mostly necessary to deliver optimal academic performance, such as the marking of test papers or the coordination of curriculum interpretation amongst teachers, set-up activities should not be deemed as availability losses in their entirety. Rather, an optimal amount of these activities should be encouraged as they would be enhancing classroom productivity.

Table 11: TOTA Template

TIME ON TASK TEMPLATE FOR CLASSROOM OBSERVATIONS

Date of observation: **School oberved:** **Subject observed:**

<table>
<tr><td colspan="6" rowspan="5">Notes:</td><td colspan="27">School day</td></tr>
<tr><td colspan="7">Scheduled non-academic time</td><td colspan="20">Scheduled academic time</td></tr>
<tr><td colspan="2">Events</td><td colspan="2">Breaks</td><td rowspan="4">Set-up: Teaching preparation</td><td rowspan="4">Meetings</td><td rowspan="4">Other</td><td colspan="16">Availability losses</td><td colspan="4">Available academic time</td></tr>
<tr><td rowspan="3">Routine</td><td rowspan="3">Non-routine</td><td rowspan="3">Snack breaks</td><td rowspan="3">Concentration breaks</td><td colspan="8">Interruptions</td><td colspan="8">Set-up</td><td colspan="2">Opportunity losses</td><td colspan="2">Time on Task</td></tr>
<tr><td colspan="5">External</td><td colspan="3">Internal</td><td colspan="3">Logistics</td><td colspan="4">Academic</td><td>Non-academic</td><td rowspan="2">Short stops (<20sec)</td><td rowspan="2">Speed losses/Idling</td><td colspan="2">Time on Task</td></tr>
<tr><td>Activity Start Time Stamp</td><td>Duration</td><td></td><td></td><td>Activity Description</td><td>Field Notes</td><td>Administrative</td><td>"Drive-by"</td><td>Maintenance</td><td>Resource availability</td><td>Other</td><td>Discipline issues</td><td>Off-topic discussions</td><td>Other</td><td>Class change-overs</td><td>In-class configuration</td><td>Other</td><td>Progress monitoring</td><td>Work instructions</td><td>Feedback</td><td>Other</td><td></td><td>Time on Task</td><td>Description
e.g Revision, New concepts, assessment, group work etc.</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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</table>

All scheduled non-academic activities should be categorised into optimal time and loss time. For example, if the optimal time allocated to a certain meeting is 30 minutes, but the meeting takes 45 minutes, the first 30 minutes are deemed scheduled set-up time and the last 15 minutes are considered a set-up loss. Similarly, if the time scheduled as concentration breaks between 30-minute periods is three minutes, then, if the break took five minutes, the first three minutes will be deemed as a scheduled break, and the two extra minutes will be categorised as an availability loss. The 'optimal time' should not be set in stone and should be frequently reviewed for applicability and further optimisation.

The principle behind the scheduling of optimal times is found in the theory on OEE (Hansen, 2002). The purpose behind the classroom observations is the improvement of classroom productivity. The identification of productivity losses is therefore paramount to the exercise and will not be served by the general exclusion or inclusion of certain activities that support optimal academic performance such as concentration breaks and the marking of test papers which is a form of set-up activity. Excluding the whole duration of such activities from scheduled academic time will allow for inefficiencies to go by undetected in the observations. Including their whole duration in the scheduled academic time will affect the credibility of the exercise as teachers might perceive that executing essential set-up activities is being penalised in their observations. Although the division of one observed activity into optimal and inefficient categories complicates the observation, it serves a purpose when considering the aim of the exercise: the identification of improvement opportunities.

Scheduled Academic Time. All minutes of the school day scheduled to be used for academic activities. This will include time scheduled for academics as well as time scheduled as such, but either spent on non-academic activities instead or inefficiently used (availability losses).

In education literature, a similar term was described by Carroll (1963) as "opportunity", and then later described as allocated academic learning time by Fisher et al. (1978) as the amount of planned time allocated to instructional activities. It therefore represents the upper limit of in-class opportunities for students to be engaged in learning (Gettinger and Seibert, 2002).

Although similar, the scheduled academic time proposed in this study accounts for scheduled losses differently and hence the new term as proposed here.

Availability Losses. All minutes that were scheduled for academic activities but used for non-academic activities instead. These non-academic activities could include straight-forward losses such as time lost due to a projector not working when it was needed to present a lesson but can also include the time that exceeded the scheduled optimal non-academic time discussed under scheduled non-academic time such as learners being slow to return to the classroom after a scheduled 15-minute snack break. The sub-categories of availability losses are interruptions and excessive or unplanned set-ups.

The equivalent of the machine breakdowns or stops in OEE in education are called interruptions. The literature classified them as either external or internal interruptions (Kraft and Monti-Nussbaum, 2020, Fisher et al., 1978).

Note that, borrowing theoretically from the excellent definition of change-over time by Shingo (1996): Any stops in academic time should be timed from the moment the learner stops being fully on task to the moment the learner is fully on task again. Thus, the interruption does not cease when the interrupter leaves the room or the teacher asks the learners to return to their activities, it ceases when the learners are fully on task again. As will be seen in Figure 26 interruptions often have a much longer effect than the duration of the interruption itself.

Interruptions. Interruptions are unplanned incidents during scheduled academic time that prevent academic work from being done and last for more than 1 minute. These interruptions can be internally or externally induced.

External Interruptions. This category of unplanned interruption of more than 1 minute comes from outside of the classroom via the intercom, a person delivering a message or requesting audience with the teacher or class. In literature, it is described as those "intrusions from outside the classroom that are not under the direct control of classroom teachers, but under direct control of school leadership" (Kraft and Monti-Nussbaum, 2020).

- **Administrative -** Interruptions initiated by school administration or management such as announcements, messages, class callouts of teacher or learners, etc.
- **"Drive-by" -** Interruptions initiated by fellow staff members or learners such as meetings between teachers in class time, phone calls taken from parents or others, other classes making noise that prevents further instruction, etc.
- **Maintenance -** Interruptions caused by the failure or unplanned maintenance of infrastructure or resources such as loud noises e.g., lawn mower, burst pipes / broken window, faulty equipment e.g., projector, etc.
- **Resource Availability -** Interruptions caused by the unavailability of facilities or learning resources such as double bookings, unavailability of rooms or equipment, missing resources, etc.

Internal Interruptions. This category of unplanned interruption of more than 1 minute comes from inside the classroom via discipline issues, an off-topic discussion etc. Although literature refers to internal interruptions as being caused by off-task student behaviour (Little and Akin-Little, 2008), the definition here also recognises that teachers are also sometimes the cause of a class being off task.

- **Discipline Issues -** Interruptions caused by, or being the result of, poor behaviour such as disruptive behaviour by learner(s), learners ignoring instructions, teachers excessively reprimanding in terms of time or target audience, etc.
- **Off-topic Discussions -** Interruptions to the academic task at hand caused by off-task discussions – academic or non-academic – that cause a disruption in concentration or delay in the task being completed. These include teacher-initiated interruptions such as announcements or off-task questions while students are completing a workbook activity etc.; Teacher taking a phone call during class time; Learner initiated interruptions such as casual conversation, asking for the instructions to be repeated where instructions were clear or asking to borrow stationery etc.

Set-up. Set-up activities are those activities that make learning or teaching activities possible but are not in themselves academic learning for learners. IMPORTANT: Only the minutes spent on set-up activities that exceed the scheduled time for these activities are included here. See the discussion on Scheduled non-academic time for how this is to be determined.

Logistics. This category of activity is concerned with activities that mostly involve movement. This movement can move learners or teachers between places of learning or move learning resources into position for learning or transportation. Activities that fall into this category are class changeovers and in-class changeovers.

Class Changeovers. This activity involves movement between places or topics of learning such as learners moving from a computer laboratory to a classroom. This activity starts the moment learning stops to start the change-over to the moment learning commences again. Examples of such activities are changes of venues – for teachers or learners, changes of books or equipment, etc.

In-class Configuration. This activity involves non-learning or -teaching related actions during class time with the intention of enabling further academic activities such as: teacher setting up a projector to teach, teacher handing out teaching material, teacher separating desks for assessment, learners taking out or putting away books or stationery (during a period), learners moving desks for assessment or group work, learners fetching materials or tools, etc.

Set-Up – Academic. This group of activities refer to those actions that are related directly to setting up for academic work but are not the teaching or learning of content in themselves such as instructions, progress discussions, marking etc.

Progress Monitoring. This category is those actions taken by the teacher to review progress of academic work such as teacher signing workbooks, teacher asking how far learners are on an assignment or how many have finished an activity, teacher checking whether learners have done what was required, teacher asking the class what work has been covered, etc.

Work Instructions. These are all actions taken to give instructions on academic work such as giving or receiving instructions regarding academic work to be done, coordination of groups for assignments, learners asking follow-up questions on instructions, etc.

Assessment Marking. All actions taken to mark assessments, capture those marks on the system and give feedback to learners regarding the mark only. Detailed feedback or discussion on the assessment is classified as revision.

Available Academic Time. All scheduled academic time left for academic work in between set-ups and interruptions. Although interruptions and inefficient setups have now been accounted for, there might still be short stops and idle time losses built into what we consider to be time left over for academic learning.

Time on Task Losses. Time on Task losses refer to those seconds lost due to short stops of less than one minute or idle time such as waiting.

Short Stops. Short stops are interruptions and set-ups of less than 20 seconds. These could include the same types of interruptions or setups defined under availability losses, but do not last as long. Borrowing theoretically from the excellent definition of change-over time by Shingo (1996): Stops should be timed from the moment the learner stops being fully on task to the moment the learner is fully on task again.

Idling / Speed Loss. According to Hansen (2002), speed losses are the difference between the theoretical time that an activity should take and the actual time it took to do an activity. In the classroom, working slower and faster than average can both result in speed losses. Taking longer to do an activity than what it should is an efficiency loss in the classical sense. When learners finish a test or activity faster than the rest of the class and are expected to wait idly, or keep themselves busy with non-academic activities, this also constitutes a loss in productivity for the fast learners due to speed differences amongst learners. Examples of speed losses are loss in concentration or focus during academic activities, waiting for learners to finish, etc.

Time on Task. As one of the terms found in the literature review, the definition used here will be the same as that first described by Stallings (1980), but also described earlier in the work of Carroll (1963) as the time spent "paying attention" or "trying to learn". Time-on-task refers to the amount of time students are engaged in academic work (Prater, 1992).

Although the model and its template were both found to be novel, valid, and valuable by the stakeholders of the focal domain, there are certain limitations to the template. These are discussed next.

LIMITATIONS OF THE MODEL / TEMPLATE

Two limitations were identified during development and use of the template – the level of complexity and the still-to-be-developed categories.

- Level of complexity

The use of the OEE model is complicated because of the strengths of the model: its ability to analyse and identify improvement opportunities. This requires detail observations, and many judgments calls during the observation study to determine into which category an observation should be placed. The definitions given in this section are already just as or more comprehensive than the definitions found in OEE literature (Hansen, 2002, Muchiri and Pintelon, 2008), but will now develop along with any changes in the domain of education.

Practitioners of OEE confirm that an analytical model such as OEE is difficult to implement, but not impossible and that the benefits of such a powerful metric outweigh the difficulty of deciding where to allocate losses precisely (Hansen, 2002, Muchiri and Pintelon, 2008). Judging by the positive response of the participants of the focus groups to the descriptive statistics (section 4.3), the benefits of the TOTA model will also be worth navigating the time allocations.

Since the lost time allocation requires some discerning thinking, making observations and categorising them at the same time might not be practical and therefore it is recommended that the observer make detailed field notes and give detailed descriptions of activities observed during the course of the work study and leave the higher order thinking of coding of the observations into the theoretical framework for after the observations.

- Time on Task sub-categories.

The literature study provided a plethora of time on task instructional strategies and teaching methods, grouped into various frameworks according to different schools of thought (Kindsvatter, 1988, Westwood, 2008, Dorgu, 2016). Dorgu (2016) for example lists 29 different teaching strategies on a teaching method wheel. The wheel is based on the work by Cruickshank et al. (1995) which organises teaching methods into presentation, discussion and independent study.

From the literature review, it was clear that the pedagogues have much to contribute regarding the variety and effectiveness of teaching methods. To synthesise this work would require an extensive study, which was outside the scope of this study, which focused on time on task losses. Considering that the time on task template is mainly concerned with how much time on task is present in a school day and how this can be maximised, the model and template presented here will stop short of defining time on task sub-categories and leave it to further research to define.

The secondary work study data, however, contained descriptions of the various types of Time on Task activities presented and these categories could thus be described in the descriptive statistics. Although the observations may be described, creating a theoretical model would require considerable understanding of the literature available on the subject. Descriptive analysis was done on the observations, but it was decided to keep the model theoretically as accurate as possible and thus leave further expansion for future research.

4.3 Statistics of Classroom Observation Data

Once the qualitative data had been coded using the TOTA template, the quantitative data was used to create descriptive analytics using the categories of the TOTA model. The descriptive analysis done can be grouped into two main categories: Main observations and side observations. The main observations were those that were produced from the activities coded into the TOTA template. The side observations were themes identified in the field notes and then deducted from the quantitative data in the coded framework. All the descriptive statistics produced by this phase are described in this section.

The colour blue was used throughout to denote learning uptime or Time on Task. The reason for this colour choice is based on the "Blue Light Time" metaphor explained in section 1.2 to illustrate value-adding time as the time during which a product, or person, is transformed. The "blue light" refers to the light emitted by a welding process the moment the welding rod touches the metal (Figure 12). It is only in the "blue light" moments that value is added to the metal. The colour blue remained consistently allocated to the teaching or learning activities, whereas the use of the other colours evolved along with the model.

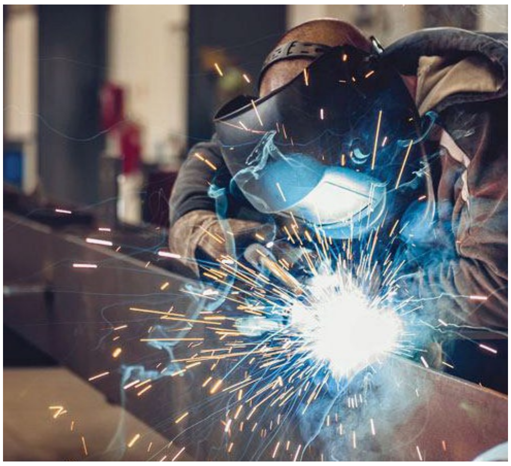

Figure 12: Welding Blue-light as Metaphor for Value-adding Activities

A DAY IN THE LIFE OF A TEACHER

Figure 13 shows the high-level view of the combined days of the three teaching days observed. Of the 450 observations contained in the classroom data, a total of 305 observations were made of three teachers over the course of three different school days. This constituted 1080 minutes or 18 hours of observations. As can be seen from Figure 13 only 33.4% of the teachers' observed days were spent teaching. The bulk of the days were spent on scheduled and unscheduled off-task activities of which Figure 14 provides more detail. 20.7% of the school day was scheduled non-academic time, 15.3% were unscheduled interruptions; 28.4% on setting up to teach and 3% was lost due to short stops and idling. The school days started at 07h30 and finished at 13h30.

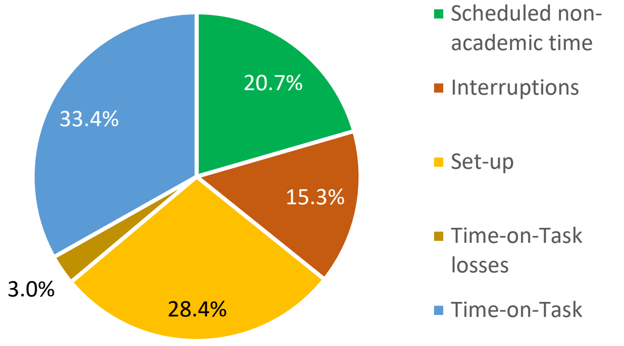

Figure 13: High-level View of Teacher Observations

Figure 14 shows that the biggest productivity losses within the scheduled academic time were logistics activities aimed at setting up to teach further such as class to class changeovers and in-class configuration set-ups such as handing out of test papers or moving desks around. Internal interruptions were the second biggest loss and include discipline issues and off-topic discussions.

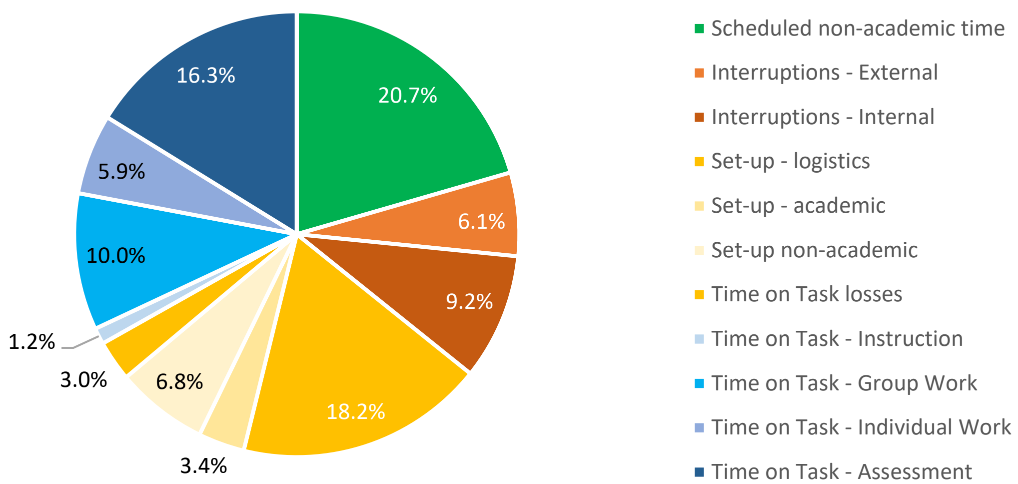

Figure 14: Mid-level Detail View of Teacher Observations

From the field notes the researcher could deduct how much of the available Time-on Task was productively used. During the classroom observations of on-task work, the number of learners who were in fact 'on task' were counted to work out a percentage of learners 'on task' during a certain time frame. Thus, although the teacher was teaching, were the learners paying attention? As will be seen later in this analysis, it was especially during workbook activities that learners failed to be on task. Thus, although the teacher was supervising a structured learning activity, i.e., teaching, not all learners were engaged in learning.

Figure 15 shows that of the 510 minutes of observed teaching time, 95 minutes, or 18.6%, were lost due to breaks in concentration caused by various time on task losses and interruptions in concentration such as off-topic discussions.

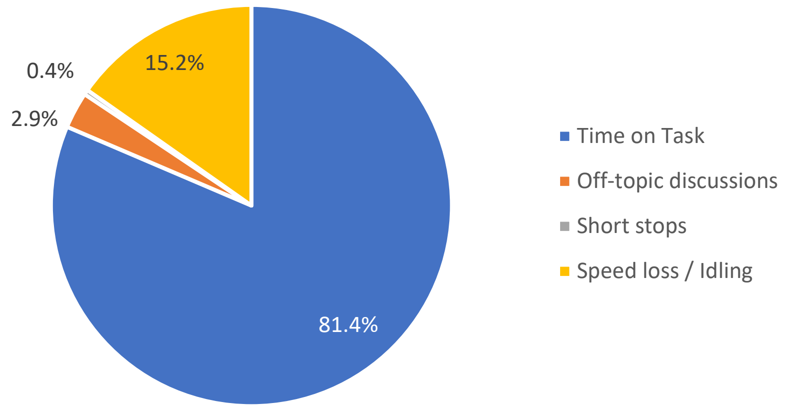

Figure 15: Breakdown of Active Teaching Time

COMPARISON BETWEEN TEACHING DAY STYLES

Although the combined teacher data gave more observations to analyse to get the most representative view of the data, it was interesting to note the variations between the days of the different teachers.

The field notes described the first day as a traditional teaching day following the formula of revision, teaching of concepts and application. The second consisted only of maths assessments. This day is therefore referred to as an "assessment day". The last day was spent on facilitating group work with the teacher walking between groups supervising and guiding and the learners engaged in collaboration. This day is described as a "group workday".

Figure 16 shows the comparison of Time on Task that was observed on each of these days. Although the assessment day had the most time *available* for on task activities, 5% of that time was lost due to off-task activities, which was mostly learners being finished with the assessment and keeping themselves busy. These learners would lose a further period of on-task opportunity as the test was set for three periods, but only two were observed. The learners would therefore be required to keep themselves busy for another period, meaning that the average time on task losses of those assessment days were actually worse than shown here.

The group workday had the second most time available for time on task, but the learners were engaged all of that time with no time on task losses observed. The traditional teaching day, with time split between revision, instruction of new concepts and workbook activities, had the least time on task opportunity. This was due to many instructions and switching between activities.

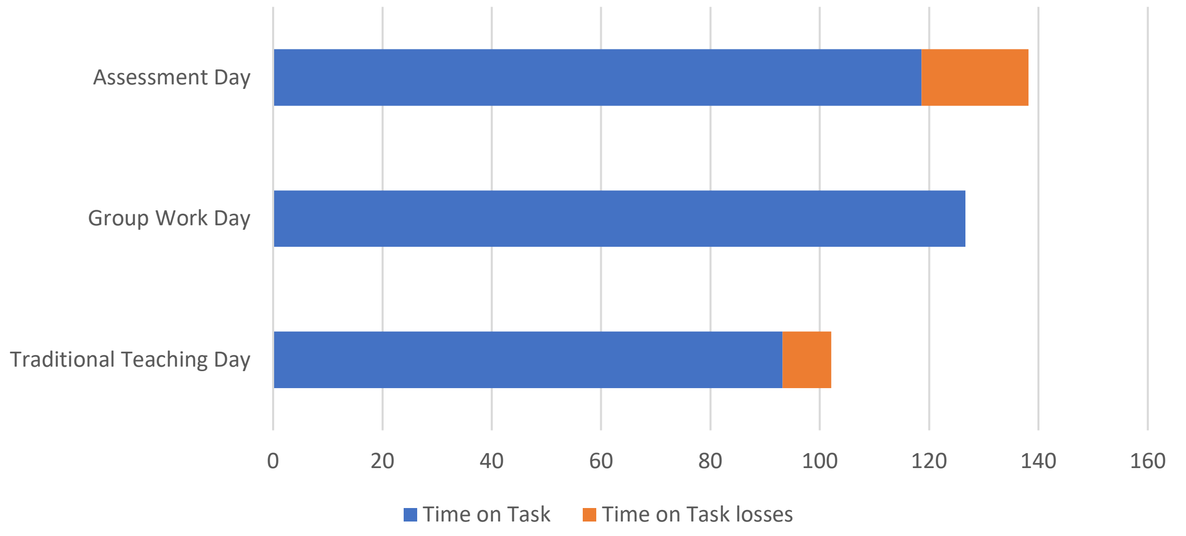

Figure 16: Breakdown of Traditional Teaching Day

Comparing the three days reveals an interesting observation that could serve as input to further in-depth research: The group workday kept the learners engaged in structured learning activities during the available teaching time. Although the teacher did not actively teach a lesson, the learners were actively engaged in learning. The teacher with the most observations or activities was the traditional teaching day teacher. So, although this teacher was much more active during the day, the learning uptime was a mere 14%, posing the question whether there is an inverse effect between teacher activity and learner activity. The assessment day also seems to confirm this postulation. The teacher was invigilating, walking amongst the tables, expending relatively little teaching energy, but still attained 33% learning uptime.

A DAY IN THE LIFE OF A GRADE 5 CLASS

The secondary data set also contained a set of observations of the activities engaged in by one class of Grade 5 learners. This was observed during 11 periods and a total of 480 minutes and consisted of 84 separate observations. The data was coded into the same framework as that of the teachers and the analysis is visualised in Figure 17, showing that 55.9% of the observed day was an opportunity for learning, but 16.9% of that time was lost due to time on task losses such as a difference in the working speed of learners or the lack of activities to do engaging all learners simultaneously. This resulted in only 39% of the day, or 136 minutes, being utilised for on-task activities.

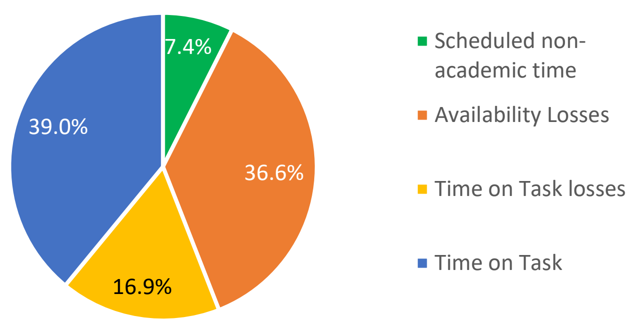

Figure 17: Breakdown of Grade 5 Class School Day

Figure 18 shows a more detailed breakdown of activities, indicating that the biggest loss of scheduled academic time was that of the movement of learners between classes and movement in the class such as taking out or packing away books and equipment. The second biggest academic time loss was idling due to learners not being kept busy with academic work while others are still on task.

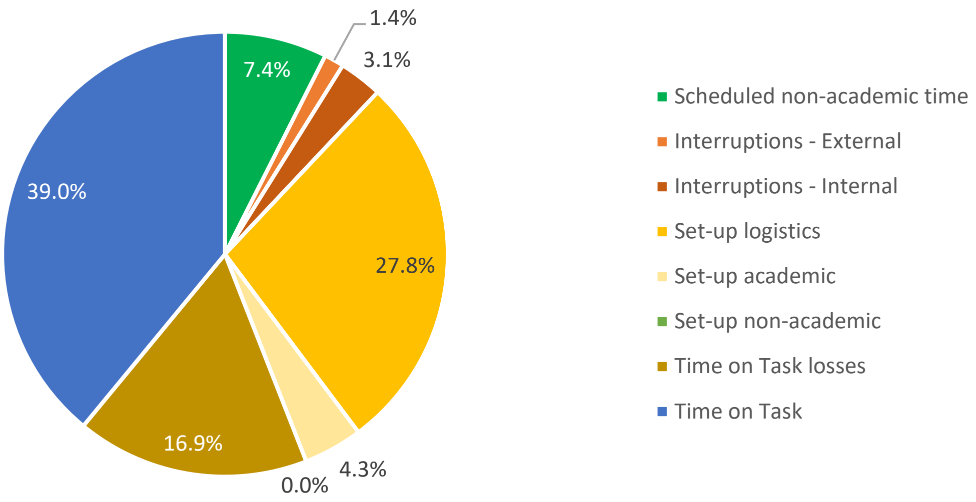

Figure 18: Mid-level Detail Breakdown of Grade 5 Class School Day

Figure 19 shows a breakdown on how time on task activities were spent and reveals the fact that none of the time spent during the course of the observed day was spent on learning new concepts. In fact, only 14 minutes, 0.97%, of the total 1440 minutes observed over the four observation days were spent on the learning of new concepts. It would be interesting to research what benchmarks exist for what proportion of learning time should be allocated to revision, new concepts, and application respectively. As was mentioned in section 4.2 under limitations of the template, the TOTA template stops short of identifying types of Time on Task activities, but this is listed as a further area for research and development of the TOTA model. It is recommended that such a benchmarking study be included in that research.

From the data of all four observed days, Figure 19 was produced to assess how learning activities had been allocated during those observation days. Of the 1440 minutes observed over the course of four school days, 631 minutes were available for learning activities. How these 631 minutes were spent is shown in Figure 19. 92.7% of the learning opportunity time was spent on application of concepts already taught. Another 3.5% was spent on revision of concepts learned previously during new concept teaching time, which constituted 2.2% of the total learning time. 1.6% of the structured learning time was spent on one-on-one coaching.

The data was then analysed to determine which of these time on task activities were the most successful in engaging the class in learning time. Counting the number of learners on task during the learning activity at every 2-3 minutes, gave a % on task engagement, which was helpful to assess the engagement level achieved by the various learning activities, shown in Figure 20.

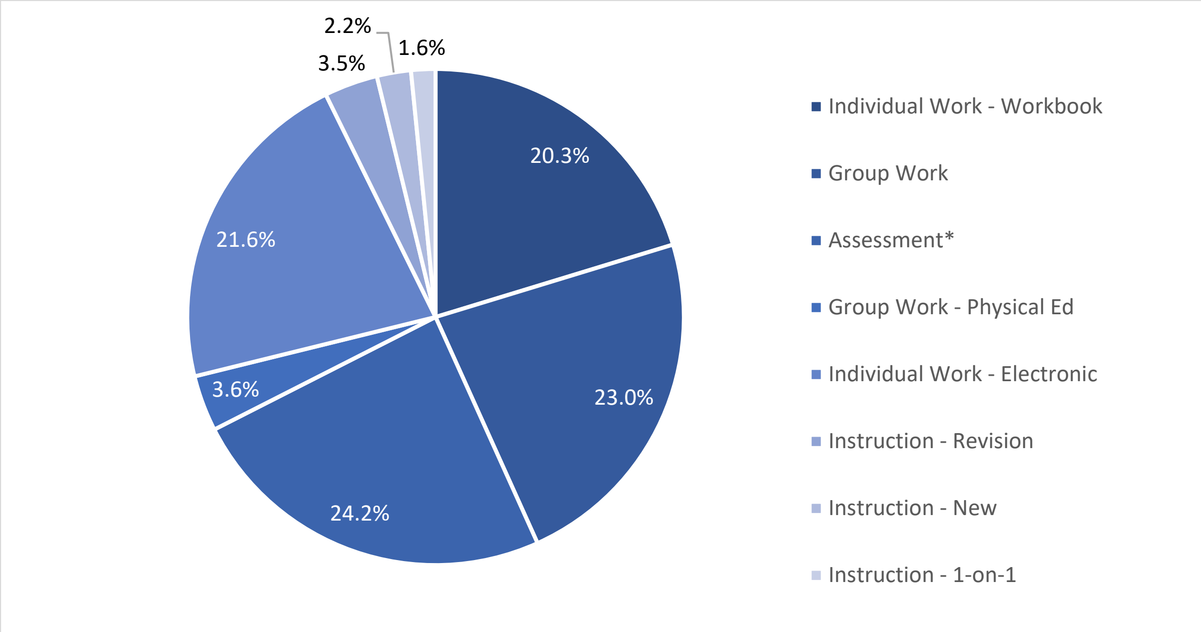

Figure 19: Allocation of Time on Task During Four Observed School Days

Although the secondary data would need to be supplemented by more representative observational data e.g., the engagement achieved by different teachers during a specific type of learning activity etc., this analysis gave an indication of engagement levels during the four days of classroom observations. It must be kept in mind that the purpose of this descriptive analysis was to showcase what an IE would glean from a set of classroom observations. It was not designed to be a pedagogic study and therefore the findings should not be taken as absolute.

Figure 20 indicates that the individual electronic learning activities produced high levels of learner engagement, as well as the group work activities. The revision activities observed also achieved excellent engagement with teachers asking questions and learners given opportunities to answer.

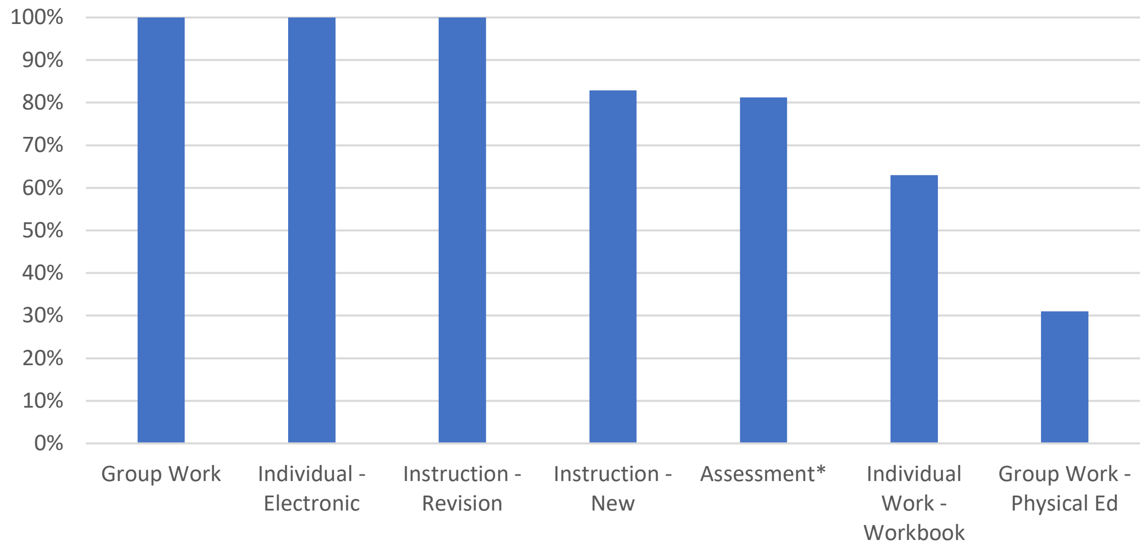

Figure 20: Level of On Task Learner Engagement During Various Learning Activities

The field notes indicated that the new concepts were taught with the teacher introducing the concept and the class then watching a video clip on the content. Just over 80% of the learner time spent remained engaged throughout the 14 minutes observed.

The assessment data* was collected during the first 60 minutes of a 90-minute test, with the test being finished during the next school day, which was not observed. This means that the engagement levels shown in Figure 20 are inflated as learners had already started handing in their completed tests and were then expected to keep themselves busy with unstructured activities such as reading or drawing. The real figure would most likely be closer to 64% engagement, calculated as follows:

$$EL_X = \frac{\left((EL_O \; x \; T_O) + (EL_E \; x \; T_E)\right)}{(T_O + T_E)}$$

Where extrapolated engagement level is denoted as EL_X, observed assessment engagement level is EL_O, observed time is T_o, estimated assessment engagement level is EL_E and estimated test time is T_E. The extrapolations and estimations were done as follows: Looking at Figure 21, on average, half of the learners had handed in their tests approximately halfway through the allocated test time. By the end of the 60 minutes observed, just over 30% of learners were still engaged in the assessment activity. Extrapolating using these observations and the assumption that most of the 30% of learners still writing were, in fact stuck and not making further progress on the assessment (as per field notes), the extrapolated time will be:

$$EL_X = \frac{\left((81\% \; x \; 55) + (30\% \; x \; 28)\right)}{55 + 28)} = 63.80\%$$

Three classes of learners had been observed over two 30-minute periods each with the engagement levels of 68 learners in total being observed.

During the focus group discussions, it was pointed out that the test standard had been misjudged based on the time taken to complete the test as per Figure 21. It was thus decided to leave the figure as is in Figure 20 with the * as a qualifying discussion.

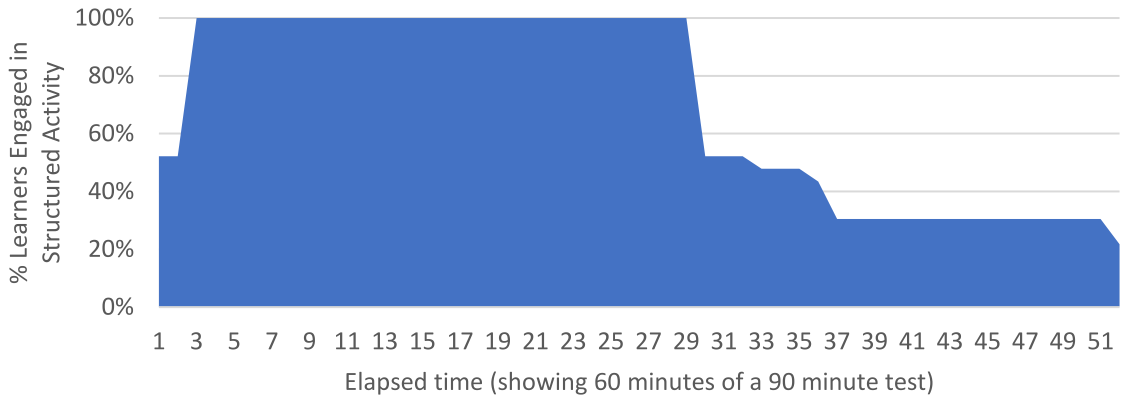

Figure 21: Engagement of Four Classes of Observed Learners During the Duration of a 90-minute Maths Assessment

In the discussion on the TOTA model in section 4.1, it was mentioned that there were three hierarchical levels of detail defined with which to analyse the data. Only the high level and mid-level details have been used so far. The focus groups were also made aware of the possibility of the detailed view of activities as shown in Figure 22, but it was not discussed in detail as it was decided that it would be overwhelming given the amount of other data shared in the presentation already. The same level of detail is thus also available of the individual and collated teacher days observed.

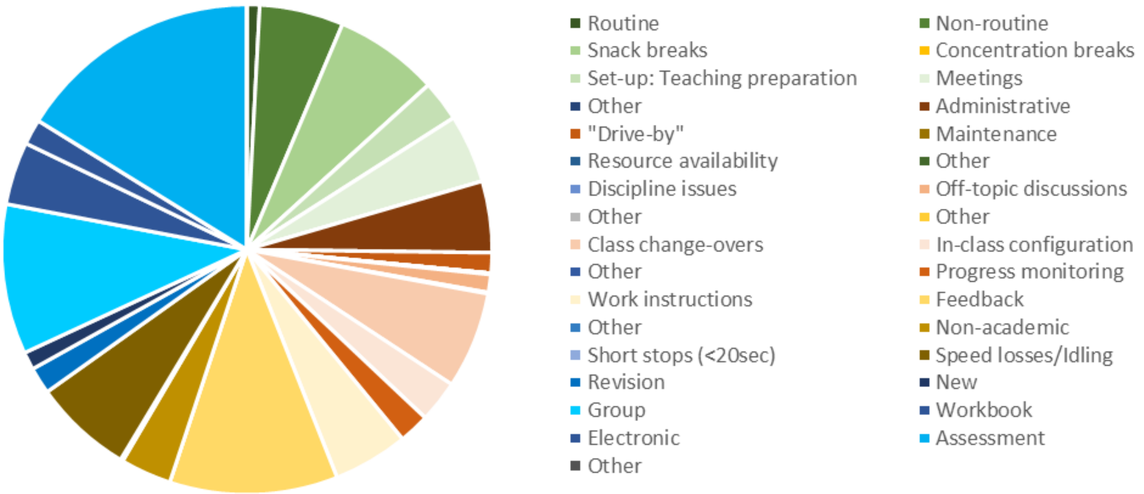

Figure 22: Detail Breakdown of Grade 5 Class School Day

OTHER INTERESTING SIDE OBSERVATIONS

The secondary data proved to be a rich source of data to analyse as more analyses were made possible from the coded quantitative data and field notes. For example, it could be calculated that during the 131 observed assessment invigilation minutes, the teacher had executed 158 invigilation actions – some initiated by the teacher, and some requested by the learners. This amount to an average of 1.2 invigilation actions per assessment minute, meaning that the teacher would not be able to multi-task during this time.

An analysis that drew a lot of interest from the focus groups is shown in Figure 28. During the observation of 52 minutes of workbook activities that learners were required to complete individually, the effect of in-class interruptions was monitored. Figure 23 shows learner engagement on the y-axis with the yellow line showing the 50% engagement mark. The remarks above the graph show three types of actions:

- Interruptions that were not task related (in red font) e.g., the teacher reminding the learners to bring signed forms for a planned camp the next day or a learner knocking over a glass of water. Most of these interruptions were initiated by the teacher making announcements or asking questions not related to the task at hand. The effect of the interruption varied from 28% loss of engagement in the class to 70%. The time to regain the level of engagement achieved when the interruption took place, ranged between 2 and 13 minutes.
- Interruptions that were task related (in yellow font) e.g., the teacher reminding learners to underline the heading of the activity in their workbooks. The effect of the interruptions in this case ranged between 0% and 9% reduction in learners on task with an engagement recovery time of 2-3 minutes.

- Actions taken by the teacher to refocus or focus the class e.g., encouraging the learners to stay on task or moving amongst the tables to mark the workbooks. The effect of these actions ranged between engagement gains of 15% to 51%. The teacher moving amongst the tables was the most effective action, achieving on task engagement of between 79% and 96%. Class 2 was observed at the end of the school day, whereas class 1 was observed in the middle of a school day, showing that the action of the teacher moving amongst the tables managed to mitigate possible fatigue felt by learners at the end of a school day.

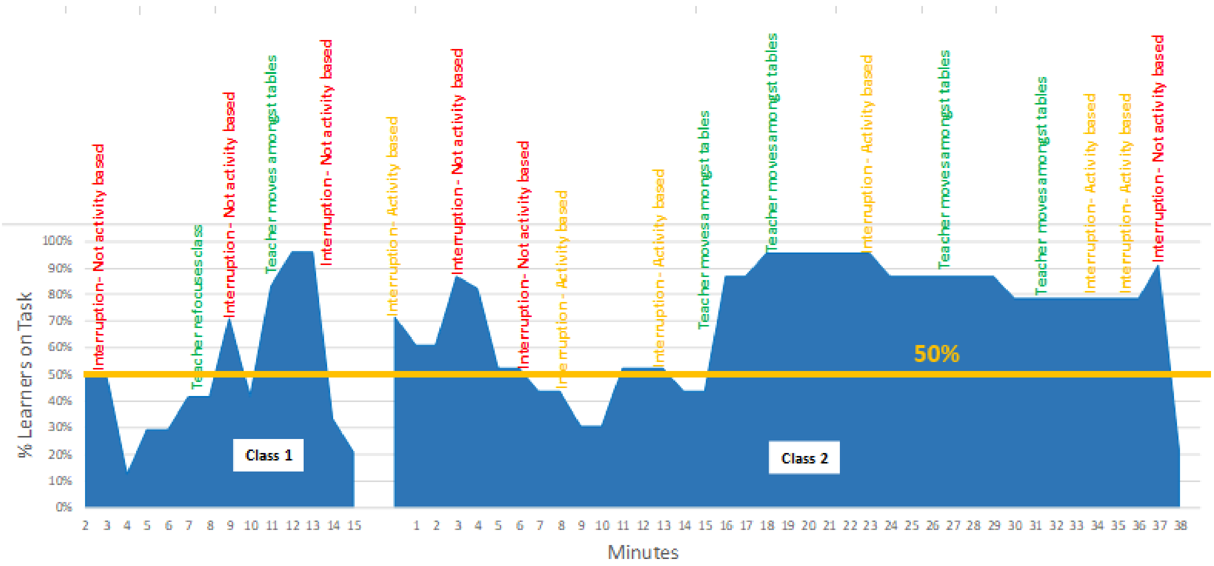

Figure 23: Effects of In-class Events on Learner Engagement During Individual Workbook Activities

The descriptive analytics described here thus demonstrated how systematic, quantified classroom observational data can be analysed using the TOTA model. The descriptive analytics were presented to and discussed in focus group format with 52 education stakeholders then responding to various questions and statements to test the novelty and validity of the model. Some of the survey questions were analysed quantitatively and the long-text questions were analysed qualitatively.

4.4 Data Analysis for Testing Model Validity and Novelty

Five focus groups consisting of a total of 52 respondents were presented the quantitative work study analysis and then asked to complete the questionnaire discussed in section 3.3. The responses to the questions will be discussed here through descriptive and inferential statistical analysis.

FOCUS GROUP PARTICIPANTS

The study aimed to get diversity in the sample group to test whether clusters responded differently to the research questions. The breakdown of the sample of 52 education stakeholders is shown in Figure 24 visualising that three quarters of the group consisted of teaching staff, whereas one quarter consisted of people involved in supporting or managing teachers. The latter group will be referred to as the 'other education stakeholders' cluster.

Based on the findings of the literature review that productivity is most influenced by the quality of teaching and time on task and is thus under the teachers' and school management's control, the proportions of the sample were considered appropriate. In assessing the validity and novelty of the TOTA model, the input of education stakeholders who had possibly received more or different exposure to productivity studies in the school environment, was also considered valuable.

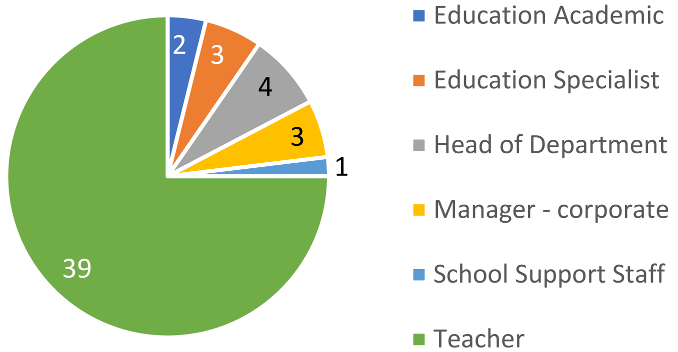

Figure 24: Respondent Clusters Based on Roles within Education

TESTING THE NOVELTY OF THE TOTA PERSPECTIVE

The novelty of the model was tested with the following two statements using a Likert scale of Strongly Agree – Agree – Neutral – Disagree – Strongly Disagree:

- The presentation of the work study analysis provides a new perspective on how productivity can be studied in the classroom. This statement explored the research question generally.
- The presentation of the work study analysis helped me to look at productivity in the classroom in a new light. This statement explores the research question personally for the respondent.

General Statement: The presentation of the work study analysis provides a new perspective on how productivity can be studied in the classroom

The responses to the testing of the novelty of the TOTA perspective generally is shown visually in Figure 25. The graph shows that most respondents, 90.3%, responded positively to the statement of whether the analysis provides a new perspective. The breakdown of the 52 responses is as follows: Strongly Agree = 12 or 23.1%, Agree = 35 or 67.3%, Neutral = 4 or 7.7%, Disagree = 0 and Strongly Disagree = 1 or 1,9%.

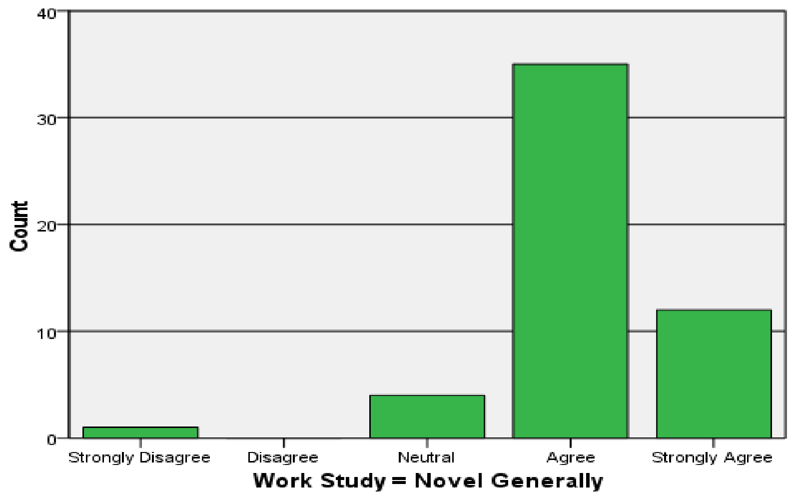

Figure 25:The Work Study Analysis Provides a New Perspective

The dot plot of Figure 26 shows the distribution of the responses of the teacher group and the other education stakeholder group. The education academics, specialists, and managers thus all felt that the analysis provided a new perspective. Of the 39 teachers participating, 34 or 87.2% responded that they agreed or strongly agreed with the statement. Excluding the outlier, this proportion increases to 89.5% of the teacher sample group.

It is reasonable to assume that the education academics, specialists, and managers have had more exposure to research than the teachers have since they are more often exposed to discussions on development in the education field and most likely hold more post graduate degrees than the teachers. The purely positive response from this group is thus significant. Indicating that the TOTA provides a fresh perspective, it can therefore be concluded that none of the 13 participating academics, specialists and managers have encountered such an analysis before.

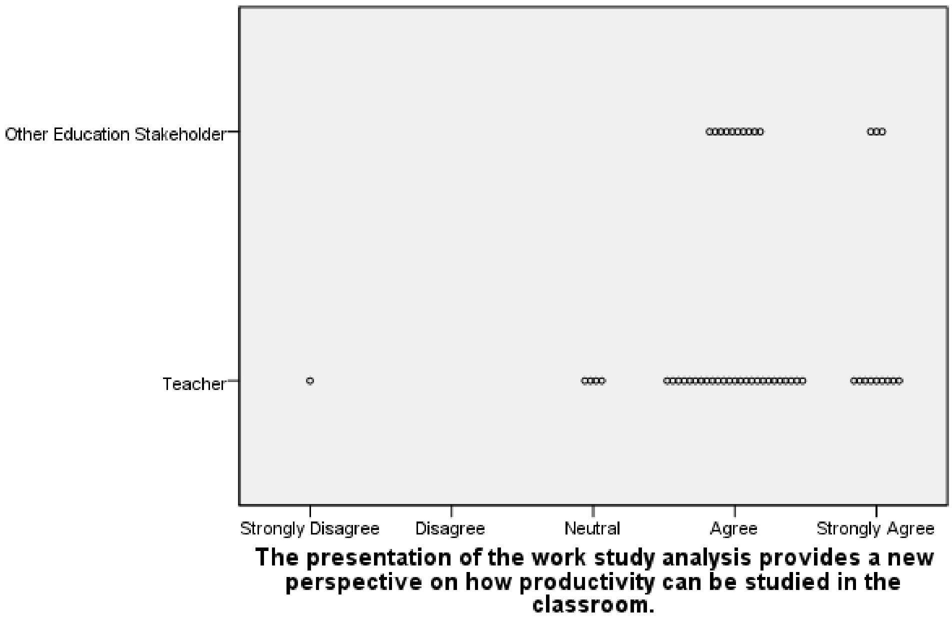

Figure 26: Responses from Teachers and Other Education Stakeholders – General Statement

Personal Statement: The presentation of the work study analysis HELPED ME to look at productivity in the classroom in a new light

Although the two statements were very similar, it did produce slightly different responses. Figure 27 visualises the responses from the 52 responses, with 88.5% of respondents stating that the analysis helped them to see productivity in the classroom in a new light. The data can be broken down as follows: Strongly Agree = 11 or 21.2%, Agree = 35 or 67.3%, Neutral = 3 or 5.8%, Disagree = 3 or 5.8% and Strongly Disagree = 0.

Again, the dot plot of Figure 28 helps visualise the distribution of the responses of the teacher group and the other education stakeholder group. In response to this statement, all but one felt that the analysis helped them see productivity in the classroom in a new light. Of the 39 teachers, 34 or 87.2% responded that they agreed or strongly agreed with the statement, whereas 92.3% of the other respondents said that the analysis helped them to see classroom productivity through new lenses.

Figure 27: Responses to Statement from Personal Perspective

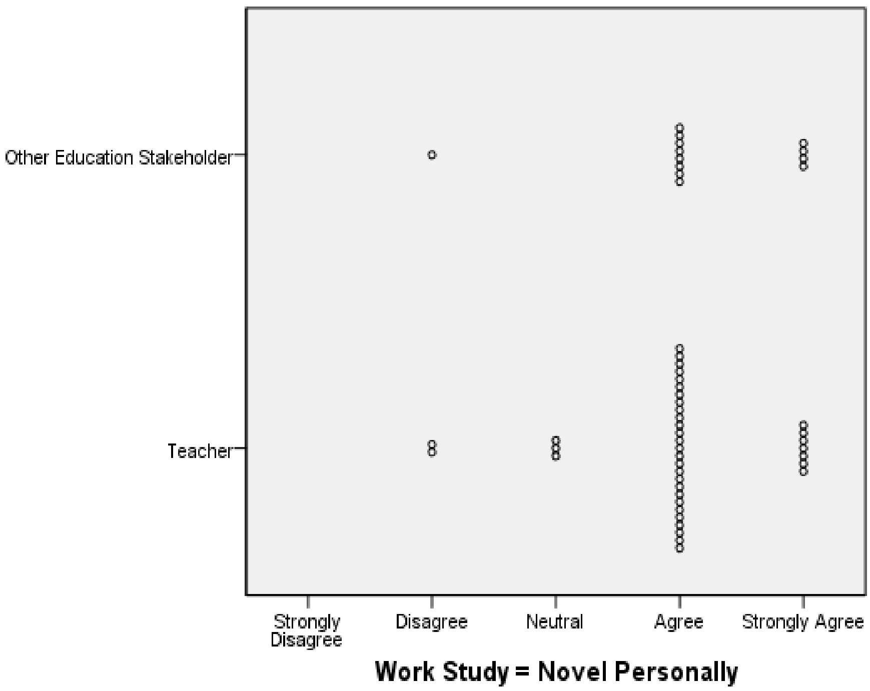

Figure 28: Responses from Teachers and Other Education Stakeholders – Personal Statement

A follow up question was asked to qualify what they found to be novel in the presentation of the data analysis. The responses are discussed next.

What did you find surprising or new? I.e., what provided a new perspective?

The results of the long-text question were coded using thematic analysis, but using the semantics provided by the TOTA model as themes where appropriate. The mid-level themes identified are shown in Figure 29. The theme most frequently mentioned by the group was the concepts embedded in Lean Management theory, namely the importance of knowing who the customer is and what constitutes value (blue-light time). 25.8% of the group mentioned this as a new perspective. The mere exposure to quantified data was cited second most frequently by the group (19.4%) as creating a new perspective – thus seeing the classroom through the data analysis provided a new perspective.

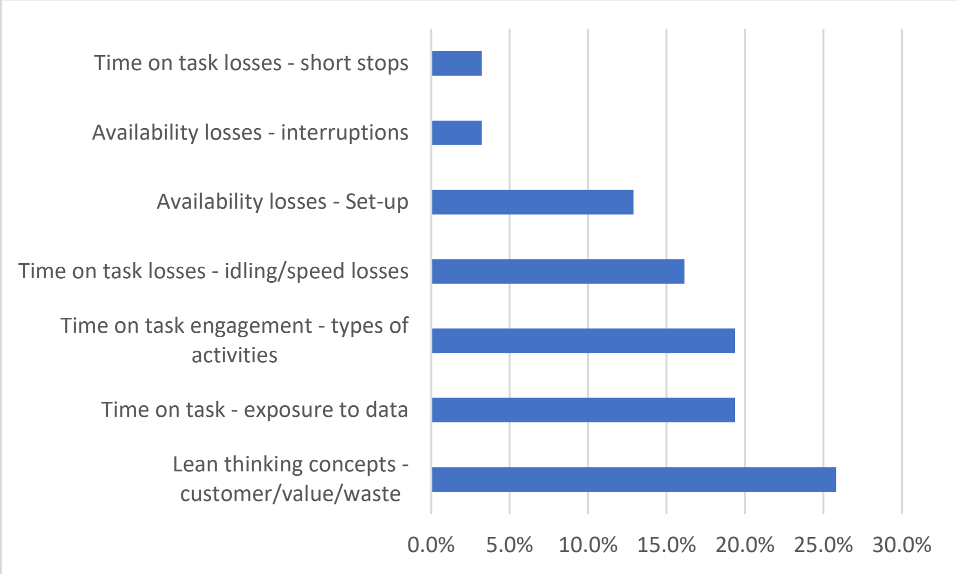

Figure 29: Breakdown of Responses - What Gave a Novel Perspective?

Another new perspective frequently listed (19.4%) was the levels of engagement of learners during various activities such as group work, teacher walking amongst the tables etc. Along the same vein were those activities that caused a loss of engagement, with 16.3% of the responses highlighting this as a new perspective to them.

The vast majority, 90.3%, of the group of 52 diverse education stakeholders indicated that the analysis of the classroom observation data using the TOTA model provided a novel perspective. Considering that systematic quantitative classroom studies are in themselves not novel (Wragg, 2011, Cobb et al., 1992, Schoenfeld, 1988), it can thus be concluded that the TOTA perspective contributed to the novelty.

TESTING THE VALIDITY OF THE TOTA PERSPECTIVE

The validity of the TOTA model has already been partly established through the testing of the model through the coding of 450 classroom observations into the structure of the model. This process established the validity attributes of completeness and freedom from conflict as defined by Shanks et al. (2003).

The researcher also synthesised the following validity attributes, which were tested through the focus groups: accuracy, individual impact, perceived organisational impact, perceived usefulness and intention to use (Brown and Jayakody, 2008). These attributes have been defined in section 3.1 and the focus group responses to the relevant questions will be described next.

As Table 10 in section 3.5 indicated, the validity attributes to be tested were covered by several survey questions and some survey questions covered several the attributes. For this reason, the responses of the relevant questions of the survey will be presented and the relevant attributes tested by that question, assessed.

The first relevant question has already been discussed, namely the presentation of the work study analysis helped me to look at productivity in the classroom in a new light. Of the focus group participants, 88.5% had responded with "Agree" or "Strongly Agree" to the statement. These responses were covered in detail in the previous section, but clearly indicate that the analysis had an individual impact on the participants in general. These responses also confirm the perceived usefulness validity attribute of the model.

I will be thinking of improvement ideas after the presentation of the work study analysis.

This statement tested individual impact, perceived usefulness and intention to use (Brown and Jayakody, 2008). Individual impact was evidenced in the fact that the participant would be willing to think of improvement, an activity that involves the participant to 'go the extra mile'. The presentation must therefore have been motivating the participant to do so, in other words, have had an individual impact. The perceived usefulness is evidenced in the fact that the participants indicated that the presentation was able to energise them toward improvement thinking, meaning that it was useful in that way. The intention to use is evidenced in the fact that the participant is declaring their intention to use the presentation to come up with improvement ideas, even after the presentation has concluded.

Looking at the data descriptively first, Figure 30 shows the distribution of the responses. An overwhelming majority of 94.2% of respondents responded positively to the statement that they would be thinking of improvement ideas *after* the presentation. These responses thus validate the Time on Task analysis as having an individual impact, being useful (for stimulating improvement ideas) and an intention to use (the analysis to generate improvement ideas).

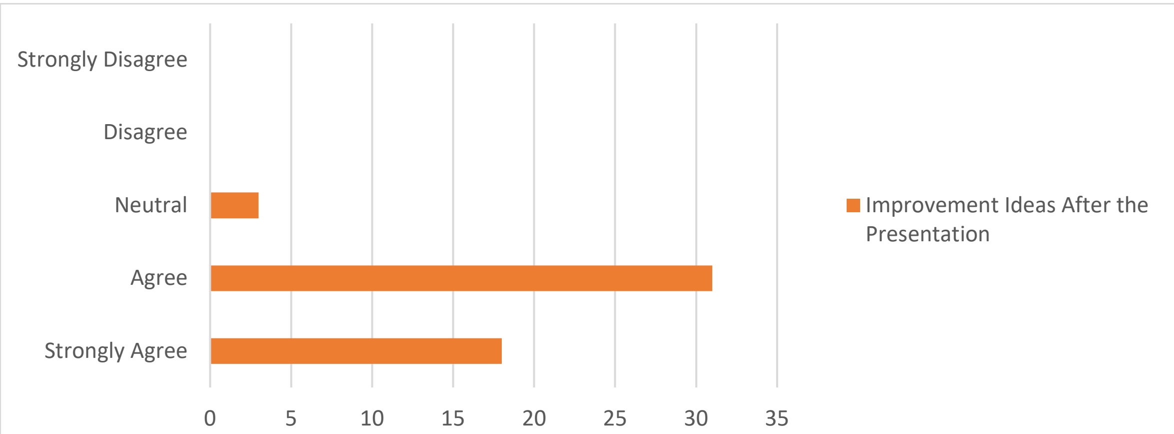

Figure 30: Did the Work Study Analysis Presentation Energise Participants Towards Improving Productivity?

Delving into the responses a bit deeper, Table 12 compares the means of the two clusters: teachers and managers (meaning other stakeholders), with 5 = Strongly Agree and 1 = Strongly Disagree. From this data improvement thinking in the managers, specialists and academics was slightly more stimulated by the data presentation, but that both groups reported a mean of above 4 (Agree) for whether the presentation had engaged them in improvement thinking post-focus group session.

Table 12: SPPS Output - Improvement Thinking

Teacher or Management		Improvement Ideas After Presentation
Teacher	Mean	4.29
	N	38
	Std. Deviation	.515
Manager	Mean	4.38
	N	13
	Std. Deviation	.650
Total	Mean	4.31
	N	51
	Std. Deviation	.547

The positive responses to this question of the questionnaire thus validated the TOTA by satisfying the requirements of individual impact as well as intention to use (Brown and Jayakody, 2008). The next question tested the validity requirements of individual impact, perceived usefulness, and intention to use, also described by Brown and Jayakody (2008).

The school/s I am involved in can/could benefit from a classroom work study project.

When asked whether the participants thought that such a work study project would benefit their school or the schools they are involved in, the response was positive, with 80.8% of the group saying that agree or strongly agree with the statement. Only one respondent responded with disagree and another one with strongly disagree. Figure 31 visualises these responses, which confirmed the validity attributes of perceived organizational impact and perceived usefulness.

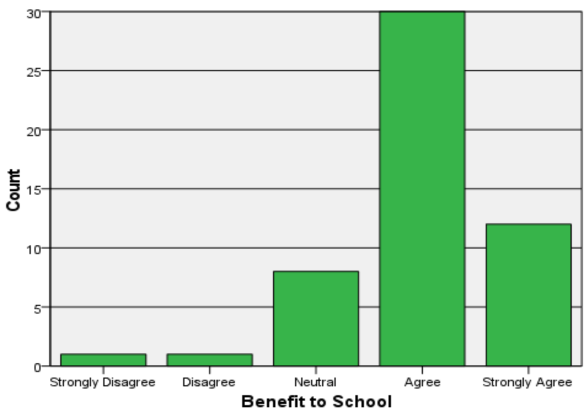

Figure 31: Benefit of Further Studies

To see whether teachers and managers responded to this statement differently, a cluster analysis was done and is shown in Figure 32. Comparing the means of the two groups reveals an interesting finding: with a mean of 4.03, the teachers were more enthusiastic about such a study in their schools than were the managers with a mean of 3.85. See Appendix C for SPPS output tables.

This finding is interesting since teachers welcome this initiative where their work is observed and analysed, a potentially exposing venture. This finding could confirm the faith Lean Management theory places in the 'worker' (Liker and Convis, 2012). One would also think that the "management" cluster would be keener to get a perspective of what is going on in the classroom than the teachers would be willing to reveal, but the finding shows the opposite, even though both groups gave positive responses.

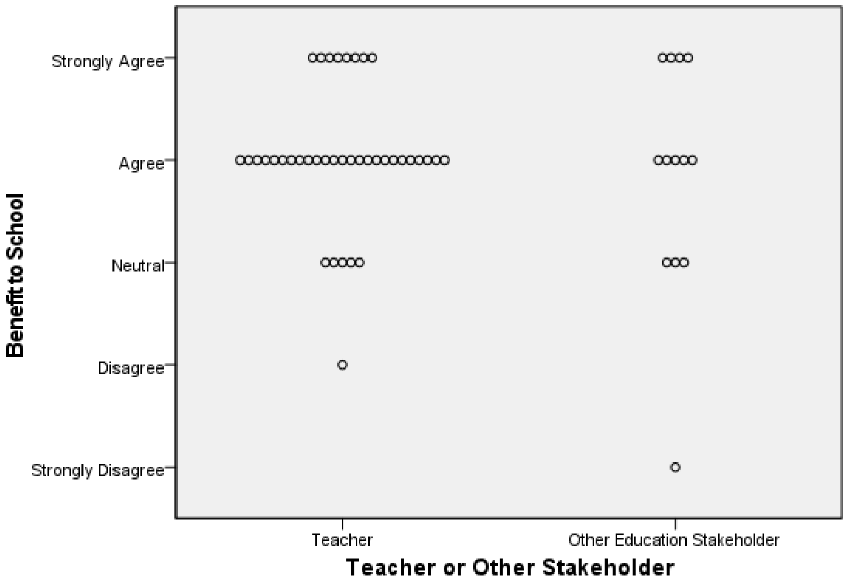

Figure 32: Cluster Responses to Benefit to School Statement

The positive focus group responses to the question of whether such an analysis would benefit their school, thus validated the model by affirming the attributes of perceived organisational impact and perceived usefulness (Brown and Jayakody, 2008).

The analysis of the survey responses indicates that the sample group viewed the TOTA to be novel and valid, as defined by Brown and Jayakody (2008) and Shanks et al. (2003). The focus group participants were keen to be part of or exposed to more such studies, which also justifies the selection of a Lean Management approach, discussed in the next section.

4.5 Assessing the Suitability of Lean Management as an Approach

The introductory chapter and literature reviews have explained the reasoning behind choosing Lean Management theory as theoretical framework for productivity improvement in schools as:

- A way of combining Scientific Management and Human Relations Theory (Tsutsui, 2001)
- A way to focus productivity improvement on what creates value (Womack and Jones, 1997)
- A method of mitigating the reported resistance to change in the education sector (Senge, 1995, Liker and Convis, 2012)
- The field covers all aspects of operations improvement and therefor offers many tools and techniques to use (Bicheno and Holweg, 2000).

The TOTA model represents Scientific Management in that it views work analytically to identify improvement opportunities (Waring, 2016). By involving different education stakeholders, at different levels of the educational hierarchy, including teachers, in the focus groups, represented the people involvement aspect of Lean Management (Womack and Jones, 1997). The questionnaire tested whether and to what extent the presentation of a TOTA could be energised towards improvement thinking. The relevant questions and their responses are discussed here:

I will be thinking of improvement ideas after the presentation of the work study analysis.

The reason for asking this was to test whether such a notoriously difficult group (Ehrenberg, 1999, Elmore, 2004, Senge, 1995) could be energised by following a Lean Management approach. As Bressant was earlier quoted as summarising a major element of Lean Management: "With every pair of hands, you get a free brain" (Totterdill, 2014). Drawing from Lean Management theory's positive outlook on people involvement in improvement, the statement was set to see to what extent the stimulation of exposure to the data would serve to energise an improvement effort.

Looking at the data descriptively first, Figure 33 shows the distribution of the responses. 94.2% of respondents responded positively to the statement that they would think of improvement ideas after the work study analysis presentation. Only three participants felt neutral about the prospect, with no negative responses. This indicates that it is possible to energise educators towards improvement – even when only exposed to a presentation of quantified classroom observation data. The Lean Management approach is to do improvement *with* people and not *at* them. Although a classroom observation exercise can be an intrusive and exposing exercise, it is clear from the data that the participants responded positively to the data, even if the data revealed how much time on task opportunity is lost during the school day.

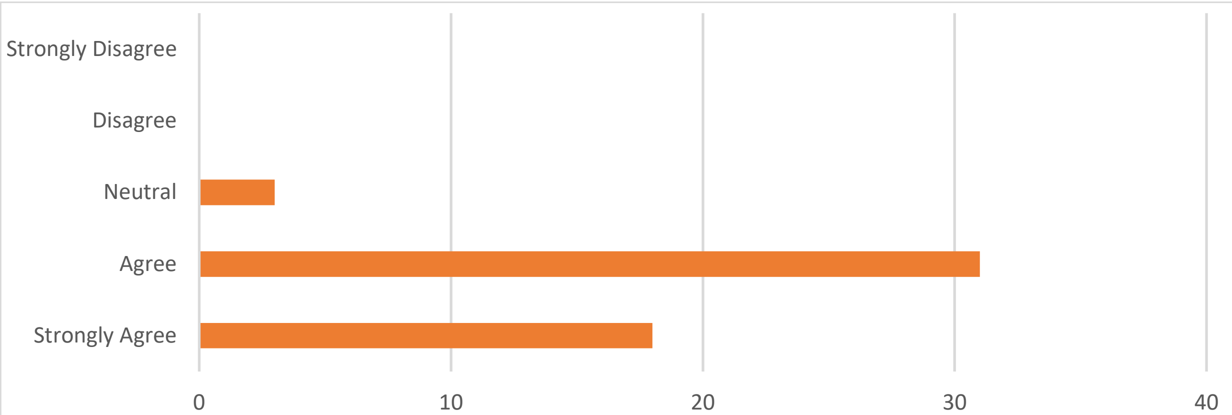

Figure 33: Did the Work Study Analysis Presentation Energise Participants Towards Improving Productivity?

The responses to the long-text question: "Which improvement opportunities became evident during the presentation of the data?" identified a few common improvement themes selected by the group, such as:

- Incorporate more high-engagement time on task activities such as group work
- Reduce the number of internal interruptions initiated by teachers
- Reduce the amount of set-up time
- Give more teachers exposure to such data analysis.

A paired samples t-test was used to test the correlation between the novelty of the information to the participants personally and the level of energy created for improvement efforts after the presentation. The dot-plot is shown in Figure 34 and visualises a statistically significant (p = 0.006) and moderately positive correlation (*r* = 0.346). The SPSS output tables are shown in Appendix C. This positive correlation thus indicates that the more novel the participants found the study, the more energised they felt. Five data points explain how the strength of the correlation could have been mitigated: Figure 34 shows five participants who did not find the analysis novel to them personally, but still found it stimulating in terms of improvement thinking. The negative t-Test statistic of *t* = -2.88 confirms this finding.

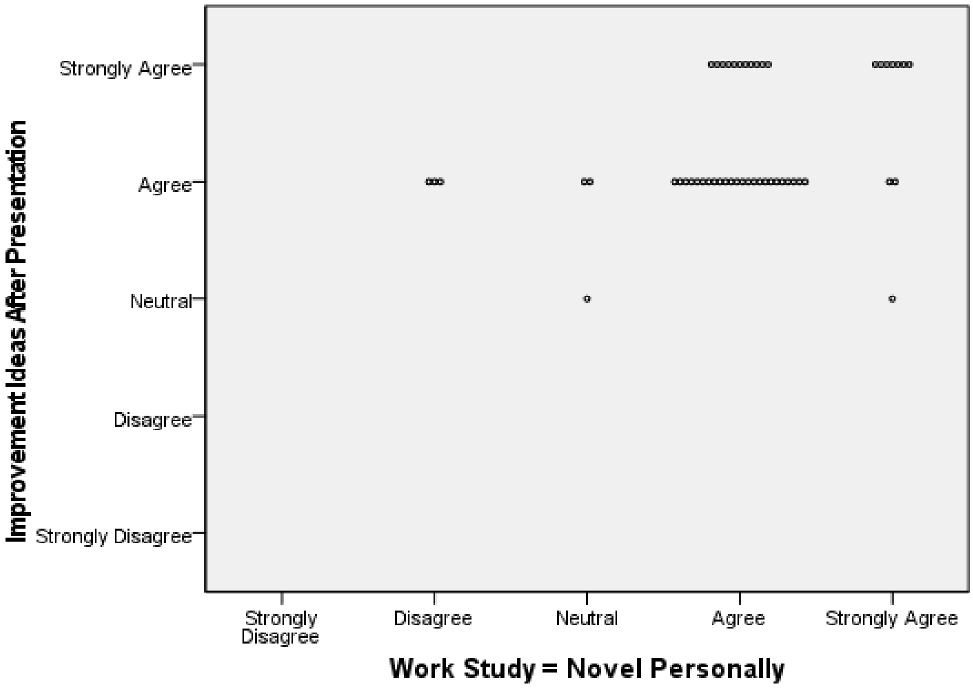

Figure 34: Novelty of Information versus Engagement in Improvement Thinking

Which education stakeholders would benefit most from exposure to the findings of the work study data?

This question tested the Lean Management approach of people involvement, where all levels of the organisation should ideally be involved in the improvement effort, most especially the people at the coal face, in this case, the teachers. The responses indicated that 50.5% of the group felt that teachers would benefit most from exposure to the findings, confirming an approach which involves people at the coal face of the operations. School management and education policy makers were selected as the target audience by 25.0% of the group each. It was decided to drill down into the data by clustering. Figure 35 shows that the teacher cluster felt that teachers should be the target group. Similarly, the management cluster felt that school management should be the target audience. This statement did not give consensus on which group should be targeted for such exposure but showed groups feeling positive about their peers benefiting from such an initiative.

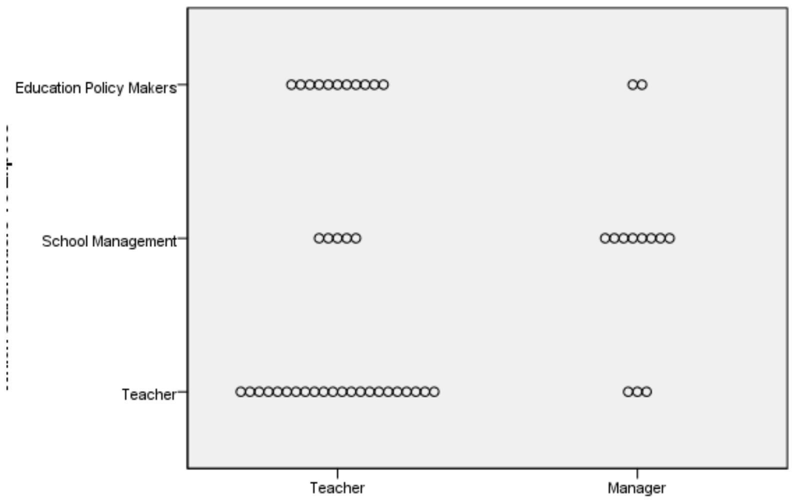

Figure 35: Which Education Stakeholders Should be the Target Audience?

How will teachers best be engaged with a work study?

The statement in the questionnaire read as follows:

Please rank the following options according to the impact that you think these options will have on productivity improvement in the classroom.

- *Teachers having been exposed to the findings of a classroom work study analysis*
- *Teachers having been observed in the classroom during a work study analysis.*
- *Techers having been part of a classroom productivity improvement workshop following a presentation on a classroom work study analysis.*

The first-choice responses are shown in Figure 36 and shows that 60% of the respondents felt that, if teachers were to be engaged, the most valuable method of engagement would be not only to expose them to the findings of the study but to allow them to participate in an improvement workshop afterwards. This ranking validates the suitability of the people involvement principle of Lean Management theory.

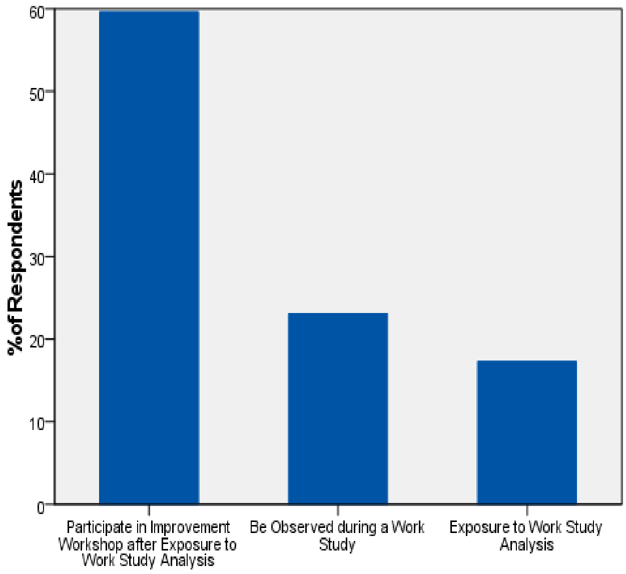

Figure 36: Breakdown of How to Engage Best with Teachers

It is interesting to note that almost a quarter of the group thought that teachers would benefit most from being observed during a study. A clustered analysis was once again done to see whether opinions differed on how teachers should be engaged, but as can be seen in Figure 37, there was no significant difference between the groups. It is again interesting to note the number of teachers who thought that teachers being observed would be most effective considering that such a study could also be perceived as intrusive and exposing by both teachers and school management. The debriefing interviews held with the participating teachers are analysed in the next section and explore the experiences of the teachers who were observed during the work study that generated the secondary data used in this dissertation.

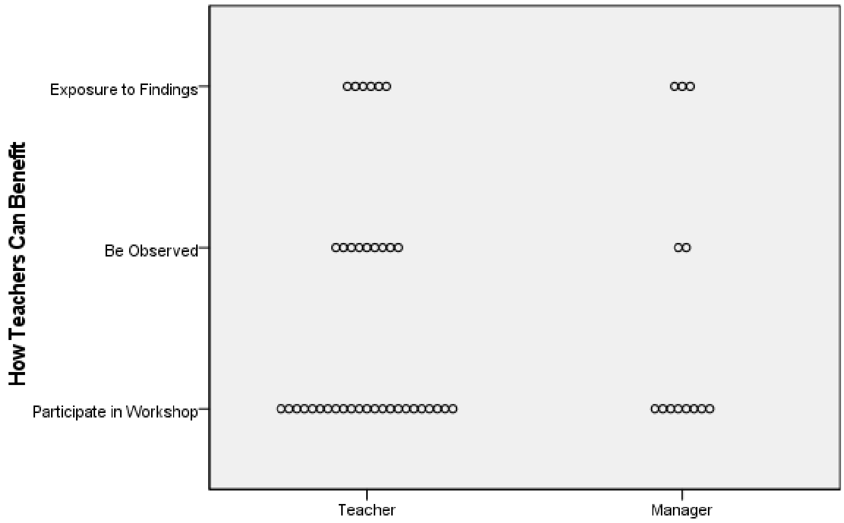

Figure 37: Clustered Responses - How to Engage Teachers

Long-text questions:

In keeping with Lean Management theory, the long-text focus group questions were set to identify what the participants thought could be the next steps after such a study. The questions are listed in Table 13.

Table 13: Long-Text Questions of Focus Group Questionnaire

What are your main observations/realisations from the data presented?
What did you find surprising or new? I.e., what provided a new perspective?
What did you find unsurprising? I.e., what confirms an existing perspective?
How do you think these studies can be used to improve productivity in the classroom?
Which improvement opportunities become evident during the presentation of the data?
What causes productivity losses in the classroom? What prevents learning from being more productive?
Do you have any other observations or some experience that you would like to contribute? If so, please elaborate.

The TOTA model developed during this research proved useful to codify the responses into the time loss categories. Some further, more general, categories were also added to assist with the codification.

Many of the responses were duplicated amongst the questions, with participants clearly focusing on one or two themes that they found important. An analysis of the different questions also produced the same ranking of responses. It was thus decided to code all responses, eliminate duplicate answers and then to rank the improvement opportunities in order of the frequency they were mentioned.

Once the 227 items of long-text input from the 52 participants were coded, the five dominant themes most often mentioned by the participants were:

- Learning about new concepts such as that introduced at the beginning of the presentation (customer, value, waste, i.e., Lean Management).
- The value of exposure to analysed data from quantified classroom observation studies:
    - Same data, other teachers
    - Same teachers, more types of data
- Exposure to what learning activities produce best time on task engagement
- Exposure to what causes Time on Task losses
- Importance of understanding and optimising set-up time
- Awareness of the effect that interruptions have on Time on Task.

Figure 38 visualises the relative frequencies of the responses:

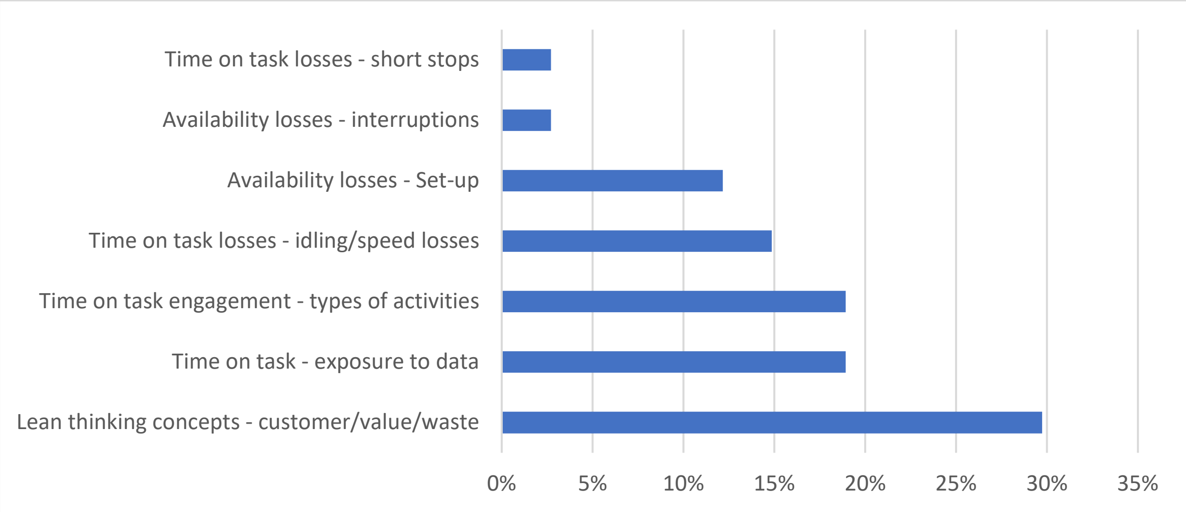

Figure 38: Frequency of Improvement Themes from Focus Groups

It was interesting to discover that the introduction to the presentation containing the story of "blue-light time" explaining some fundamental Lean Management concepts, had a big impact on the participants as it was the most frequently cited element of the presentation within the context of what the participants considered worth exploring further. Participants either asked for training for themselves on more such concepts or asked for peers to be exposed to the same concepts contained in the presentation.

Secondly, the participants felt that the mere exposure to such analysed and visualised data was worthwhile rolling out to other education audiences. Seven teachers wrote that they had never looked at their school day from the TOTA perspective, while many others used adjectives such as "insightful" or "valuable perspective" to describe the analysis. Presenting the analysis to more education audiences, with or without a preceding work study, was thus second on the list of recommended next steps.

The other aspects mentioned frequently had to do with various aspects of the data found to be interesting, which is useful for identifying further research that will be relevant to the focal domain stakeholders. These are expanding on the types of activities that make up Time on Task and what types solicit the highest engagement levels from learners; studying idling losses and how to overcome these; a more in-depth study of set-up losses; studying the impact and duration of different types of interruptions; and the impact that short stops have on the school day.

DEBRIEFING INTERVIEWS WITH THE PARTICIPATING TEACHERS

A debriefing interview was held with the three teachers who participated in the work study. One of the limitations of work studies is the risk of the Hawthorne Effect affecting the participants' behaviour during the study (Kanawaty, 1992) and hence distorting the data to reflect something other than the true situation being studied. During the debriefing interview, the teachers were asked whether being observed had affected their productivity during the work study day. Two out of the three teachers responded that their productivity had not been affected by being observed and one teacher reported that her productivity was better under observation.

The two teachers who reported no change in their productivity had days where the teachers played a smaller role and the learners were doing most of the work, i.e., assessments and group work. The teacher who reported improved productivity was more active during the day, with classes generally following the revision, teaching, application pattern. In her day, there were thus more changeovers between activities, and she was more in control of her productivity than the other two teachers who were invigilating or supervising learner activities.

This analysis of the teachers' responses suggests the hypothesis that if a teacher can change their productivity during a school day, the experience of being observed would most likely have a positive effect on productivity. The small sample of data in this pilot study unfortunately does not allow for any conclusion in the matter, but the relatively large group of respondents indicating that teachers being observed will be the most effective way of engaging teachers (Figure 36) poses an interesting opportunity for research in this line of thinking.

Should the hypothesis prove to be correct, i.e., that the Hawthorne Effect is at play during the observations, it does not necessarily mean that such studies would be invalid or of lesser value. Within the greater aim of effecting productivity improvement in schools, the mere fact that teachers are adapting their behaviour shows that the experience of being observed stimulates a critical self-assessment of the teacher's activities, the teacher identifying opportunities as well as improvements with which to then experiment during the study.

If a classroom work study is to be used to measure and compare teachers' productivity, the Hawthorne Effect would pose a threat to the validity of the data. However, in the context of a productivity improvement initiative, the work study exercise could prove to be a powerful tool.

Although only one of the three teachers reported increased productivity levels during the study, all three teachers reported identifying productivity improvement during the work study day, confirming the hypothesis that the mere experience of being observed can stimulate improvement thinking, albeit only initially.

Two of the three teachers reported thinking of more improvement ideas after the study, indicating that a work study might also have longer lasting improvement thinking effects than simply during the study itself.

It is important to mention some limitations to the findings of the debriefing interviews. Volunteer sampling was used for the work study which could skew the responses towards more pro-active answers due to the nature of the participants. Teachers who volunteer to be observed with little warning probably are welcoming of feedback on their performance hence they might also be more prone to be pro-actively seeking improvement opportunities. It would be ideal if random sampling could be used, but work study is a relatively invasive study and poses labour relations challenges if buy-in has not first been created.

CONCLUSION

This chapter has described all the research outcomes produced by this study, such as the structure of the novel and valid TOTA model and its layers of loss categories as well as their detail definitions. The chapter has also presented the template derived from the model and used to create the descriptive analytics of the classroom observations of how time is spent during a school day, which the education stakeholders of the focus groups had also found to be novel and valid, stimulating them to think of productivity improvements and indicating that they would welcome more such initiatives in their organisations and schools.

Chapter 5 summarises and discusses the answers to the research questions, the limitations of the research and further research opportunities that were identified during this study.

5 CONCLUSION AND RECOMMENDATIONS

This research consisted of different phases, combined theory employed by two diverse disciplines and produced several outputs. This chapter synthesises the different threads of the research and provides a springboard for further research into how schools can be made more productive.

5.1 Answer to the Research Question

The research question was developed after an extensive preliminary literature review in which a gap was identified in the body of knowledge of productivity in schools: using quantitative classroom observation analysis to enable productivity improvement through time on task optimisation. The research question was articulated as follows:

Does Lean Management theory, and in particular the use of Overall Equipment Effectiveness (OEE) as analytical framework for quantitative classroom observation studies provide a novel and valid perspective with which to enable productivity improvement in schools?

The research design established two phases: the creation of a Time on Task Analysis (TOTA) model, based on the framework of OEE and then the testing of the novelty and validity of this model.

DOES THE TOTA MODEL PROVIDE A NEW PERSPECTIVE ON CLASSROOM PRODUCTIVITY?

Quantitative classroom observation studies are not novel (Apter et al., 2020, Wragg, 2011), but the TOTA perspective on classroom data was found to be novel by 90.3% of the 52 education stakeholders surveyed. The breakdown of the 52 responses is as follows: Strongly Agree = 12 or 23.1%, Agree = 35 or 67.3%, Neutral = 4 or 7.7%, Disagree = 0 and Strongly Disagree = 1 or 1,9%. A clustered analysis showed that 87% of the teachers and 100% of the other education stakeholder group felt that the work study analysis provided a new perspective. The vast majority of the sample group of education stakeholders consisting of 39 teachers and 13 principals, heads of department, academics and corporate managers thus found the Time on Task Analysis novel.

The diverse composition of the sample group mitigated the question of whether the participants had been exposed to other quantitative studies as the group consisting of senior and experienced education academics and corporate managers all indicated that the TOTA perspective was novel in their opinion.

A review of the literature on quantitative classroom observation studies also did not identify any classroom observation templates resembling that of the TOTA template. In fact, these studies tended to focus on more pedagogic or sociological aspects of the classroom (Wragg, 2011). Where literature was closely aligned to the TOTA work (Carroll, 1963), the level of detail of the TOTA was not present.

IS THE TOTA MODEL A VALID FRAMEWORK FOR ENABLING PRODUCTIVITY IMRPOVEMENT IN THE CLASSSROOM?

Revisiting the definitions of the validity attributes (Table 14) as proposed by Shanks et al. (2003), a model is deemed accurate and complete when it accurately and completely represents the semantics of the focal domain as perceived by the stakeholders from the focal domain.

Table 14: Definitions of Validity Attributes (Shanks et al., 2003)

Model Attribute	Attribute Definition
Accuracy	The model should accurately represent the semantics of the focal domain as perceived by the stakeholder(s) of the focal domain.
Completeness	The model should completely represent the semantics of the focal domain as perceived by the focal stakeholder(s)
Conflict-free	The semantics represented in different parts of the model should not contradict one another; and there should be no redundancy. To reduce the likelihood of conflicts arising if and when the model is subsequently updated the model should not contain redundant semantics.

Although the definitions by Shanks et al. (2003) place emphasis on the perception of the stakeholders of the domain, the TOTA model was also tested by using it to analyse 450 classroom observations, thus data from the focal domain. The data provided the semantics of the target environment, which tested whether the model was accurate, complete and free from conceptual conflict (Shanks et al., 2003). The model consisted of six hierarchical levels, with the framework of Overall Equipment Effectiveness corresponding to the fourth level of the model's hierarchies. Up to this level the model proved to be accurate, complete, and conflict-free with no need for any conceptual adjustments.

At the two detail levels, where the six major losses had been broken into more detailed losses and definitions had been created with examples, there were some refinements to be made to the completeness and conflict-free attributes. The completeness of the model was enhanced by adding further examples to the detail definitions and expanding other definitions to make them more descriptive using the semantics provided by the data. Categories called "other" were added to the model to allow for ad hoc data that does not warrant a category on its own, but also to allow for future refinements should a category of data show to be more prevalent than anticipated.

Conflict freedom screens for redundancy and contradictions. Although no contradictions were found, some detail categories could be collapsed, and others expanded to clarify their use or to make the model more streamlined. The detail data thus strengthened the model at a detail level, but also showed the model to be structurally and conceptually valid.

During the focus group discussions involving 52 stakeholders from the focal domain, the use of the model, rather than the model itself, was presented through the descriptive analytics of the secondary data to test the further validity attributes of Brown and Jayakody (2008), but these discussions also in effect tested the model's structure and semantics. None of the stakeholders questioned the model or its semantics, but rather affirmed it with statements such as those shown in Table 15, which also indicates the education roles fulfilled by the relevant participants as context to the comments.

Table 15: Focus Group Comments and Participant Background

Comment	Teacher	Principal or Head of Department	Corporate Manager	Academic or Specialist
"It's very accurate."	X	X		
"Very interesting approach to the study of teacher effectiveness."	X	X	X	
"Insights resonated with teacher coaching work and instructional leadership strategies"	X	X		X
"This data can be particularly useful from an education management perspective to inform principals and their management teams of the efficiency and effectiveness of the management structures and procedures in their schools.	X	X	X	
Analysis is "consistent with our current work developing teacher insights."	X	X		X

Only two participants offered criticism, but not of the model per se. One teacher commented on the timing of the presentation ("I strongly feel that this work study was completed and presented at the wrong time") possibly due to schools functioning in the online mode as part of schools' closure due to the Covid-19 schools' closure. The other comment, by an academic and corporate manager, mentioned that some assumptions made were not supported by the data, but did not qualify this statement. The presentation however, only presented the descriptive analytics described in section 4.3 and no assumptions were made except for the extrapolation, mentioned as such, and detailed in section 4.3, of the engagement time of the assessment day (Figure 20). It was thus difficult to ascertain which assumption the participant was referring to, or whether this had been a misunderstanding of some part of the presentation. The other participants' long text answers focused on the insights gained and opportunities identified. Thus, although the stakeholders were not asked outright whether they found the model to be valid, the insights produced by the semantics of the model were very well received by the participants.

Brown and Jayakody (2008) added the validity attributes of individual impact, perceived organisational impact, perceived usefulness and intention to use to the original validity attributes defined by Shanks et al. (2003). These attributes were tested through the focus groups, thoroughly testing the perceptions of the stakeholder group of the target domain, as prescribed in the definitions in Table 14.

The responses of the focus groups were analysed and presented in section 4.4 and confirmed all the validity attributes tested through the focus group questionnaire after the participants had been exposed to the data analysis using the TOTA model. Table 10 in section 3.4 indicated how the different questionnaire items targeted the various validity attributes.

Perhaps the most significant validation of the model is a group of schools engaging with the researcher to roll out a TOTA "blue light time" initiative in three of their schools' divisions during the course of 2022 as part of a longer-term initiative. The management of this schools' group were participants in the focus groups of this research.

CONCLUSION

The TOTA model was adapted from Overall Equipment Effectiveness to enable productivity improvement in the classroom through the identification and quantification of time on task losses during the course of the school day. The intention is for the analysis produced to be presented to the teachers involved to energise and empower them towards improving productivity in their own classrooms. The recommended Lean Management approach would then recommend that these teachers be equipped with tools and techniques that could help them convert improvement opportunities into improvements. However, without the adoption of a Lean Management culture, and its fundamental principles, the gains will remain isolated and sustainability and synergistic progress will be compromised (Liker and Convis, 2012). It is thus imperative that not only the Scientific Management tools and techniques embedded in Lean Management be utilised, but also the Human Relations side of the theory regarding organisation culture and leadership (Tsutsui, 2001).

5.2 Discussion

The TOTA model provided a novel and valid platform with which to engage education stakeholders in the quest for improving productivity in schools. A Time on Task Analysis is based on actual data instead of theory and experience, and can be used for one individual teacher, one group of learners, or aggregated as part of a bigger body of knowledge.

The positive responses by the education stakeholders participating in the focus groups, indicates an openness to and even an appetite for perspectives, such as that provided by the TOTA model, in facilitating productivity improvement initiatives in their schools and classrooms. 90.3% of participants indicated that the presentation of the data gave them a new perspective. 94.2% of respondents indicated that the presentation had energised them to come up with improvement ideas and 80.8% of the sample said that they believed the schools they were involved in could benefit from work studies being done in their school.

The aspects of the focus group presentation and discussion most frequently mentioned as novel or valuable were the descriptive work study analytics and exposure to Lean Management concepts such as blue-light time and the focus on the customer. The participants' improvement suggestions centred around the reduction of Time on Task losses, but also on the curiosity of how to optimise Time on Task.

The resistance to change well documented in literature (Sarason, 1990, Horsley and Kaser, 1999, Flumerfelt and Green, 2013, Ehrenberg, 1999) was thus not experienced in this study, which involved engaging with various education stakeholders, challenging their perception with the TOTA model, analysed classroom observation data and solicited improvement ideas. This is most probably due to the participative approach followed, which correlates with both Lean Management theory and education scholars such as Senge (1995) and Elmore (2004). The latter scholar noted: “One does not ‘control’ school improvement processes so much as one guides them and provides direction for them, since most of the knowledge required for improvement must inevitably reside in the people who deliver instruction not in the people who manage them.”

This quote summarises the approach proposed by and, to some extent proven effective already, by this study: Firstly, empowering the people at the coal face, the teachers, with data analysis and valuable new concepts and the secondly, if improvement energy has successfully been created by the first step, to facilitate and guide the teachers on both individual and collective paths of productivity improvements in their school.

Thus following a kaizen, or continuous improvement, approach as promoted by Lean Management theory not only satisfies many of the principles postulated by Human Relations scholars such as Maslow, McGregor, Argyris and Herzberg (Singh and Singh, 2009) , but also combats many of the pitfalls of big change initiatives. Kaizen by nature is continuous, incremental and participative (Imai, 1986). Participating in improvement generates intrinsic psychological and quality of work-life benefits for employees (Singh and Singh, 2009), making change a positive experience rather than one to be feared and resisted.

The TOTA was received positively by the teachers even though it could have been perceived as invasive and incriminating. The teachers and other stakeholders expressed the need for wider dissemination of such data analysis. The researcher strongly recommends that data collected through classroom observation studies should remain the ownership of the particular teacher group as data interpretation is relatively subjective. Collected data might be aggregated with other studies to build on a greater body of knowledge, but the researcher suspects that, as soon as it is used as a comparison to some standard, in other words, as soon as the focus changes from improvement to measurement, the positive view towards the initiative will change from support to suspicion.

Collecting data for comparison and collecting data for improvement, are also two different things. When collecting data for comparison, the definitions and understanding of various analytical categories becomes paramount to the credibility of the data analysis. In contrast, collecting data for improvement allows for more freedom of interpretation as inefficiencies perhaps wrongly allocated during the early phases of improvement will be addressed in the later phases, or can be correctly allocated as the group engaging with the problem becomes aware of new insights.

Due to the positive reception by the focus groups, disseminating the data analysis of this study to stimulate improvement thinking amongst school staff, and conducting more such systematic quantitative classroom observation studies to add to the accuracy and representativeness of the descriptive analytics presented in this paper, seems to a be the most apparent next step of this research to further contribute to the study and improvement of productivity in schools.

From the descriptive analytics, long text responses of the focus groups as well as the field notes of the secondary data, a list of Industrial Engineering or Lean Management techniques could be synthesised as subjects of further research in the classroom, but also concepts which teachers could be exposed to during improvement workshops that should follow the presentation of the work study data analysis. This list includes:

- Quantitative, systematic observation studies

The data indicated that more of these studies should be done as the study itself generates energy and improvement thinking within schools. Future studies can make use of the TOTA template (Table 11) to guide observations to specifically focus on Time on Task losses in the school day.

Some other aspects highlighted by the data to be focused on during further studies is the effect and duration of interruptions on Time on Task, looking at which learning activities are more easily disrupted, and for longer, than others. Additionally, what type of interruptions are more disruptive than others.

- Visual management

As schools consist of a lot of human interaction, which is individualised, visualising some interactions may serve to streamline communication and coordination of resources, but may also assist teachers to reduce learner idle time. Visual management tools such as Kanban could be introduced into the schools' environment to facilitate both teaching and learning.

- Technology adoption

Technology could be used to reduce learning idle time caused by a difference in the speed at which learners within a class complete their tasks. The use of tablets might allow for learners to progress at their own pace, allowing faster learners to be challenged, while flagging learners who need intervention on a specific topic. The classroom observation data confirmed this as the time spent on tablets, either playing educational games or designing a poster, showed high levels of engagement. The use of such individualised learning experiences through the use of technology could thus be explored to target the reduction of idle time or work speed related losses associated with mass education.

- Lean Management training, including Theory of Constraints

Another prominent theme produced as a possible future intervention was the exposure and training of teachers and school management to the principles of operations improvement. Specifically mentioned, and used during the focus group presentations, were the concepts of value, waste and customer focus found in Lean Management theory.

From the field notes and the work study data, an understanding of the Theory of Constraints (TOC) could also prove to be valuable to teaching. The TOC steps of managing bottlenecks are firstly to identify the bottleneck, secondly to exploit the bottleneck, thirdly to subordinate to the bottleneck, fourthly to elevate the bottleneck and lastly, to identify the new bottleneck (Goldratt and Cox, 2016). In mass education, the difference in learning and working speeds inevitably leaves some learners behind and bores others learners to the point of distraction (Tomlinson, 2001). The education literature offers a wide variety of teaching strategies and tools (Randi and Corno, 2005, Tomlinson, 2001), but these are not presented in the systematic framework that is offered by TOC. Thus, exposing teachers to the principles contained in TOC, might provide a stimulating perspective as to how to integrate some of the many instructional strategies already on offer in education literature with those provided by TOC.

- Optimisation and Scheduling

Data from quantitative classroom studies can be used to optimise scheduling of venues, rosters and learning activity types to reduce time on task losses, but also maximise the effectiveness of the time on task. For example, if teachers are unaware of what types of instructional activities took place in previous periods, they might contribute to monotony in teaching by not building in sufficient variation into the learners' school day and thereby contributing to a loss in engagement levels of learners. An algorithm of optimal variation in instructional activities based on the levels of engagement produced by specific combinations of instructional activities, could be used as a guide by teachers and grade coordinators to ensure that the school day contains variation to optimise engagement levels of learners.

Such an optimisation exercise could also enable the reduction of other time losses as more optimal combinations of instructional activities could reduce the need to change classes as frequently as is currently the case in most schools.

- Quantifying Time on Task Quality

The TOTA model currently only looks at Time on Task losses during the school day. It can be expanded to cover the full spectrum of the OEE model, which would include the Quality of Teaching aspect. This would then ask the question of how effective the Time on Task was, rather than just how much Time on Task there was in the school day. In other words, in the time a learner spent on task, how effective was that time spent in terms of the learning that took place?

Although these six themes emerged from the data as being concrete tools or methods to introduce into the study of productivity in schools, Lean Management theory propagates the empowerment of the workforce through doing improvement with them rather than at them. Building improvement technique awareness among teachers would mean that teachers can "pull" improvement into their workspaces, rather than the improvements being "pushed" into their workspaces without the need for change existing with the particular teacher being asked to adopt the change.

Considering Lean Management theory and the outcomes of this research, the recommendations of this research to enable productivity improvement in schools are that:

1. Further work studies be done – to create energy and build the body of data.
2. These work studies use the TOTA template.
3. These TOTAs are presented to the teachers and school management of the schools involved in the study, and/or associated schools.
4. These TOTA presentation be used to introduce fundamental concepts of Lean Management theory such as the customer focus, definition of value-addition and waste.
5. The TOTA presentation be followed up with an improvement brainstorming workshop with the school staff.
6. The improvement workshop be used to expose school staff to appropriate Industrial Engineering and Lean Management techniques, some already identified in this study.
7. Improvement efforts be sustained by regular improvement workshops and a wider adoption of Lean Management culture.

8. School staff be given implementation support in the form of Industrial Engineers.

These recommendations are based on the feedback from the focus groups, in conjunction with the theoretical framework used for this study. There are, however, also limitations to this study worth noting. These are discussed next.

5.3 Limitations of the Research

Several limitations to the research were identified during the course of the study. These are described here.

CHALLENGES TO THE NOVELTY ASPECT

Collecting data by observation at the place where value is added, such as the factory floor, is a basis of scientific enquiry. The act of collecting quantitative and qualitative data in the classroom is thus not new to the education or the study of productivity in the classroom. Only the lens through which it is collected and analysed leaves room for innovation and thus novelty.

The research described in this paper shows that the data analysis presented to the focus groups provided a fresh perspective to the study of productivity in the classroom. This is good news as it implies that there is still opportunity for contribution to the work in this essential industry.

The focus groups interviewed showed an overwhelmingly positive response (90.3% and 88.5%) to the questions of whether the presentation of the work study data provided a new perspective to the participants – generally and personally respectively. These strong responses prompted the researcher to identify a follow-up research question: to what extent have education stakeholders been exposed to data from quantitative classroom observation studies? In this question lies a possible limitation of the research: did the novelty lie in the TOTA perspective or in exposure to quantitative classroom observation data per se? This problem was not initially anticipated but would need to be explored if the research was to claim absolute novelty.

The researcher attempted to answer this challenge from the data generated by the existing study and also from insights gleaned from the literature review. A cluster analysis of the focus group responses provided some input. The presence of education academics and managers within the sample group represented education stakeholders that one can reasonably assume would have had more exposure to literature, data and/or studies during their careers than teachers would have. One could therefore expect this group to have a higher standard of novelty due to their assumed greater exposure to education literature or data.

As can be seen in Figure 39, this group that could be assumed to have had more opportunity to be exposed to classroom data, rated the novelty of the analysed data higher than the teachers did. In fact, 100% of the 13 education academics, specialists and managers said that the analysed data provided a new perspective. Two of these participants were senior academics who have both had considerable exposure to education literature and research. The 13 participants were spread over seven different focus groups, so were also relatively independent in answering the questionnaire.

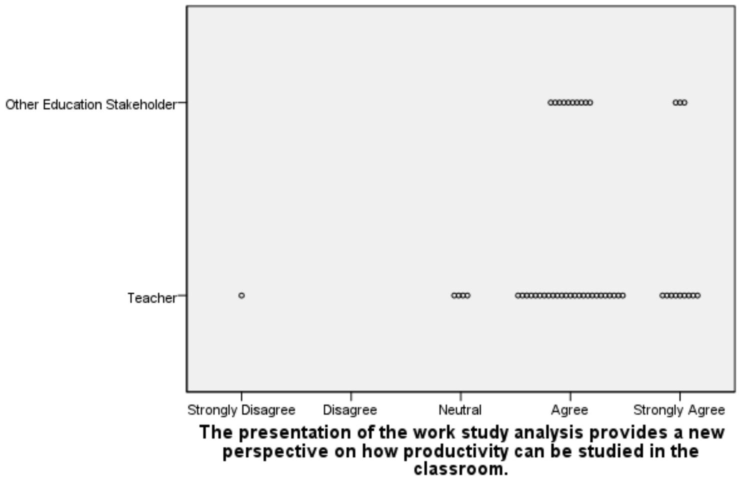

Figure 37: Breakdown of Focus Group Responses to Primary Research Question

However, insights gleaned from the literature review showed that the dissemination of such data in the education sector could be quite low. According to Wragg (2011) relative to other fields, little money is spent on formal research into education and in particular into what takes place in the classroom, citing a source that estimates that only 0.0001% of education investment is spent on research. Of this relatively little research, a "very small" amount is spent on researching what happens in the classroom (Wragg, 2011). It could thus be that the TOTA analysis was novel by the mere fact that classroom observations studies, and particularly quantitative studies, are rare. Any such study would then have a good chance of being relatively novel. Again, the academics and corporate managers did add a degree of filtering to this aspect by indicating that they too found it to be novel even though this might not have been their first exposure to such studies.

Another finding from the education literature was that the quantitative studies referenced in the literature mostly had a pedagogic or sociologic focus, counting for example how many learners read to the teacher during the day, or who had more contact with the teacher during the day: boys or girls? How many questions and what type of questions were asked by the teacher? How many questions obtained the correct response? The text book An Introduction to Classroom Observation by Wragg (2011) lists a few of the templates available and the types of focus that these studies might have. The 32-page chapter on quantitative methods does not describe any examples that are similar to the TOTA categories, indicating that based on a relatively recent textbook (2011) on classroom observations, that the TOTA perspective is indeed novel.

The literature thus indicates that quantitative classroom analyses are rare, but where they do exist, do not focus on the aspects that the TOTA focuses on. The stakeholders of the focal domain indicated that they found the analysis to be novel. Thus, although the absolute novelty was not tested by asking the respondents to what extent they had been exposed to quantitative classroom analyses previously, both the literature and the responses show a high probability that the TOTA is indeed novel.

SCOPE LIMITATIONS

The literature review described how the quality of teaching and amount of time spent on task are the factors that have a dominant impact on productivity in schools. These have been established as important factors within the schools system as we know it today, which many critics argue has not moved with the times (Robinson, 2011, Senge, 1995, Ball and Goldman, 1997).

Improving the productivity of an ineffective system is no real productivity improvement. Optimising within a set of parameters might sound like a noble endeavour, but one must question whether the parameters are correctly defined. The scope of this study was to improve productivity in schools, as they are currently defined, but it must be said that productivity must be considered in a more global way.

DEFINITION OF VALUE AND THUS PRODUCTIVITY

The preliminary literature review described the different ways in which productivity is measured and the factors influencing productivity. In Lean Management Theory, value is defined by the customer, meaning that when focusing on productivity improvement, the outputs being measured and maximised, must be in line with what the customer ultimately considers to be value.

In this study, the focus was on measuring Time on Task, as a proven predictor of academic achievement. Is academic achievement what the customer considers to be value? And who is the customer? Thus, although the study focused on what education literature defines as the output to the productivity equation, academic achievement might not be the only output of value to the customer. If the parents are considered the customer, opportunities for social interaction and participation in extra-curricular activities might also be considered to be part of the value offering the customer would like to be measured as part of the productivity measurement. If the customer is considered the economy in general, then the skills needed by the economy must be considered the output to be measured, rather than achievement on a curriculum that has not changed much for decades (Robinson, 2011).

This study, however, focused on optimising the school system as it stands currently: a batch processing, make to stock educational operation following a highly prescriptive curriculum with rigorous quality control through frequent and standardised testing, leaving little time for proper quality assurance (Robinson, 2011, Salpeter, 2003, Volante, 2004). Who the customer is and what that customer considers as value deserves research attention and subsequent action. This and other future research opportunities in the field of productivity in schools were defined during the study. These opportunities are listed and described next.

5.4 Further Research Opportunities

This was an exploratory study for the Industrial Engineer (IE) in a new field: schools. The development of the TOTA model provided a springboard for the IE to contribute to productivity improvement in schools, but the research also allowed for several further research opportunities to be identified.

THE CUSTOMER AND VALUE

As discussed in section 5.3, knowing who the customer is and what the customer defines as value, is a cornerstone of Lean Management theory and greatly influences the measurement of productivity as it determines what is considered output.

The customer and what constitutes value might differ between schools, districts, and models. The research should thus aim to identify various types of value-addition as well as try and develop a predictive algorithm that might be used by schools and districts to determine what they should focus on.

BENCHMARKING

The literature review revealed several potentially useful benchmarks for teachers and principals. Some of these are quoted here:

- "Allocated Academic Learning Time for second graders ranged from 62-123 minutes per day, and for fifth graders from 49-105 minutes per day" (Stallings, 1980).
- "The engaged time of second-grade students varied from 39-98 minutes, and that of fifth-grade students varied from 49-105 minutes. Student-engaged time" (Stallings, 1980).
- "…researchers concluded that as little as half of each school day may be devoted to instruction in some classrooms, and engagement rates among students may range from as low as 50% up to 90%..." (Hollowood et al., 1994, Gettinger and Seibert, 2002).
- "We estimate that a typical classroom in PPSD is interrupted over 2,000 times per year, and that these interruptions and the disruptions they cause result in the loss of between 10 to 20 days of instructional time." (Kraft and Monti-Nussbaum, 2020).

As mentioned in section 5.2, it is not recommended to work study data be used to formally compare schools with each other, but that it might be useful to the teachers and principals to know whether their measured data is within range of what happens in other industries. A literature review could thus be done to gather such data for use by school staff.

THE EFFECT AND DURATION OF INTERRUPTIONS ON VARIOUS LEARNING ACTIVITIES

This topic was informally explored in the descriptive analytics of the work study data and attracted a great deal of attention from the focus group participants. It is a productivity factor dependent on a set of sub-factors and hence makes for an interesting research opportunity.

Are certain types of learning activities more affected by interruptions than others? Does the level of interest in the subject influence the effect of the interruptions? A study by Federman (2019) for example concluded that although interest level predicts learning, it does not moderate the effect than an interruption has.

The TOTA model developed in this study allows for interruption data to be collected and described, which could be used as input into such research.

WASTE OF PROCESSING (AND OTHERS) IN THE CLASSROOM

Taiichi Ohno identified the waste of processing or overprocessing as one of the seven wastes, sometimes manifesting in having too many processing steps for what is required (Ohno and Bodek, 2019). In a school environment the different learning rates of learners create a situation where the teacher might explain a concept to a class again, or in more detail, but where some of the learners have already grasped the concept and are ready to move on to the next. Repetition is, however, a natural part of the learning process. Identifying when repetition has become wasteful, to which learners and how to reduce the waste, could be the focus of interesting research.

The identification of the waste of processing in the classroom, as well as the other seven wastes referred to in Lean Management theory, might provide valuable input to teachers to be able to 'see' inefficiencies in the classroom more clearly.

CORRELATION BETWEEN TEACHING ENERGY AND LEARNER ENGAGEMENT

The comparison of the three different teaching days observed during the work study (Figure 21) sparked an interesting research question: whether there is a negative correlation between learner engagement and teacher control of the lesson. In the secondary data, the teacher who worked the hardest, had the least learner engagement, and the teacher who allowed the learners to get on with learning on their own initiative, such as in group work, had the highest learner engagement, but put in the least amount of teaching energy.

This question will most likely best be answered as part of a study looking at which teaching activities solicit the greatest level of learner engagement.

TEACHING ACTIVITIES AND LEARNER ENGAGEMENT

Figure 25 indicated the various learner engagement levels observed during different teaching activities. This Figure too was of great interest to the focus groups, indicating a need for more robust research to be done. The TOTA template can be used to expand this research during more classroom observation studies.

REVISION, NEW CONCEPTS AND APPLICATION

Over the course of the 1440 minutes of classroom observations made, only 12 minutes were spent on introducing new concepts. Other learning activities focused on revision and application. Is this distribution of learning activities normal? Is it optimal?

A work study spanning more days would be needed to give a more representative reflection of what is normal in any given school. The secondary data analysed in this study spanned four school days, of which one was an assessment day, and the other was group work day.

A benchmark / gap analysis between recommended standards of how learning time should be distributed between revision, new concepts, and application and how learning time is currently allocated in schools could provide useful input into gauging the outcome of further work studies in this regard. A review of literature could be used to identify current best practice.

ACTIVITY SAMPLING

The field notes of the secondary work study data set recommended the use of activity sampling to measure both teacher and learner activities in a different manner to that of classroom observations. Because activity sampling is less intensive than a systematic classroom observation study, it might allow a broader sample group to be observed.

Activity sampling, is however, an invasive study that could be regarded with suspicion by the people being observed. The approach recommended by Iwao Kobayashi should rather be followed whereby the teachers themselves act as observers instead of being observed by an IE (Kobayashi, 1995).

EXPANDING THE TOTA MODEL TO INCORPORATE EFFECTIVENESS

As mentioned in the literature review on OEE, the TOTA model is based on the truncated OEE model, called Equipment Operating Rate (EOR), which only takes into consideration Availability and Performance, but not Quality. The TOTA model thus also stops short of assessing how effective the Time on Task was in terms of the quality of learning that took place in that time. Research into education literature and conceptual thinking will have to go into the expansion of the model to become a true analytical model for academic productivity.

CONCLUSION

This study was an exploratory foray into a new field for the Industrial Engineer. Using Lean Management theory and tools, a novel and valid model was created with which to enable productivity improvement. Extensive literature review, model testing and engagement with focal domain stakeholders were done, but as with all pioneering work, these efforts lead to the identification of much more work to be done. It is an exciting challenge. The work done up to this point will now be concluded in the final section of this paper.

5.5 Conclusion

The study produced the TOTA or Time in Task Analysis model and template as a novel and valid platform with which to enable productivity improvement in the classroom using Lean Management as stakeholder engagement approach.

The TOTA model was successfully used for, and further refined through, the analysis of classroom observation data. This analysis was presented to 52 education stakeholders, who reported being energised towards productivity improvement by the new perspective provided by the analysis. These stakeholders requested more such studies (quantitative, TOTA classroom observation studies) be undertaken and requested more exposure to the concepts of Lean Management theory.

Literature indicated that systematic quantitative classroom observation studies are rare, and this research indicated that Industrial Engineers could provide a new perspective to the way the data is collected and viewed. The TOTA template was created for the purpose of scaling further such studies using the same perspective the focus groups of this study described as novel and valuable.

The overwhelmingly positive response of the 52 education stakeholders to the data analysis presented to them indicates an appetite for improvement as well as a willingness to contribute. This is a precious type of energy which the Industrial Engineer can guide into contributing to the productivity improvement of an essential industry.

This was an exploratory, pioneering study for the IE into the school classroom. It aimed to find a way to contribute to the study of productivity in schools. The study found a way, but also created a map for further exploration.

Productivity in schools has been declining for decades. The trend must be reversed. This study has found a way to combine Scientific Management with Human Relations Theory to enable productivity improvement in schools.

"Education is the quintessential upstream industry" (Hoxby, 2004).

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APPENDIX A – LITERATURE REVIEW DOCUMENTATION

Table 16: Search Term Matrix (Bezuidenhout, 2019)

Concepts	**Industrial Engineering**	**Principles and techniques**	**applied**	**School environment**	**Improve**	**Productivity**
Synonyms	Production Engineering Process Engineering Systems Engineering	Methodology Concepts Fundamentals	Implemented Practiced Adapted Utilised	Primary Education Secondary Education Schools Primary Schools Secondary Schools	Increase Boost Enhance	
Broader terms	Engineering	Theory Field		Education		Teaching outcomes Education outcomes Profit
Narrower terms	Operations management Operations improvement Continuous improvement Lean Business analysis Manufacturing Engineering Business Engineering Change Management	Tools Ideas Innovations		Teaching		Efficiency Effectiveness Resource utilisation
Related terms			Introduced			
Alternative spelling			Utilized			Resource Utilization

APPENDIX B - SURVEYS

Productivity in the Classroom

* Required

SURVEY INFORMATION AND INFORMED CONSENT

1. Dear Participant,

This workshop is an opportunity for your team to interact regarding productivity in the classroom. By participating in this survey, you are also participating in research titled: An exploratory study to establish whether Industrial Engineering techniques can bring a new perspective to the study of productivity in schools.
The purpose of this questionnaire is to find out what your perspective is on the work study data presented to you during the session, as well as to collect your insights on productivity in the classroom.

You were chosen as a respondent because you have experience in productivity in the classroom - either as a teacher, a specialist or as manager.

Your participation is voluntary, and you can withdraw at anytime without penalty. Throughout the survey your privacy will be protected, and your participation will remain confidential. I do not wish to analyse data individually and all the data will be transferred to a computer programme to analyse clusters of responses. This means that you are assured of anonymity.

If you agree to participate, please complete the survey that follows this cover letter. It should take about 10 minutes of your time. By completing the survey, you indicate that you voluntarily participate in this research. If you have any concerns, please contact me with the detail provided below.

Researcher name: Ilse Doyer
Email: ilse.doyer@tuks.co.za
Phone: 083 402 8224

Question 1:
By selecting the "Yes" option I hereby voluntarily grant my permission for participation in this anonymous survey. The nature and the objective of this research have been explained to me and I understand it.

I understand my right to choose whether to participate in the research project and that the information provided will be handled confidentially. I am aware that the results of the survey may be used for academic publication. *

- (●) YES
- ( ) NO

Next

Productivity in the Classroom

* Required

SURVEY INFORMATION AND INFORMED CONSENT

1. Dear Participant,

This workshop is an opportunity for your team to interact regarding productivity in the classroom. By participating in this survey, you are also participating in research titled: An exploratory study to establish whether Industrial Engineering techniques can bring a new perspective to the study of productivity in schools.
The purpose of this questionnaire is to find out what your perspective is on the work study data presented to you during the session, as well as to collect your insights on productivity in the classroom.

You were chosen as a respondent because you have experience in productivity in the classroom - either as a teacher, a specialist or as manager.

Your participation is voluntary, and you can withdraw at anytime without penalty. Throughout the survey your privacy will be protected, and your participation will remain confidential. I do not wish to analyse data individually and all the data will be transferred to a computer programme to analyse clusters of responses. This means that you are assured of anonymity.

If you agree to participate, please complete the survey that follows this cover letter. It should take about 10 minutes of your time. By completing the survey, you indicate that you voluntarily participate in this research. If you have any concerns, please contact me with the detail provided below.

Researcher name: Ilse Doyer
Email: ilse.doyer@tuks.co.za
Phone: 083 402 8224

Question 1:
By selecting the "Yes" option I hereby voluntarily grant my permission for participation in this anonymous survey. The nature and the objective of this research have been explained to me and I understand it.

I understand my right to choose whether to participate in the research project and that the information provided will be handled confidentially. I am aware that the results of the survey may be used for academic publication. *

- ◯ YES
- ◯ NO

Next

CONTEXT INFORMATION

2. What is or has been your role within the education sector? *

- ☐ Teacher– pre-primary
- ☐ Teacher - primary
- ☐ Teacher– secondary
- ☐ Head of Department
- ☐ Principal - pre-primary
- ☐ Principal - primary
- ☐ Principal - secondary
- ☐ Manager - corporate
- ☐ Education specialist
- ☐ Education academic
- ☐ Other

Back Next

FEEDBACK ON WORK STUDY PRESENTATION

Using the Likert Scale provided for each question, please select your answer to each statement based on your own work experience and exposure to date.

3. WORK STUDY NOVELTY AND VALUE *

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
The presentation of the work study analysis provides a new perspective on how productivity can be studied in the classroom.	○	○	○	○	○
The presentation of the work study analysis helped me to look at productivity in the classroom in a new light.	○	○	○	○	○
I came up with improvement ideas <u>during</u> the presentation of the work study analysis.	○	○	○	○	○
I will be thinking of improvement ideas <u>after</u> the presentation of the work study analysis.	○	○	○	○	○
The school/s I am involved in can/could benefit from a classroom work study project.	○	○	○	○	○

WORK STUDY POTENTIAL

4. Please rank the following options according to the impact that you think these options will have on productivity improvement in the classroom. Use the arrows to rank the statements from most impactful (top) to least impactful (bottom). *

- Teachers having been exposed to the findings of a classroom work study analysis.
- School management having been exposed to the findings of a classroom work study analysis.
- Education policy makers having been exposed to the findings of a classroom work study analysis.

5. Please rank the following options according to the impact that you think these options will have on productivity improvement in the classroom. Use the arrows to the right of the statements to move the statements according to most impactful (top) and least impactful (bottom). *

- Teachers having been observed in the classroom during a work study.
- Teachers having been exposed to the findings of a classroom work study analysis.
- Teachers having been part of a classroom productivity improvement workshop following a presentation on a classroom work study analysis.

Back | Next

YOUR INSIGHTS AND IDEAS

6. *What are your main observations/realisations from the data presented?*

Enter your answer

7. *What did you find surprising or new? I.e. what provided a new perspective?*

Enter your answer

8. What did you find unsurprising? I.e. what confirms an existing perspective?

Enter your answer

9. *How do you think these studies can be used to improve productivity in the classroom?*

Enter your answer

10. *Which improvement opportunities become evident during the presentation of the data?*

Enter your answer

11. *What causes productivity losses in the classroom? What prevents learning from being more productive?*

Enter your answer

12. *Do you have any other observations or some experience that you would like to contribute? If so, please elaborate.*

Enter your answer

Back Submit

APPENDIX C – SPSS OUTPUTS

Paired Samples t-Test: Novelty Generally versus Novelty Personally

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Work Study = Novel Generally & Work Study = Novel Personally	51	.409	.003

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Work Study = Novel Generally - Work Study = Novel Personally	.137	.693	.097	-.058	.332	1.414	50	.164

Paired Samples t-Test: Novelty Personally versus Improvements After Presentation

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Work Study = Novel Personally & Improvement Ideas After Presentation	51	.346	.013

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Work Study = Novel Personally - Improvement Ideas After Presentation	-.294	.729	.102	-.499	-.089	-2.880	50	.006

Paired Samples Effect Sizes

			Standardizer[a]	Point Estimate	95% Confidence Interval	
					Lower	Upper
Pair 1	Work Study = Novel Personally - Improvement Ideas After Presentation	Cohen's d	.729	-.403	-.687	-.116
		Hedges' correction	.735	-.400	-.682	-.115

a. The denominator used in estimating the effect sizes.
Cohen's d uses the sample standard deviation of the mean difference.
Hedges' correction uses the sample standard deviation of the mean difference, plus a correction factor.

Comparing Means of Clusters – Benefit to School

Including outlier

Report

Benefit to School

Teacher or Other Stakeholder	Mean	N	Std. Deviation
Teacher	4.03	39	.668
Other Education Stakeholder	3.85	13	1.144
Total	3.98	52	.804

Excluding outlier

Report

Benefit to School

Teacher or Other Stakeholder	Mean	N	Std. Deviation
Teacher	4.03	39	.668
Other Education Stakeholder	4.08	12	.793
Total	4.04	51	.692