Chapter 2
A Review of the Existing Literature on Globalization of Science Curricula

Abstract  Given the extensive nature of globalization and its wide-ranging impact, the review of the literature on the effect of globalization on science education and science curricula was restricted to three particular aspects. Firstly, identifying the factors that potentially contribute to the globalization of science education; secondly, exploring research evidence for the globalization of science curricula over time; and thirdly, analyzing the approaches and methods that have been used in previous research studies to empirically investigate the globalization of curricula. A wide range of factors were identified as promoting the globalization of science education and curricula, including the growing use of information technologies and the increasing influence of intergovernmental organizations in education. However, regional and local cultural factors may counteract globalization to some extent. The literature review identified some evidence for globalization of science curricula over time; the impacts of international large-scale assessments, such as the Trends in International Mathematics and Science Study (TIMSS), may have driven changes and reforms in the science curricula of many participating countries. The literature revealed that a number of both qualitative and quantitative methods had been used to investigate globalization of curricula over time, and the advantages and drawbacks of each of the approaches were considered.

Keywords  Curriculum alignment · Curriculum convergence · Globalization
International large-scale assessment · Science education · Science curriculum
Trends in Mathematics and Science Study (TIMSS) · TIMSS video study

2.1 Introduction

Globalization is a process with far-reaching impacts in many different disciplines, including education. Globalization is an extensive concept, although in its simplest form it can be described as relating to “reforms and structures that transcend national borders” (Astiz et al. 2002). Within education, the process of globalization has the potential to exert a wide range of effects on national education policies and
school science curricula. Whilst globalization has distinctive effects on education, it is important to note that this cannot be completely removed from wider economic and cultural globalization.

Given the variety of ways in which globalization can impact education and curricula, this literature review had three key aims:

(1) to identify and explore the factors contributing to globalization in science education and science curricula
(2) to investigate the research evidence for the globalization of science curricula over time
(3) to identify the approaches and methods that have been used in previous research studies to empirically investigate the globalization of curricula, and to use these to inform the statistical analyses conducted during this research project.

A literature search was conducted during the autumn of 2016. Given the large number of published articles on globalization in education and the resources available for this report, we did not attempt to present an exhaustive overview of all published articles relating to globalization of curricula. Instead, we employed a highly focused search strategy. The literature search was designed to identify studies that provided evidence of countries that had redesigned or modified their science curricula to mirror high-performing jurisdictions or to align more closely to the TIMSS framework (curriculum) content. The literature search also looked for studies that had already employed TIMSS data to investigate globalization of curricula.

The search strategy was designed to maximize the chances of identifying the most pertinent literature within those constraints. The date parameters were limited to recent (2010 onwards) evidence on issues surrounding global alignment/globalization of science curricula. However, the date parameters were extended to 1995 to identify research that had used TIMSS data to explore issues surrounding global alignment/globalization of science curricula (the influential Third International Mathematics and Science Study, the first cycle of what later became known as TIMSS, was administered in 1995). This ensured that significant studies based on data from the 1995 study were not missed from the literature review.

Key education bibliographic databases (the Australian Education Index, the British Education Index and the Education Resources Information Center [ERIC]) were searched using globalization/curriculum alignment terms combined with science education terms tailored to the specific search capability of each database (see Appendix A for a detailed explanation of the search terms employed). In addition, the table of contents of the key science education journal, the International Journal of Science Education, were reviewed from 2010 onwards and relevant research papers were noted. The publications list on the International Association for the Evaluation of Educational Achievement (IEA) website was also reviewed.
The literature search identified 76 research articles. The abstracts of each of these articles were then appraised by three researchers in order to identify the most relevant articles to include in the literature review. A number of quality criteria were applied to establish the relevance of the article to the literature review. Priority was given to: articles that considered the curricula/education system of more than one country; articles published in peer-reviewed journals; articles that focused on science curricula (as opposed to other subject curricula); empirical studies; and studies that made use of data from international large-scale assessments such as TIMSS. A set of questions was used to appraise the articles identified in the literature search (Appendix B).

We used a template (see Appendix C) to review and evaluate the contents of the ten most relevant articles and summarize any data or evidence related to our three research questions.

The research in this literature review identified forces that are contributing to and driving globalization in science education and science curriculum and also forces that are counteracting or mediating globalization.

2.2 Factors Contributing to the Globalization of Science Education and Science Curricula

Spring (2008) identified a number of different forces that are involved in driving globalization within education more generally. These forces include:

- the emphasis on education as a mechanism for economic growth
- intergovernmental, governmental and international non-governmental organizations
- information technology
- multinational corporations
- international large-scale assessments.

Whilst these forces are shaping globalization in education in a more general sense, they are also influencing and impacting the globalization of science education and science curricula. The specific impact of each of these forces is outlined below. Although each force is discussed separately, it is important to appreciate that these forces do not exist in isolation and interact with each other to shape the process of globalization in science education.

2.2.1 Education as a Mechanism for Economic Growth

The twenty-first century has seen growing convergence in political agendas in relation to education, particularly in the developed world. Spring (2008) identified
the concept of the knowledge economy as one of the most significant factors contributing to the globalization of education and curricula. As countries around the world become more engaged in the globalized economy, there develops an important need for nations to prepare their young people for active participation within these globalized markets (Sellar and Lingard 2014). Also, as countries seek to build and develop knowledge-based economies, this has a direct effect on education and school curricula as politicians seek to equip learners with the skills and competencies that are needed to succeed in the global economy. Weber (2011) identified this phenomenon in the Gulf states, where the focus on the knowledge economy is influencing school curricula as politicians seek to diversify these states from their current hydrocarbon-based economies.

The knowledge economy is linked to the increased focus in many countries on the role of education in promoting economic growth. As a consequence, there has been greater emphasis in many countries on schools developing and equipping students with workplace skills and competencies and preparing them for life beyond education. This in turn has the potential to lead to convergence in science curricula as countries adapt curricula to focus on aspects of science that have more potential to facilitate future economic growth.

Globalization and the economic aspects of globalization are of particular relevance to science education and science curricula, as many of the most globalized sectors of the economy have a technological or scientific basis that requires specific scientific knowledge and skills. Computer and mobile technologies, pharmaceuticals and biotechnologies, petrochemicals and emerging clean energy technologies are for example some of the most globalized sectors of the world economy. Therefore, countries seeking to develop economic engagement in these areas may consider changes to science curricula as a medium- to long-term strategy for successful involvement in these sectors.

2.2.2 Intergovernmental and Non-governmental Organizations

In addition to the knowledge economy and economic globalization, some intergovernmental and nongovernmental organizations are important actors in the globalization of education. For example, intergovernmental organizations such as the World Bank and the Organisation for Economic Cooperation and Development (OECD) are influential in both shaping educational discourse and the educational agenda in many countries. Both organizations view the purpose of education from an economic perspective and consider education as a mechanism from which to stimulate economic growth. Sellar and Lingard (2014), for example, suggested that “the rise of the OECD’s education work is linked to the economization of education policy”. These organizations consider one of the primary roles of school is to prepare students to be successful participants in the knowledge economy (OECD 1996).
2.2.3 Information Technology and Multinational Corporations

The increasing role of information technology and the internet has had a significant impact on globalization in science education. This has largely been due to the speed and ease with which information can be accessed and transferred (OECD 1996). Potential impacts of this on science curricula include the rapid sharing of scientific information and ideas across borders by universities and educational institutions, as well as multinational corporations who provide educational services and curriculum resources to schools and education ministries across the world.

Information and communications technology (ICT) has already transformed science education and curriculum in a number of different ways, for example by “expanding the spaces, methods and times for its spread” (Cornali and Tirocchi 2012). Science teaching materials have been enhanced by ICT, with added functionalities including animations and multimedia content. In science education, this has meant that experiments that could not be undertaken in the average school science laboratory may now be simulated by such teaching tools. The quantity and accessibility of learning resources has increased dramatically with the proliferation of ICT, and personalized learning tailored to the needs of the individual student has become more feasible and cost effective. ICT has also allowed instantaneous sharing of information and content and permitted interactions between learners over larger geographic distances. In future, the impact of ICT on science education and curricula is likely to increase further, as traditional science curricula based on factual knowledge are replaced with more open science curricula centered on the acquisition of specific skills (Cornali and Tirocchi 2012).

2.2.4 International Large-Scale Assessments

One of the most powerful forces shaping globalization in science education and science curricula is the development of international large-scale assessments of science such as TIMSS and the Programme for International Student Assessment (PISA). The PISA assessment has been described as playing “a major role in the standardization of education” (Spring 2008). International assessments are growing in influence as the number of countries participating in them increases. Large-scale assessment is contributing to the globalization of science education and science curricula in a number of different ways, as we will discuss.

A review of the effects of TIMSS 1995 on teaching and learning in 29 different countries highlighted the role that it had played in the restructuring of national science curricula and the subsequent integration of science curricula across some countries (Robitaille et al. 2000). Following TIMSS 1995, a number of the participating countries embarked on extensive science curriculum revisions, changing
the science content taught (as in Kuwait) or the skill areas emphasized within the curriculum (as in Latvia) (see Table 2.1).

Evidence from Israel (Klieger 2015) supports the idea that international surveys and the content assessed in them can promote the convergence and globalization of science curricula. Following poor TIMSS results in both 2003 and 2007, the Israeli Ministry of Education opted to reform its science curriculum so that it was more aligned to the TIMSS science content domains. Therefore, in some countries at least, the TIMSS assessments have directly affected national science curricula.

By contrast, interviews with experts in science education in Australia (a country which has traditionally performed relatively well in TIMSS and PISA) suggest that the international assessments have not had a major impact on the curriculum (Aubusson 2011). However, these interviews did suggest that TIMSS and PISA were nonetheless influential, and there was a clear desire amongst Australian policymakers and the science education community to ensure that standards on these assessments were maintained over time.

Robitaille et al. (2000) also noted that for some countries (such as Japan), the impact of TIMSS on the science curriculum had been relatively minor. Differences in the impact that international large-scale assessments have had on countries’

Table 2.1 Responses to TIMSS 1995 science results

| Type of response | Description of response | Example countries |
|------------------|--------------------------|-------------------|
| No major changes to curriculum | No changes or very minor changes in response to TIMSS | Japan, Netherlands, Flemish Belgium |
| Changes to content in science curriculum | Extra topics added to the science curriculum, for example the inclusion of environmental science topics | Iran, Kuwait |
| Changes to skills emphasis in curriculum | Shift from acquiring knowledge to being able to apply knowledge; greater emphasis on practical and problem-solving skills | Latvia, Czech Republic |
| Increased status of science within education system | More time allocated to teaching science, particularly at primary age | Iceland |
| Change to structure/organization of science curriculum | Introduction of an integrated science curriculum in the primary phase of schooling | Romania |
| Changes to science assessment | Change from sampling assessments to full cohort testing | Philippines |
| | Amendments to science assessments to incorporate TIMSS items | British Columbia (Canada) |
| Changes to teacher training and development | Increased support and training to strengthen pre-secondary school teachers’ science knowledge | Norway |
| Changes to curriculum to address student attitudes | Science curriculum amended to address students’ negative attitudes towards science | Republic of Korea |
curricula reveal that each country participating has “its own unique set of motivations for participating, and each of them has their own set of expectations for the study” (Robitaille et al. 2000).

2.2.5 Policy Borrowing and Standardization

Linked to the rising influence of international large-scale assessments is “policy borrowing”, where countries adopt education reforms and policies that have been successfully implemented in other countries, typically high-performing jurisdictions. There has been a suggestion that the rate of policy borrowing is increasing over time, and that this is directly affecting national education policies (Rutkowski and Rutkowski 2009). This increase in policy borrowing is perhaps unsurprising, as international assessments facilitate comparison between countries and provide evidence for the most successful and high-performing countries (as measured by the assessment).

In addition to policy borrowing and international large-scale assessments, Astiz et al. (2002) outlined the global trend towards greater emphasis on standardization, achievement and assessment in science and mathematics curricula. This has been achieved through approaches strengthening school accountability and is also contributing to greater convergence of curriculum goals in different countries.

However, despite the wide range of forces driving globalization in science education and curricula, there are other factors that are counteracting or mediating the rate of globalization in this area. One of the most important counteracting factors is local culture. For example, research comparing science teaching in Grade 6 classrooms in Australia and China highlighted the impact of culture on curricula and educational practices in these countries (Tao et al. 2013).

The study found that the contrasting cultures and education philosophies in Australia and China had an impact not only on classroom practices but also on how education reforms are enacted. For example, in China, despite reforms to the science curriculum to give a greater emphasis to constructivist approaches, the research identified resistance to these reforms, with traditional teaching approaches (such as the memorization of facts, reading books and watching teachers conduct experiments) still the dominant approach to science teaching in many schools. Clearly, even if the intended science curricula in different countries or jurisdictions may be becoming more globalized, this does not necessarily mean that the implemented science curriculum experienced by students becomes more closely aligned.

The misalignment between countries’ intended and implemented science curricula and the complex interplay between central and local forces is not limited to China. Astiz et al. (2002) identified similar issues in Spain and the United States. In Spain, a common curriculum is specified by central government, but this curriculum is then adapted and interpreted locally in the different regions of the country.
This means that students in the different regions will have different interpretations of the same curriculum.

In the United States, there are several contrasting forces that exert an influence on the curriculum. On one level there has been the centralization of curriculum goals, but opposing this there has been decentralized curriculum implementation. Once again, the localization of curriculum interpretation and implementation means that the implemented curriculum is likely to be far less standardized and more variable than the intended curriculum prescribed centrally. These countries provide strong examples of how global forces act on curriculum at a national level but are then modified and adapted at a more local level.

Other evidence also suggests that the effect of globalization in science education and science curricula is relatively limited. Research using TIMSS data, which compared the content standards, textbook content and teaching time allocated to science topics for students at Grade 8 in participating countries, indicated that science teaching and science curricula in Grade 8 in different countries were far less homogenous than for mathematics (Cogan et al. 2001). Considerable differences in countries’ approaches to science education have also been attributed to cultural differences between countries: “how the curriculum is specified and organized, what students are expected to learn and be able to do – are all reflections of that culture” (Cogan et al. 2001, p. 106).

This preliminary overview reveals a number of different factors have been identified as contributing to the globalization of science education and science curricula. Whilst there are strong driving forces promoting globalization of science education, evidence on the extent of their impact and for convergence in science curricula is variable, with no consistent pattern to the effect on countries. The next section of the literature review specifically considers the evidence for the globalization of science curricula over time.

2.3 What Evidence is There for the Globalization of Science Curricula Over Time?

As noted in Sect. 2.2.4, each country has its own set of local conditions which impact both curriculum decisions and their motivation for participating in international assessments such as TIMSS and PISA. However, several of the research studies identified in our literature review provided evidence for the globalization of science curricula over time, identifying international large-scale assessments such as TIMSS and PISA as playing a role in this convergence. This is, in part, due to the way that these assessments facilitate the comparison of different education systems. This, in turn, may act as a catalyst for change and convergence, with countries making changes to their education systems in order to address perceived weaknesses or deficiencies identified as a result of their participation in the international assessments.
The TIMSS 1995 survey provides a strong early example of the impacts of international large-scale assessments on science education and curricula, with many governments analyzing the results from TIMSS 1995 and using the outcomes to inform decisions about future educational and economic development.

### 2.3.1 How Different Countries Responded to TIMSS 1995

Robitaille et al. (2000) analyzed the changes that were made to science curricula in a wide range of countries following the publication of the TIMSS 1995 results. Countries’ responses to their performance in TIMSS could be sorted into several broad categories (Table 2.1).

For some high-performing countries, such as Japan, the TIMSS 1995 results had minimal impact on their science curriculum. Other countries, which performed reasonably well in TIMSS 1995, used the wide range of data reported in the study to modify specific aspects of their science curriculum. For example, in the Republic of Korea, the government reduced the overall content of the curriculum to address students’ negative attitudes to science, as reported in the TIMSS data. Both the Czech Republic and Latvia modified performance expectations to promote the application of science and problem-solving skills.

Kuwait introduced a module on environmental science and Romania reorganized its curriculum into a more coherent whole to improve students’ abilities to make connections between different curriculum areas. Some changes were more closely related to policy or application of policy than the specific curriculum. For example, Norway placed a much greater emphasis on strengthening the subject knowledge of teachers, whilst the Canadian province of British Columbia introduced new assessments for Grades 4 and 7, with about half of the assessment questions drawn from released TIMSS items.

For several countries, a relatively poor performance in TIMSS 1995 acted as a direct prompt to institute significant science curriculum change, in an attempt to improve their performance in future international comparison tests. In Iceland poor performance in TIMSS 1995 started a process of curriculum review where the TIMSS framework itself was used as a curriculum model, leading to an increase in the importance of science and mathematics teaching in Icelandic schools. Similarly, in Iran, poor results in TIMSS 1995 led to the identification of factors that merited increased attention in the curriculum, prompting changes to the curriculum again based on the TIMSS framework. These increased the focus on scientific skills, as well as the cognitive demand of the curriculum, and extended curriculum coverage to include areas such as the environment.
2.3.2 Case Study: Israel

Israel provides an interesting case study of how a country has responded specifically to the results from international large-scale assessments by changing its curriculum and how this was implemented. Klieger (2015) outlined a series of policy changes made between 1996 and 2011; the country’s poor performance in the international surveys provided a major incentive for reforms, leading, in 2009, to the Ministry of Education setting achievement targets to progress at least ten places in the rankings for the TIMSS 2011 and PISA 2012 assessments. They aimed to achieve this by intervening at both the intended and implemented curricular levels, through a series of curriculum changes and operational changes to the delivery of the curriculum. Klieger (2015) reviewed the evidence for those changes from government documents and compared the science curriculum from 1996 to that of 2011 for evidence of globalizing effects. International surveys had clear impact on the content of the Israeli science curriculum. Topics that were absent from the international frameworks were dropped, including “the Earth and the universe” (some sub-topics were integrated within other topics), “information and communication” and “the senses”, whilst topics that appeared in the international frameworks were added, including “human health” and “acids and bases”. The structure of the curriculum and the way that skills were presented and organized within the curriculum were also aligned to the international frameworks. For example, the 2011 Israeli curriculum integrated problem-solving skills within the science content and further emphasized high-order thinking skills (HOTS) such as argumentation. In line with international frameworks, scientific inquiry skills continued to be presented separately.

The Israeli Government also sought to address the implemented curriculum by interventions at the teacher level, seeing this as a more immediate way to bring about change than through the intended curriculum. For example, in 2005, advice was issued to ensure that teachers taught the content of international surveys even when it did not appear in the Israeli curriculum at that time. In 2009, there was an intensive in-service training program for teachers based on the findings of the TIMSS and PISA studies, accompanied by closely specified “kits” of teaching materials that teachers were obligated to use.

The desired impact of these changes to the curriculum and its implementation was seen in the results from TIMSS 2011. The baseline achievement for TIMSS 1995 (Grade 8) in Israel was an average scaled score of 486, placing the country 26th out of the 38 participating jurisdictions. After the implementation of many of the changes highlighted above, the average scaled score for Israel had risen to 516 by 2011. This exceeded the scaled international average of 500 and ranked the country 13th out of the 42 participating educational jurisdictions. Klieger (2015) concluded that, because of the policies of the Department of Education, the international frameworks have had a conspicuous influence on the curriculum content, but, as a consequence, classroom activities have become much more prescriptive over this time.
2.3.3 Factors That Oppose the Globalization of Science Curricula

The influence of globalizing factors on the intended curricula, through policy-makers engaging with globalizing influences such as international large-scale assessments, has been documented (Klieger 2015; Robitaille et al. 2000). However, the implemented curriculum is delivered by teachers in the classroom, who are exposed to a different set of influences, especially at a more local, cultural level. Cogan et al. (2001) examined how different localized educational "cultures" can affect the implementation of curricula by analyzing the TIMSS 1995 dataset to look for culturally specific patterns in the teaching of science across 36 of the countries that participated. In this context, the educational culture is defined in terms of how schooling is organized – the goals and purposes identified for each year, how decision making authority is distributed (or not)... how the curriculum is specified and organized, what students are expected to learn and be able to do.

(Cogan et al. 2001, p. 106).

Cogan et al. (2001) analyzed the different curricula at three levels: the intended curriculum, the potentially implemented curriculum, and the implemented curriculum. Firstly, the intended curriculum was measured by coding the different content statements specified in the curricula of the educational jurisdictions. The study compared these to the 48 TIMSS science framework topics for Grade 8 assessment. Whilst most countries specified teaching the majority of these topics, there were significant variations. Seven countries included fewer than half of these topics in their curricula (Republic of Korea, Hong Kong, Romania, Japan, Germany, Greece and the Czech Republic), whilst three countries included all topics (Iran, New Zealand and the United States).

The study quantified the potentially implemented curriculum by coding the content of science textbooks. Whilst most countries’ textbooks covered the majority of the 48 TIMSS science framework topics, there were six countries that covered less than half of these in textbooks (Denmark, Japan, Iran, Singapore, Israel and Germany), whilst four (Canada, Colombia, Switzerland and the United States) covered all, or nearly all topics.

The implemented curriculum was measured by the allocation of teachers and teaching time to the different topics. The picture in terms of teaching time is complicated by the teaching of science as different courses (e.g. biology, chemistry, physics and earth sciences), which means that no single topic in science was taught by more than 70% of all science teachers (compared to an average of 90% of all teachers for mathematics topics). This produced a disparate picture, with substantial variations apparent from a statistical analysis of the percentage of teachers teaching specific topics in different countries.

In conclusion, Cogan et al. (2001) indicated that there were few commonalities across countries, or even within countries at different curricular levels. For example, they were unable to define five “core” science topics across participating countries.
as they derived a different list of topics at each curricular level (curricular content, textbooks, teaching content and instructional time allocated). This variation is in contrast to a similar study conducted for mathematics that did exhibit consistency across countries and levels of organization. They concluded that this “reflects the greater diversity in the way science is organized and delivered across the TIMSS countries, at least in comparison to mathematics” (Cogen et al. 2001, p. 128).

Other studies have reported regional cultural effects. Kjaernsli and Lie (2008) adopted a cluster analysis approach using item responses to TIMSS 2003 science questions and identified a number of countries that clustered together largely along geographic or linguistic lines. For example, the study identified an Arabic cluster, an English-speaking cluster and a South Eastern European cluster. This study provides some evidence for the alignment and convergence of science curricula along geographic and cultural lines.

A more detailed approach to looking at cultural differences in implemented national curricula was taken by the 1999 TIMSS video study (Roth et al. 2006). The study was conducted in conjunction with the IEA by the US National Center for Education Statistics and the US Department of Education under a contract with LessonLab, INC of Los Angeles (for further details see http://www.timssvideo.com/timss-video-study). This study compared science teaching and learning in the United States to that of four higher achieving countries (namely Australia, Japan, the Czech Republic and the Netherlands) by coding the science content and instructional approaches evidenced by video recordings of 439 representative Grade 8 lessons across the five countries.

The study findings showed that science teaching in the United States exposed students to a wide variety of both pedagogical approaches and content, whilst the other countries reflected a common content-focused instructional approach (Roth et al. 2006). However, even within this common approach, there were significant variations in the learning cultures of the different countries, with the Czech Republic focused on whole class discussion, Australia and Japan on connecting ideas through data and inquiry, and the Netherlands employing independent textbook-centered reading and writing activities. The cultural differences meant that each of the countries had a distinct approach to science teaching, providing students with different opportunities to learn science and different visions of what it meant to understand science.

2.3.4 Conclusions

The studies explored in Sect. 2.3 present evidence for the differing global, regional and cultural influences on science curricula. Taken as a whole, these studies imply that whilst there is pressure on policymakers to globalize their intended curricula, there are also local cultural pressures working at the level of implementation and realization that may provide some resistance to this globalizing effect.
It is important to note that our literature review was limited to research on the globalization of science curricula from 2010, with studies making use of TIMSS data extending back to 1995. However, it has been suggested that 1995 may be too late a starting point to detect changes in the globalization of curricula because by this time globalization had already exerted a large influence on science curricula (Rutkowski and Rutkowski 2009). This needs to be taken into account when considering the evidence for globalization in science curricula.

2.4 What Methods Have Been Used Previously to Investigate Globalization of Curricula?

The literature review identified a number of different methods that have been used to investigate globalization of curricula. These methods were evaluated to review their appropriateness and robustness for different contexts and to inform the design of the methodology for this study. The methods used include both qualitative and quantitative approaches (Table 2.2).

Qualitative methods used to investigate the globalization of curricula include the documentary analysis of policy documents. For example, Klieger (2015) examined the effect of international surveys on science education and the science curriculum in Israel between 1996 and 2011 by analyzing curriculum and policy documents and how these changed over the period. The study also compared these documents to the requirements of the international surveys such as the TIMSS content domain.

| Study                          | Method                                           | Data source                                         |
|-------------------------------|--------------------------------------------------|-----------------------------------------------------|
| Klieger (2015)                | Documentary analysis of education policy documents and curriculum documents | Israeli Ministry of Education policy and curriculum documents |
| Tao et al. (2013)             | Comparison of teaching and learning of science in Chinese and Australian Grade 6 classrooms | Lesson observations, teacher interviews, student questionnaires |
| Roth et al. (2006)            | Comparison of science teaching in the USA and four high-performing jurisdictions | TIMSS 1999 video study |
| Cogan et al. (2001)           | Median polish analysis                           | TIMSS 1995 curriculum and teacher questionnaires   |
| Rutkowski and Rutkowski (2009)| Hierarchical cluster analysis and non-linear principal component analysis | TIMSS 1995 and 2003 (Grade 8 mathematics item response data) |
| Kjaernsli and Lie (2008)      | Hierarchical cluster analysis                    | TIMSS 2003 (science item response data)            |
| Zanini and Benton (2015)      | Latent class analysis                            | TIMSS 2011 Grade 8 mathematics teacher questionnaire |
This qualitative approach provided evidence that, over time, the Israeli science curriculum was converging on the requirements of international surveys such as TIMSS.

Another study which contained a significant qualitative element to investigate globalization compared the approaches used to teach science in Australian and Chinese elementary schools (Tao et al. 2013). This study used a multiple comparative case study approach in which three Australian schools and three Chinese schools were paired together for comparison based upon socioeconomic status (high, medium or low). The research consisted of analysis of curriculum documents in each school, lesson observations, school tours, teacher interviews and student questionnaires. The methods used in this research enabled comparison of both the intended and implemented curriculum in Australian and Chinese schools, and observation of the impact of culture on the curriculum in each school.

Other research methods used in the literature review studies identified were predominantly quantitative in nature. One study compared aspects of the implemented science curricula in the United States, Australia, the Czech Republic, Japan and the Netherlands by reviewing eighth grade science lessons from the TIMSS video study (Roth et al. 2006). The content of the science lessons was coded and the commonalities and differences between the content of the lessons in the United States and the four comparator countries were identified. This study concluded that each country had a distinct approach to science teaching, providing students with different opportunities to learn science and different visions of what it means to understand science. Additionally, the science lessons in each country varied in terms of their organizational features and in the extent to which students were actively involved in their science lessons.

Some studies made use of the responses to the TIMSS teacher and curriculum questionnaires to investigate globalization of curricula. For example, Cogan et al. (2001) used TIMSS Grade 8 questionnaire responses to investigate similarities in countries’ science curricula. Detailed analysis of the questionnaire responses enabled information about science content standards, textbook content and teaching time for each science topic to be collated for each country. Matrices of the curriculum for each country were produced and median polish analysis conducted in order to look for the effects of country by topic interactions.

Several studies made use of hierarchical cluster analysis to investigate the similarities and differences in curricula. This has been done for mathematics curricula (Rutkowski and Rutkowski 2009) and science curricula (Kjaernsli and Lie 2008). In mathematics, Rutkowski and Rutkowski (2009) investigated 16 countries that participated in TIMSS Grade 8 mathematics in both 1995 and 2003. They conducted an item analysis to establish the strengths and weaknesses in student response patterns in each country and how this compares across countries. A hierarchical cluster analysis was then conducted for the 1995, 1999 and 2003 TIMSS cycles to investigate the degree of alignment in curricula across different countries and how this changed between the three TIMSS cycles.

Kjaernsli and Lie (2008) used a similar approach with TIMSS 2003 science data. Probability value (p-value) residuals were calculated, which measured how much
better or worse students in each country performed on a particular science item compared to what would be expected based on the average student achievement of the country and the overall difficulty of the item. A hierarchical cluster analysis was then performed on each country to investigate how participating countries cluster together based on similarities in the strengths and weaknesses of their students’ responses to different types of answer.

In addition to hierarchical cluster analysis, latent class analysis has been used to identify groups of countries with similar curricula. For example, Zanini and Benton (2015) investigated groupings of countries with similar mathematics curricula by conducting a latent class analysis using responses to TIMSS 2011 Grade 8 teacher questionnaires. In this study, teacher responses to questions regarding which mathematics topics were taught to their students were used in the latent class analysis. The analysis found five distinct groupings of countries based on the teacher responses to the questionnaire, thereby providing evidence to suggest some degree of alignment and harmonization in mathematics curricula.

The literature review suggests that there are a range of different methods that can be successfully employed to investigate globalization of curricula. Each of these approaches has its own unique set of advantages and limitations. Among the qualitative studies, the documentary analysis of education policy and curriculum documents has a number of strengths. This approach enables a country’s curriculum changes to be scrutinized in depth. The curriculum documents and associated government policy papers also often provide information about the explicit aims of any changes or reforms to the curriculum and the rationale for them. This has the advantage over some other approaches in that it can provide an insight into why changes have been made to the curriculum and what the intended aims or aspirations of the changes were.

There are also disadvantages. Curriculum and policy documents can be time consuming to analyze and review, and this places a natural limit on the number of countries that can be examined given the constraints of time and budget. This type of qualitative approach is thus better suited to studies that consider one or a small number of countries as opposed to a large number of countries. Other disadvantages include the difficulty of obtaining documents in a common language for some countries, as well as the variation in the quality and extent of curriculum and policy documents in different countries; this may make direct comparison between countries challenging. Furthermore, these documents often focus on the intended curriculum as opposed to the implemented curriculum, and so caution needs to be exercised when making inferences about a country’s implemented curriculum.

Other qualitative approaches identified in the literature review, such as lesson observations and interviews with teachers and students, have a number of advantages when studying the possible globalization of science curricula. As well as providing the opportunity to observe the implemented curriculum in schools as opposed to the intended curriculum, such studies often take the viewpoints of several different actors in the school system (teachers and students) into account. However, this type of study can be time consuming and expensive, constraints that may influence the number of countries that can be considered. It is also difficult to
ensure that the data collected is truly representative when relying on a small sample of observations and interviews.

Analyzing extracts from the TIMSS video study has a number of benefits, including the ability to observe science lessons in different countries and to code for different pedagogic features in those countries. This approach also permits teaching methods in different countries to be compared, and so enables aspects of the implemented science curriculum to be explored. However, the TIMSS video study was only undertaken at one time point for science, and so it is thus difficult to use the data to investigate the globalization of science curricula over time or to estimate how representative the recorded lessons were of typical everyday science teaching. Indeed, it must be acknowledged that teacher and pupil awareness that the lessons were being recorded may have affected the quality or nature of the lessons in some way.

The quantitative approaches identified in the literature review, such as cluster analysis and latent class analysis, have a number of advantages but also some disadvantages over the qualitative approaches outlined. Firstly, the quantitative approaches make it easier to include a greater number of countries in the investigation. This is an important consideration when analyzing the globalization of science curricula across the full cohort of countries taking part in an international survey such as TIMSS. These techniques have the potential to allow for more robust large-scale investigations into the globalization of science curricula over time than the qualitative approaches. Both cluster analysis and latent class analysis are well suited to this type of analysis, and cluster analysis has the additional benefit of being able to be conducted on a smaller dataset than latent class analysis.

Having considered the relative merits of each of the techniques identified in the literature review, and the datasets and resources available for this research, the methods we have chosen to use and our rationale for using them are outlined in Chap. 3 of the report.

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