MATHEMATICS IN THE SUCCESSFUL TECHNICAL EDUCATION OF 16-19 YEAR OLDS

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INTRODUCTION

For some time, a great deal of policy and research attention has focused on the mathematical preparation and needs of entrants to university STEM disciplines.[1] Much less attention has been devoted to the mathematical preparation of STEM technicians, although the supply of mathematically skilled STEM technicians is acknowledged as a greater problem than that of STEM graduates.[2]

This report explores the mathematics in technical education by focussing on six countries: four European countries known to have strong vocational educational systems and well-documented STEM apprenticeship pathways (Germany, Netherlands, Norway and Switzerland), and two Pacific Rim countries which are known to produce a strong cadre of STEM technicians (Singapore and South Korea). All of these countries have a relatively high level of mathematical attainment in international surveys.

We address the following questions:

- What is the content and level of mathematics preparation for, and within, STEM technical education, and how does this differ across STEM sectors and pathways?
- How is the mathematics provision delivered? (For example, to what extent is mathematics "embedded" within STEM technical education? Who is responsible for delivery?)

Our aim is to build on and extend relevant work in the area.[3]

The report is developed from detailed country insights provided by both desktop exploration and work with country experts. The methodology is described briefly below. Further to this we present a summary and synthesis of the research in a comparative table. Finally, we discuss a set of key emerging issues focusing on differences and similarities between the countries surveyed and England.

METHODOLOGY

In this study, we used a "fiche method" as in our previous international studies.[4] We first drafted a country profile (or fiche) based on a synthesis of the "grey"/policy-oriented literature and information available on government websites, together with (where available) relevant academic literature. We then asked an expert on STEM vocational education in each system to check and comment on the country profile. (See Appendix 1 for a list of these experts.) During this process, we were able to incorporate additional information. We then used the final country profiles as the basis for a comparative analysis of the systems.

It is important to note that there are significant limitations to this small-scale study. First, comparative judgments in education are fraught with difficulty given the substantial cultural differences between countries. This is particularly the

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[1] For example: Advisory Committee on Mathematics Education (ACME). (2011). *Mathematical Needs: Mathematics in the workplace and in Higher Education*. London: Royal Society; Hodgen, J., Marks, R., & Pepper, D. (2013). *Towards universal participation in post-16 mathematics: lessons from high performing countries*. London: The Nuffield Foundation; Hodgen, J., Pepper, D., Sturman, L., & Ruddock, G. (2010). *Is the UK an outlier? An international comparison of upper secondary mathematics education*. London: The Nuffield Foundation.

[2] Sainsbury, D. (2016). *Report of the Independent Panel on Technical Education*. London: Crown Copyright.

[3] Education and Training Foundation. (2014). *Effective practices in post-16 vocational maths. Final report*. London: Education & Training Foundation.

[4] Hodgen, Marks, & Pepper. (2013). Op. cit.; Hodgen, Pepper, Sturman, & Ruddock. (2010). Op. cit.

case for vocational education systems. Our aim is to provide a snapshot of mathematics in the different systems in order to inform policy in England. Second, 'successful' policies are enacted within a wider educational context and, as a result, it is difficult to ascribe causation to any particular policy. Elsewhere, we have cautioned of the dangers of 'cherry-picking' policies from other systems out of context.[5] We repeat that warning here, particularly as the countries we have chosen to survey are not in any way representative in terms of any aspect of mathematics education: rather they have been selected because of their acknowledged successful approach to technical education. Third, this study could not have been carried out without the help of the country experts and we are extremely grateful for their help and advice. However, inevitably, as English researchers, we will have made errors of interpretation, particularly given the scale and desk-based nature of this study. Any errors are our responsibility as authors.

A COMPARISON OF THE MATHEMATICS IN VOCATIONAL EDUCATION IN UPPER SECONDARY ACROSS THE SYSTEMS SURVEYED: A SUMMARY

In Table 1, we summarise the evidence from the country profiles which have been prepared on the basis of desk research by the team and information obtained from the expert in each country. The full country Profiles are available in Appendix 2 of this report.

[5] Askew, M., Hodgen, J., Hossain, S., & Bretscher, N. (2010). *Values and variables: A review of mathematics education in high-performing countries*. London: The Nuffield Foundation.

Table 1: Main points of comparison relevant to vocational education and mathematics between England and the six sampled countries

	England	Germany	Netherlands	Norway	Switzerland	Korea	Singapore
Structure of VET system	School/college-based + Some apprenticeships	'Dual-track' apprenticeships + Vocational school-based + General (academic) pathway with vocational element	Stratified vocational school-based (2 pathways) + Employer-based	2-year vocational school-based + 2-year apprenticeship (equivalent to 1-year each of training & productive work)	'Dual-track' apprenticeships + Vocational school-based (aimed at 'professional' white collar occupations)	Vocational school-based	Stratified vocational college / polytechnic-based (2 pathways)
Age at which vocational education commences	16 Some pre-vocational options available to at age 14	16 Prior options & school influence choices at 15/16	16 Approx. 25% take pre-vocational courses taken at age 14	16	16	15	16 Some continue in academic (O-level) to 17 Some take a 'technical' curriculum pre-16
Proportions (of cohort) on vocational pathways	Approximately 30%[i]	18 % academic; 51% vocational (dual-track); 9% general education with vocational element; 22% other options (vocational school-based).	69%	41%	Approximately 67% (90% of whom are on dual track system)	24%	69%

	England	Germany	Netherlands	Norway	Switzerland	Korea	Singapore
Links between vocational and academic (HE) pathways	No formal links, although there is substantial movement between routes[ii]	Pathways available to HE from all starting points – standard route predominates but flexible options	Some	Pathways for conversion are available	Federal Vocational Baccalaureate (FVB) enables progression to HE through assessment of academic skills	No formal links	A relatively large proportion following the more academic polytechnic pathway go on to HE
PERFORMANCE IN INTERNATIONAL SURVEYS[iii]							
PISA 2015 (age 15)[iv]	492	506	512	502	521	524	564
TIMSS 2015 Grade 8	518	N/A	N/A	487[v]	N/A	606	621
PIAAC Survey of Adult Skills 2013: Numeracy ages 16-24 (Ave Numeracy ages 16-65)[vi]	256 (262)	275 (272)	285 (280)	271 (278)	N/A	281 (263)	287[vii] (257)

	England	Germany	Netherlands	Norway	Switzerland	Korea	Singapore
MATHEMATICS IN VOCATIONAL EDUCATION AND TRAINING							
Entry qualifications required	Entry requirements vary by subject and ISCED level of programme. Some STEM subjects require a higher grade than C in GCSE mathematics.	Entry to vocational education pathways in upper secondary is possible from any option within lower secondary and there are concerns that some students have weak core academic skills	Vocational (MBO) programmes are offered at different levels and entry requirements vary. During the VMBO in lower secondary all students take mathematics for 2 years and in some vocational areas they are required to take maths for a further 2 years	Entry to upper secondary is an entitlement. Poor performance at 'basic' skills (including mathematics) appears to contribute to VET dropout rate.	Entry to upper secondary education is dependent on successful completion of lower secondary. 13% take transitional 'preparation' options at end of lower secondary	Entrance Examination taken at the end of lower secondary education (age 16) determines pathway in upper secondary.	O-level or lower N-level required for entry. 89% pass O-level (ISCED Level 2)
Is mathematics compulsory in vocational education?	No. Compulsory if ISCED level 2 not achieved (GCSE maths grade C)	No. In some vocations there is a maths component – not all have distinct units. All contain some elementary arithmetic (curriculum often informed by text books)	Yes. All work towards national 'basic mathematics' examination	Yes. Common core during school-based vocational element	Yes	Yes. Compulsory for the first year of upper secondary education	No

	England	Germany	Netherlands	Norway	Switzerland	Korea	Singapore
Mathematics qualifications taken in vocational education	Depends on GCSE Maths grade: Grade D: re-take GCSE Maths; Grade E or below: Functional Maths or other ISCED Level 1 maths qualification; Grade C or higher: dependent on programme.	No separate / distinct mathematics qualification. Mathematics may be part of a vocational pathway and examined (varies across vocations and region) but no common mathematics certificate across courses	From 2015/16 satisfactory performance in national examination in 'basic mathematics' is required for vocational diploma	Locally-based 'continual' assessment by examination and teacher. Moderation of a random sample of students	Students do not take a separate mathematics qualification. Different vocational qualifications have different mathematics requirements	Most take Basic Mathematics course, although other options (General & Advanced) are available	Students do not take a separate mathematics qualification. Different vocational qualifications have different mathematics requirements
Type of mathematics curriculum in vocational education	GCSE mathematics is an academic knowledge-based curriculum. Functional mathematics focuses on the use of mathematics. Occupationally-specific mathematics is embedded into vocational learning	Complexity across vocational areas and regions. May be integrated or embedded into vocational course. Varies further in implementation. No national curriculum	The national test focuses on the use of mathematics. Occupationally specific mathematics is embedded into vocational courses	Common core mathematics during school-based vocational education	Integrated into vocational course. Varies between vocational areas. No common curriculum	General mathematics is taken in the first year. Further mathematics modules (e.g. Calculus, Statistics) are available but optional in the second and third years	Integrated into vocational course. Varies between vocational areas. No common curriculum

	England	Germany	Netherlands	Norway	Switzerland	Korea	Singapore
Who decides the content in vocational education?	Varies according to route	Definitions for over 300 routes set at Federal level, informed by vocational education bodies. Interpreted regionally by different Lander. Strong cooperation with stakeholders	Joint responsibility of government, social partners (employers, trades unions) & educational institutions. Numeracy content of basic mathematics qualification decided by government centrally	Partnership between government and employer stakeholders locally and nationally	Strong collaboration between government and employer bodies nationally and locally	Ministry of Education. Central government has a high degree of control over the content	Institute of Technical Education under the Ministry of Education. Central government has a high degree of control over the content
Who teaches mathematics in vocational education?	Varies according to route and institution	Vocational teachers normally. Some have mathematics specialism. Some specialist mathematics teachers	Vocational teachers generally without a mathematics specialism, although some training provided since introduction of basic mathematics	Specialist (school) mathematics teachers during 2-year school-based vocational education. Any mathematics in apprenticeship training is taught by vocational trainers	Specialist mathematics teachers in school element of dual-system	High school mathematics teachers	Vocational teachers normally teach all elements including mathematics using an integrated approach
Time allocated to mathematics	Varies	Between 0 and 6 hours depending on vocational route	No standard hours	84 hours in Grade 11	Varies according to vocational route	4 hours per week	Varies according to vocational route

	England	Germany	Netherlands	Norway	Switzerland	Korea	Singapore
Difference / similarity in the mathematics curriculum for academic and vocational education	The mathematics studied post-16 depends on prior attainment. Students with low attainment at age 16 years (the majority of these being on vocational courses), will re-sit this examination or take a Functional Mathematics qualification. High attainers (the majority being on the academic pathway) may choose to take Advanced Mathematics	No similarities between academic and vocational pathways although some developments of vocational schools adopting more academic pathways	In post-16 education all students have to work towards a national test in mathematics. Occupationally relevant mathematics is also taught within vocational courses depending on the demands of the vocational area	The mathematics in vocational education is identical to 3/5 of the mathematics in Grade 11 General Education	College teaching time available on the 'dual track' pathway (20-40%) restricts the curriculum but there is recognition that numeracy is an important transferable skill	During the first year of upper secondary education mathematics is compulsory but vocational and academic students usually take different mathematics courses. Mathematics is then optional and vocational students would typically spend less time on mathematics at this stage	Vocational education involves only occupationally relevant mathematics. Mathematics for students on academic pathways is an option and involves traditional advanced mathematics

[i] In 2015 in England of 16-18 year olds, 7% were in apprenticeships and 16% were taking courses leading to ISCED Level 3 vocational qualifications. An additional 14% were taking courses leading to Level 2 qualification or below and many of these students are likely to be on vocational routes. BIS / DfE. (2016). Technical education reform: the case for change [DFE-00163-2016]. London: Department for Education. https://www.gov.uk/government/publications/post-16-skills-plan-and-independent-report-on-technical-education We note, however, that the most popular Level 3 vocational qualification, the BTEC, is very extensively used as a pre-university qualification. See: HEFCE. (2015). Young participation in higher education: A-levels and similar qualifications. London: HEFCE. http://www.hefce.ac.uk/media/hefce/content/pubs/2015/201503/HEFE2015_03.pdf

[ii] The 'churn' (or movement) between routes amongst 16-18 year olds is estimated to be as much as 25% of the cohort. BIS / DfE. (2016). Op cit.

[iii] Where a country did not take part in a particular survey, this is indicated by 'N/A'.

[iv] Scores for PISA and TIMSS are scaled to have an overall mean and standard deviation of 500 and 100, respectively. The between country variation is greater for TIMSS (e.g., the mean attainment scores for the highest performer on both surveys in 2015, Singapore, were 621 and 564 for TIMSS and PISA, respectively.

[v] Norway's assessment focus in TIMSS 2015 was Grade 9, but benchmarking data for Grade 8 were also collected. Grade 8 attainment is reported in the table.

[vi] PIAAC international mean for age 16-24 [267]; international mean (and interquartile range) for ages 16-65 [263 (68)]. Updated results reported: OECD. (2016). *Skills Matter: Further Results from the Survey of Adult Skills*. Paris: OECD Publishing; Additional tables: dx.doi.org/10.1787/888933366463

[vii] Singapore carried out PIAAC survey in 2014/5.

Table 1 highlights the different structures of vocational education routes across the countries surveyed. To some extent, by necessity, it masks the complexity and variation of possible progression routes within countries. However, it does provide access to a simplified overview of commonalities and differences between countries. Of note in this regard are:

- All countries include a school/college based element of education within their vocational/apprenticeship routes. These routes almost always are designed to facilitate progression and transferability to and academic pathways through curriculum design.

- The proportion of students taking vocational pathways varies but England is at the lower end of the range. In the most favourable systems the vocational route can attract up to approximately 70% of students: in England the reverse is the case with only approximately 30% of students following vocational routes.

- The common age at which students specialise in vocational education is 16. England is in line with this.

- In England the mathematics score on the international comparative PISA test is below average at 492 (mean score 500) and is the lowest of the nations in our comparative study. England also scores lowest on the PIAAC study tests that measures adults' numeracy competency.

- Entry requirements in mathematics for vocational study are strict in high preforming jurisdictions: this is not the case in European countries where mathematics ability is recognised as important and is supported through a range of different mechanisms and support. This is the case in England with the GCSE qualification being the goal of many because of government policy which is supported by funding arrangements.

- There is similarly considerable variation in approach to the inclusion or not of mathematics education within vocational routes. However, many countries ensure that some level of 'basic mathematics' capability is achieved either prior to, or whilst, undertaking vocational education.

- Although students on some, particularly technical, routes learn new mathematics in general this is not separately certificated.

- Mathematics is mainly integrated or embedded in vocational contexts and taught by vocational specialists. The specification of this mathematics is often achieved through close collaboration between curriculum specialists and employers or employer organisations. A consequence of this is that there is little similarity between mathematics on vocational and academic routes.

The table does not address issues relating to the stability of educational systems and structures in which vocational education and training are situated. However, noticeable in this regard, in our desk work and discussion with the country experts it is striking that, in comparison to all the other systems surveyed, England undergoes more significant change much more regularly, with new vocational qualifications being developed on a regular basis to replace the previous 'discredited' model. In general, the other systems surveyed undergo small iterative changes which appears to facilitate allowing these changes become embedded and valued by stakeholders including students, their teachers and parents and employers.

THE MATHEMATICS IN VOCATIONAL EDUCATION FOR 16-19 YEAR OLDS IN SUCCESSFUL SYSTEMS: A COMMENTARY

The following section provides a summary of the emerging issues and possible hypotheses from a preliminary study of mathematics within pathways for STEM technicians using country comparisons. The main points of comparison on which these issues and hypotheses are based are summarised in Table 1.

The vocational context

Vocational education is *complex* in all the countries surveyed. This complexity is due to considerable differences between the skills and competencies required for different occupations, the consequent and variety breadth of the vocational curricula and the different stakeholders and institutions involved. The range of vocational courses is wide, as might be expected considering the number and variety of occupations for which substantial training is required. The mix of provider institutions, pathways and qualifications leads to complexity in the English system that appears to exceed that in other country systems in this study.

Within the different country systems surveyed *pathways to becoming a STEM technician* tend to be more well-established and clearly defined than in England. In England, for some STEM technician occupations there are clear entry pathways through specific apprenticeships that lead to recognized professional qualifications (e.g. Electrician). However, for other STEM technician occupations, the entry routes are less clearly defined, particularly if students initially follow a more general college-based course rather than securing a more direct entry through a relevant apprenticeship.

Most countries identify *areas for improvement* within their vocational education systems and are seeking to improve perceived weaknesses but it is clear that in some countries (e.g. Switzerland, Norway and Germany) the system is widely viewed as highly effective and there is less dissatisfaction than in England. These countries are of particular interest but contextual factors, such as the historical backgrounds and underpinning philosophies of these vocational education systems, need to be taken into account in any comparisons. In all the systems surveyed, the policy and reform cycle appeared to be longer-term and more iterative than in England. Importantly, their systems are well-established and understood by all stakeholders.

The *status* of vocational education in different countries also differs. In many systems it has lower status than academic education although countries such as Singapore have worked on strategies to address the imbalance. Other countries, such as Switzerland, Germany and Norway, have developed systems over time in which general understanding of differences between vocational and academic education is understood and valued. This is helped by the industrial infrastructure that is supportive of a large number of employers who make a contribution to vocational education. Where vocational education has low status, such as in England, this can make vocational education less attractive to high-attaining students and reinforces public perceptions (such as those previously identified by Singapore) that vocational education is only for low-attaining students. This is likely to lead towards lower levels of academic achievement being required for entry into vocational pathways than in countries where vocational education is more highly valued.

Within this sample of countries, the vocational education systems are founded on *different strategic approaches t*hat affect the way in which the system functions. In England, the range of provision offered is largely in response to student demand and funding incentives. In contrast, in most of the other systems surveyed, vocational education is closely linked to the demands of the labour market. In Switzerland, Norway and Germany, this is achieved through strong collaboration between government, employers and other stakeholders. In Singapore the government has focused on specific areas of vocational education aimed at providing the necessary workforce for a strategic development of the economy in a global market. The range of provision and promotion of certain vocational areas within a country system affects the numbers of students on different courses and may lead to higher or lower numbers on STEM technician pathways.

The influence of different stakeholders in different countries in defining vocational education is an important variable. There are varying levels of *influence from employers* in both the qualifications and the delivery of the vocational curriculum across the different countries, either directly or through intermediary representative organisations. For example, in Singapore and Korea, the vocational systems are largely government-controlled but in all four European systems surveyed (Switzerland, Norway, Netherlands and Germany), there is a well-established shared responsibility between government, social partners and educational institutions. In the Swiss and German 'dual track' systems employers are the main providers, working in conjunction with schools, and qualifications are closely aligned to the professional ordinances. In England employers have some influence over vocational qualifications since these have to be approved by the relevant sector skills council. They have less responsibility for delivery than some other countries since they are providers only of apprenticeships and the number of students (aged 16-18 years) on college-based courses exceeds those on apprenticeships. These differences between countries can affect the alignment of qualifications and training to specific areas of vocational employment. This seems of significance because it can affect how effective the qualifications are in supporting preparation for employment and as a result the value placed on them by students, employers and other stakeholders.

Mathematics in vocational education systems

The *division between academic and vocational pathways* starts at different ages in the different countries but the main separation of pathways usually occurs at age 15-17 years. This is the case in England where the main division is at age 16 years. In other countries, such as the Netherlands and some parts of Germany, vocational options are available earlier. The mathematics curriculum for academic and vocational pathways after this division is often different, in which case students do not have the same opportunities to develop their mathematics in upper secondary education with the mathematics they study very much depending on their choice of academic or vocational route. In some systems, such as in Switzerland and Germany, the strong employer-based 'dual track' system results in an emphasis on mathematics for vocational purposes. In Korea mathematics remains compulsory for the first year of upper secondary education but students on academic and vocational pathways usually take different mathematics options within the shared curriculum. In contrast, the Netherlands has recently introduced compulsory national mathematics tests of a more generic nature, without which students will not be able to achieve their vocational diploma. Many systems incorporate each of these different forms of mathematics within vocational pathways although the emphasis between these may vary. All countries, in different ways, emphasise the need for 'basic' mathematical competency and this is addressed in different ways, such as through the compulsory mathematics test in the Netherlands or the entry requirements in Singapore.

Vocational education systems generally include both *schools-based vocational programmes and apprenticeships*, leading to qualifications with different emphases but the split in student numbers between these two types of courses in different countries varies widely. This leads to different numbers of students in the different countries taking what might be considered either knowledge-based mathematics courses with more of an academic orientation or skills-based courses with more of a vocational orientation. Within a country these different courses vary in the content, level and quantity of mathematics included. There are indications in the study of there being issues for apprentices learning mathematics that is certificated separately because only a small proportion of their time is spent in college and this does not allow much space for generic subjects.

Within vocational upper secondary education *mathematics is compulsory* in some countries (e.g. Netherlands, Norway and Korea) but not in others (e.g. Singapore). Even when mathematics is compulsory there are differences between the mathematics curriculum on academic and vocational pathways (and qualifications where available). When the mathematics is embedded into vocational competencies, or taken as a separate module within a vocational qualification, then there are differences between vocational courses and qualifications even at the same level. This is not surprising since mathematical demands vary between vocational areas and occupational practices even within related areas. Further work that identifies differences between countries in the mathematics studied on pathways towards certain well-defined occupations will provide insight into issues of content and level that might be illuminating.

Even in countries where the study of mathematics is compulsory in both academic and vocational pathways, the students' experience of mathematics on these pathways may be different. Mathematics in vocational education may:

- be taught separately;
- integrated within vocational teaching;
- embedded into vocational competencies and consequently often not recognised as mathematics.

Related to these differences in the mathematics between vocational areas is the emphasis within the system and the *interpretation of the notion of vocational competency*. For example, in Korea vocational education is conducted with a fairly academic orientation, whilst the Swiss and German systems have a greater focus on vocational competency. These different orientations affect the content of courses in ways that has much impact on the nature of the mathematics included. Definitions of competencies, therefore, vary. Countries such as Germany, Netherlands, Norway and Switzerland take a broader view of occupational competency than the narrower English focus on atomized practical skills related to the occupation.[6] This means that the embedded and modular forms of mathematics within vocational qualifications, even for the same occupation, are unlikely to be the same in different countries. Variations in the content and level of mathematics within pathways leading to similar occupations in different countries may, therefore, be linked to interpretations of vocational competency and not solely to mathematics policy.

The *level of attainment* in mathematics prior to entering a vocational pathway also varies between countries. In Singapore and Korea, high performance in international comparisons such as PISA and TIMSS indicates that most young people have a strong foundation in mathematics prior to entering vocational education. Hence, in Singapore students are considered to have sufficient general mathematics knowledge and skills before entering upper secondary education and therefore only need to apply this knowledge and learn any additional occupation-specific content during their vocational courses. Evidence from the OECD's PIAAC 2013 Survey of Adult Skills suggests that the numeracy attainment 'gap' between the Pacific Rim and the European systems of Norway, Netherlands and Germany has narrowed for 16-24 year olds. Indeed, in Norway young people appear to 'caught up' with their Pacific Rim counterparts. In contrast, the numeracy skills of 16-24 years olds in England are well below the mean and the 'gap' gets wider.[7]

The *mathematics curriculum* in upper secondary education for vocational students often includes both 'basic' in addition to vocationally oriented mathematics. For example, in Norway, Netherlands and Korea, young people on vocational pathways all study a 'basic mathematics' that is closely related to secondary school mathematics.

These indicate different aims and purposes for mathematics, suggesting that in comparisons of the mathematics curriculum within vocational pathways the aims and purpose of learning mathematics need some consideration in addition to level and content. It is difficult to quantify the amount of time dedicated to the study of mathematics within countries, particularly because of the different routes that students may follow. However, it is clear that the *time allocated to mathematics* varies between systems and some systems (e.g. Norway) allocate more hours to mathematics than in England.

Mathematics teaching within vocational education is sometimes carried out by vocational teachers, such as in Singapore, whilst specialist mathematics teachers may be used elsewhere, for example for teaching leading to the national test in the Netherlands. This may be linked to whether the mathematics is being studied for a separate generic mathematics qualification or is occupation-specific and also to whether the teaching takes place within the school system (as in Norway). This raises questions about whether

[6] See also, Winch, C. (2010). Dimensions of expertise: a conceptual exploration of vocational knowledge. London: Continuum., for a related argument.

[7] Switzerland did not take part in the OECD's PIAAC survey, so up to date information is not available.

one approach is more effective than another and whether vocational teachers are suitably trained to teach mathematics. There are variations in the *qualifications and training of teachers*, both mathematics and vocational, across countries since there are differences in the length of initial teacher training courses, the content and the qualification requirements for entry to the profession, both in terms of general and mathematics qualifications. A more detailed examination of these differences may lead to some indicators of key differences and the effectiveness of specialist vocational or mathematics teachers might also be further explored in relation to the aim and purpose of the mathematics rather than just the content and level.

CONCLUSION

In conclusion, it is clear from our desk research that, in comparison to the other countries surveyed, England's mathematical preparation in technical education is weak.

In general, in other systems, young people enter technical education with stronger mathematical skills and their mathematic skills appear to improve during technical education. The other systems surveyed are well-established, either because they have embedded over a relatively long time-period of many years or, in the case of newer systems, are expected to be in place for such time-scales. Changes are iterative, unlike in England where there has been regular whole-scale redesign of technical qualifications. Consequently, in other countries the mathematical demands of technical routes are well-understood and appropriately tailored to the needs of relevant occupations.

Bringing English technical education 'up to speed' in this regard is not straightforward. In particular, the mathematics required for occupations is often 'invisible' to those involved. Hence, we consider that there is an urgent need to describe explicitly the mathematics involved in technical occupations. Since there are many synergies in the mathematics across occupations, one potential approach would be to produce a bank of mathematical occupational standards.

This would have significant additional benefits in highlighting the relevance of mathematics to young people and raising the status of mathematics for employers and other stakeholders. It would also enable the certification of mathematics in courses of technical preparation, which would be a positive way of promoting greater visibility of, and emphasis on, as well as recognising the value of mathematics in different occupations. This could also support future transferability of mathematical skills and knowledge. Finally, it is also important to recognise that implementing these changes, and improving mathematics in technical education, will require additional curriculum time for mathematics-related teaching as well professional development for teachers.

APPENDIX 1: THE COUNTRY EXPERTS

We are very grateful to the following country experts who provided advice and guidance on the country profiles:

Germany: Prof. Dr. Rudolph Straesser, Justus-Liebig-Universität, Giessen, Germany.
Korea: Youngsup Choi, Korea Research Institute for Vocational Education & Training (KRIVET), Korea.
The Netherlands: Dr. Monica Wijers, Freudenthal Institute, Utrecht University, The Netherlands.
The Netherlands: Dr. Kees Hoogland, Netherlands Institute for Curriculum Development (SLO), The Netherlands.
Norway: Prof. Dr. Pauline Vos, University of Agder, Norway.
Norway: Trude Sundtjønn, University of Agder, Norway.
Singapore: Lee Khim Song, Singapore Institute of Management, Singapore.
Switzerland: Prof. Dr. Ursula Reynold, KOF Swiss Economic Instititute, ETH Zurich, Switzerland.

APPENDIX 2: THE COUNTRY REPORTS

MATHEMATICS AND VOCATIONAL EDUCATION IN GERMANY

Introduction

Germany's vocational education system is often referred to as a particularly successful model by other countries and is "deeply embedded and widely respected in German society".[8] The 'dual system' dominates post-16 education. For example, in 2004, 53% of the cohort completed 'dual system' courses and 15% completed courses in vocational schools (See Cedefop report: Spotlight on VET in Germany[9]). The apparent effectiveness of the system has attracted attention from countries that wish to improve their own systems, although Euler (2013) warns that the system may be a useful "model, but not a blueprint" and therefore cannot simply be replicated in other countries with equal success.[10] Results in PISA 2000 caused concern in Germany and prompted work to improve standards in mathematics. These included national (Federal) curriculum guidance, increased assessment (such as compulsory national assessment at Grade 8[11,12]) and pedagogic and curricular initiatives (such as the SINUS project which put more emphasis on problem-solving and mathematical literacy than had previously been the case).[13]

Mathematics / numeracy performance in international surveys

PISA 2015 (age 15)[14]	506
TIMSS 2015 Grade 8[15]	N/A
PIAAC Survey of Adult Skills 2013[16]: Numeracy ages 16-24 (Ave Numeracy ages 16-65)	275 (272)

[8] OECD (2011). *OECD reviews of vocational education and training*. Paris: OECD Publishing. (p.33). https://www.oecd.org/edu/skills-beyond-school/LearningForJobsPointersfor%20PolicyDevelopment.pdf

[9] http://www.cedefop.europa.eu/en/publications-and-resources/country-reports/germany-vet-europe-country-report-2014

[10] http://www.eunec.eu/sites/www.eunec.eu/files/attachment/files/2013_study_german_vet_system.pdf

[11] http://timss2015.org/encyclopedia/countries/germany/monitoring-student-progress-in-mathematics-and-science/

[12] https://www.iqb.hu-berlin.de/vera

[13] http://sinus.uni-bayreuth.de/2955/

[14] OECD. (2016). *PISA 2015 Results (Volume I): Excellence and Equity in Education*. Paris: OECD Publishing. DOI: http://dx.doi.org/10.1787/9789264266490-en

[15] Mullis, I. V. S., Martin, M. O., Foy, P., & Hooper, M. (2016). *TIMSS 2015 International Results in Mathematics*. CHestnut Hill, MA: TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College / International Association for the Evaluation of Educational Achievement (IEA).

[16] OECD. (2016). *Skills Matter: Further Results from the Survey of Adult Skills*. Paris: OECD Publishing; Additional tables: dx.doi.org/10.1787/888933366463

Background

Education in Germany has much organisational variation across the different Länder that comprise the Federal Republic. However this variability is based upon a common structure that covers the ten years of compulsory schooling and beyond (see Figure 1 for an overview). Although there are a number of variations in the Länder, particularly in the different types of schools available in Secondary education, progression can be generally described as involving all students in primary schools until aged 10 to 12 after which they are educated in one of three types of secondary school: the Hauptschule which provides a *basic* general education, Realschule which provides a more extensive general education, or the gymnasium in which students study traditional academic subjects. In some places, comprehensive schools are on offer or even compulsory for secondary education. After this, students, at age 16, either continue with either an academic education (progressing from either a Realschule or (predominantly) a Gymnasium) or a vocational education in one of a number of different forms of Berufsschule. This is when students may first encounter the 'dual system' in which part of a student's education is within the vocational context with an employer of all types of companies (from small to medium sized or even large), and the other part in the 'school'. On the other hand some students may enter a Berufsfachschulen which is a full-time vocational school. (For an overview see information produced by The Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany.[17])

[17] https://www.kmk.org/kmk/information-in-english.html

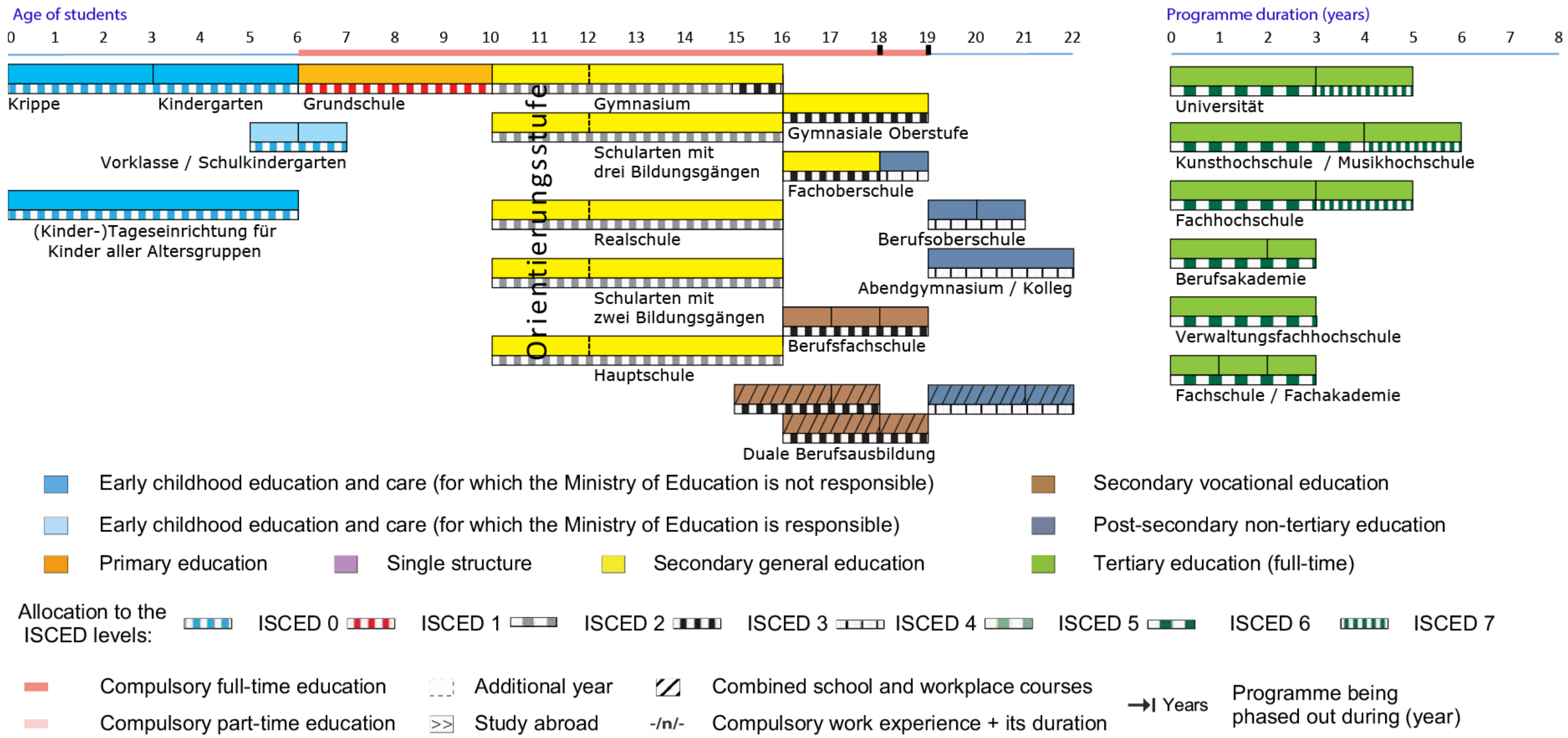

Figure 1: Overview of education in Germany, Eurydice, Nov 2014[18]

[18] https://webgate.ec.europa.eu/fpfis/mwikis/eurydice/index.php/Germany:Redirect

One result of the German system is that typically 18% of the workforce are university graduates and 54% skilled craftsmen from the dual system.[19]

According to the OECD[20], the VET system in Germany is well-resourced and a strength of the dual system is "the high degree of engagement and ownership on the part of employers and other social partners. But the system is also characterised by an intricate web of checks and balances at the national, state, municipal, and company levels that ensures that the short-term needs of employers do not distort broader educational and economic goals." At a Federal level, national definitions of training in approximately 300 different routes are developed. These are informed by vocational education bodies[21]. These definitions are interpreted at a regional level to provide appropriate specifications and are further interpreted by providers in developing vocational courses for students. "Some students leave compulsory school with weak core academic skills. The VET system is not currently organised to ascertain whether this is in fact a problem or, if so, to address it."

The results of PISA 2000 had a major effect across Germany's education system. This 'PISA shock' led to reforms that included the introduction of standards for measuring students' competencies at the end of secondary schooling and large-scale *national* assessment at Grades 4 and 8. Each Länder is still heavily responsible for defining education for schools operating under its remit and this leads to an unusual mix of both central and regional influence on the governance of systems and structures that define the curriculum. This continues into the tertiary sector and vocational training proper with a large number of stakeholders at national and regional levels having input into the specification of courses for apprentices.

Mathematics education in Germany, redesigned following the PISA shock emphasises goals that focus on "mathematics as a *theory* and as a *tool for solving problems* in natural and social sciences, including modelling", experiencing fundamental ideas in mathematics such as generalization and proof, reasoning, argumentation and representation in all fields of mathematics and gaining an understanding of the historical aspects of mathematics. (http://www.history.didaktik.mathematik.uni-wuerzburg.de/meg/weidiga2.html). These ideas of course are all underpinned by developing mathematical content knowledge which is in many ways equivalent to that associated with revised GCSEs in England.

[19] http://www.gtai.de/GTAI/Content/EN/Invest/_SharedDocs/Downloads/GTAI/BLG/blg--most-wanted--dual-vocational-training-in-germany-pdf.pdf?v=4

[20] OECD (2011). OECD reviews of vocational education and training. Paris: OECD Publishing. (p.33).

[21] https://www.bibb.de/en/40.php

Given the complexity of possible routes in Secondary education in Germany and the desire for flexibility of movement from vocational to academic routes at the Secondary Tertiary transition point, and of course due to the national testing at the end of secondary education, a general mathematics course is available until that point which complies with national specifications. Following this in the apprenticeship 'dual system' Straesser (2014) reports that there is an increasing tendency in vocational education for mathematics to 'disappear' due to it increasingly being integrated into vocational knowledge leading to a lack of mathematics as a subject in vocational schools.[22]

What is the content and level of mathematics in STEM technical education for 16-19 year olds and how does this differ across STEM sectors and pathways?

In the apprenticeship 'dual system' students develop their ability to apply mathematics already known to them but now within their chosen vocational context (this will include some 'new' mathematics specific to the vocational area if appropriate). Students do not follow 'resit' courses relating to 'school' qualifications.

Within vocational pathways there are concerns (Sträßer, 2014)[23] that mathematics is becoming less visible due to being integrated into vocational knowledge rather than taught as a separate subject. This suggests a danger in the integrated approach when this is a replacement for mathematics subject teaching rather than being an addition to support mathematical development (and promote a more integrated view of the subject).

Figure 2 below shows the curriculum in Baden Wuttenburg vocational schools. It is worth noting the lack of a compulsory mathematics element (in comparison to the 'general' subjects of German, Social Studies, job-related English and RE. The 'disappearing' mathematics issue is also picked up to some extent in the OECD's summary document which recommends that Germany should…"place greater priority on general education and broad academic skill development in the part-time vocational schools."[24]

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[22] Straesser, R. (2014). History of teaching vocational mathematics. In A. Karp & G. Schubring (Eds.), Handbook on the history of mathematics education (pp. 515–524). New York: Springer. doi:10.1007/978-1-4614-9155-2_ 25.
[23] Op cit.
[24] OECD (2011). *OECD reviews of vocational education and training*. Paris: OECD Publishing. (p.34).

CURRICULUM WITH INDIVIDUAL SUBJECTS OR VOCATIONAL COMPETENCIES*

Vocational School	Technical vocational school	Economic vocational school	Vocational school for home economics, nursing, social pedagogics	Agricultural vocational school
General subjects 4 lessons/week	• German • Social Studies • job-related English (gradual implementation) • Religious Education			
Job-related subjects 8 hours/week	**Economics or Economic Competence e.g. mechatronic with focus on** • component manufacture • analysis of information flow in complex mechatronic systems • start-up, trouble-shooting, and maintenance and repair	**e.g. industrial clerk with focus on** • business administration • monitoring and controlling • macroeconomics • data processing • project competence	**Economics e.g. professional housekeeper** job-related topics such as • dietetics and food science • hygiene • production tools • customer service • related maths • related drawing • practical job-related skills	**Economics e.g. farmer** job-related topics such as • food production • livestock breeding • agricultural machinery • business administration • related maths • practical job-related skills
Compulsory elective subjects 1 hour/week				
special courses	e.g. German, Technical Mathematics			
supplementary courses	e.g. special job-related topics, additional qualifications (for example, the Advanced Certificate of Vocational Education can be acquired at various vocational schools by students with a GCSE), or general subjects such as foreign languages			

* For new and restructured professions the curriculum is divided into learning competencies instead of individual subjects.

Figure 2: Overview of the VET curriculum in Baden Wuttenburg[25]

How is the mathematics provision delivered?

Delivery varies between VET routes. The 'closer' the VET pathway is to a university pathway, the more likely there is to be a separate – and more academically oriented - course in mathematics. Such a mathematics course is likely to involve somewhere between 0-6 hours weekly depending on vocation and level. In addition, mathematics may be embedded in vocational aspects of the course and will be taught if and when necessary as part of vocational competence. Teachers have the freedom to decide what mathematics is taught and how to embed this into the vocational programme of learning. There is in general no separate assessment of this mathematics but it is integrated into vocational assessment as an element present within the relevant work processes.

There are some specialist mathematics teachers in vocational education but these are a small minority. At the apprenticeship level, the teaching of mathematics is typically carried out by vocational specialists

[25] http://www.km-bw.de/site/pbs-bw/get/documents/KULTUS.Dachmandant/KULTUS/kultusportal-bw/zzz_pdf/Vocational%20school%20-%20online%20Version.pdf

leading to much variability in practice that is heavily influenced by how the vocational specialist was taught.

Teachers in VET have a vocational teaching qualification incorporating training in two specialist areas. However, although maths is one of the specialisms available, few teachers pursue maths as a specialist area in their training.

MATHEMATICS AND VOCATIONAL EDUCATION IN KOREA

Introduction

Korea's education system is widely recognised as highly successful due to its high-performing students and skilled workforce[26]. The system for older students (post-15) focuses on school-based academic or vocational education rather than dual-track or apprenticeship programmes and therefore has a contrasting approach to European countries such as Switzerland and Germany. In upper secondary education mathematics is compulsory for the first year but the options followed by academic and vocational students are not necessarily the same.

Mathematics / numeracy performance in international surveys

PISA 2015 (age 15)[27]	524
TIMSS 2015 Grade 8[28]	606
PIAAC Survey of Adult Skills 2013: Numeracy ages 16-24 (Ave Numeracy ages 16-65)[29]	281 (263)

Background

Education is compulsory to age 15 years in Korea. Students attend a Lower Secondary School until this age and then may continue into upper secondary education, where they would normally follow a three-year programme in a High School. Participation in post-compulsory education is high with 98% of the student cohort completing upper secondary education[30]. An overview of the education system is shown below[31].

[26] http://www.ncee.org/programs-affiliates/center-on-international-education-benchmarking/top-performing-countries/south-korea-overview/
27 OECD. (2016). *PISA 2015 Results (Volume I): Excellence and Equity in Education*. Paris: OECD Publishing. DOI: http://dx.doi.org/10.1787/9789264266490-en
[28] Mullis, I. V. S., Martin, M. O., Foy, P., & Hooper, M. (2016). *TIMSS 2015 International Results in Mathematics*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College / International Association for the Evaluation of Educational Achievement (IEA).
29 OECD. (2016). *Skills Matter: Further Results from the Survey of Adult Skills*. Paris: OECD Publishing; Additional tables: dx.doi.org/10.1787/888933366463
[30] http://www.ncee.org/programs-affiliates/center-on-international-education-benchmarking/top-performing-countries/south-korea-overview/
[31] http://www.ncee.org/programs-affiliates/center-on-international-education-benchmarking/top-performing-countries/south-korea-overview/

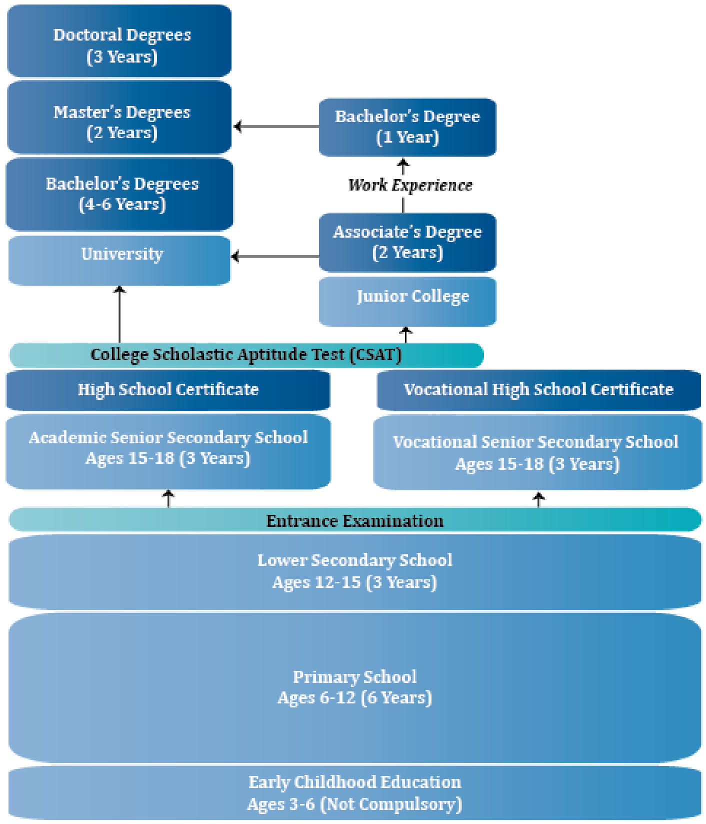

Figure 1: The structure of the education system in Korea
Reproduced with permission from The National Center on Education and the Economy

This system has been developed from a position in which access to education was very limited until the end of Japanese occupation in 1945 and there was wide-scale illiteracy. Extensive re-construction and development by the Ministry of Education has resulted in a system considered to be particularly successful since Korea has now become one of the highest-performing countries in international comparisons[32]. Education is highly valued in Korea and students have high aspirations but the system is considered to be highly test-driven and intensive[33].

In upper secondary education there are two main options available to students, each offered by a different type of school. These are referred to as:[34]

- Academic Senior Secondary School (*or* General High School);
- Vocational Senior Secondary School (*or* Vocational High School).

Entry into the two pathways is determined by performance in the Entrance Examination, which is taken at the end of lower secondary education.

32 http://www.oecd.org/korea/SBS%20Korea.pdf

33 http://monitor.icef.com/2014/01/high-performance-high-pressure-in-south-koreas-education-system/

34 http://eng.krivet.re.kr/eu/ec/prg_euCDAVw.jsp?gn=M06-M060000056

Vocational education is conducted in a similar way to formal education and is generally interpreted fairly broadly as a range of educational activities that improve job skills or vocational abilities.[35] The vocational pathway is often perceived as having an academic orientation[36] and vocational high schools are required to provide an advanced general education in addition to vocational subjects. Graduates from Vocational High Schools may choose to enter employment or progress to further study.

In Korea there is no formal apprenticeship programme with all vocational education having a school-based approach. From 2008, a number of Vocational High Schools were designated as Meister High Schools. These schools are more closely aligned to the needs of specific industries and focus on developing professional knowledge and technical skills in preparation for the workplace. The option of progression to further study is not available for students from this pathway.

The pathways available for students in upper secondary education are summarized in Table 1[37].

Type of education	Organisation	Normal course length	Qualification	Progression
Academic	General High School	3yrs	High School Certificate	University or other HE institution
Vocational	Specialised Vocational High School	3yrs	Vocational High School Certificate	Employment or college or other HE institution
	Meister High School	3yrs	Vocational High School Certificate	Employment

Table 1: Academic and vocational pathways in upper secondary education

Data in Table 2 show how the academic pathway is dominant. For example in 2008, 75.5% of 15 year olds entered General High Schools and 23.5% entered Vocational High Schools[38]. Over time there has been a downward trend in the number of entrants to Vocational High School, from about half of the cohort in 1995 to less than a quarter in 2012, as shown in the table below[39].

Type of education	2000	2005	2010	2012
Percentage of student cohort in Vocational High School	36.1	28.5	23.8	22.1

Table 2: Proportion of student cohort on vocational pathway in upper secondary education

[35] http://eng.krivet.re.kr/eu/ec/prg_euCDAVw.jsp?gn=M06-M060000056

[36] http://www.oecd.org/korea/SBS%20Korea.pdf

[37] http://english.moe.go.kr/web/1691/site/contents/en/en_0203.jsp

[38] http://www.oecd.org/korea/SBS%20Korea.pdf

[39] http://eng.krivet.re.kr/eu/ec/prg_euCDAVw.jsp?gn=M06-M060000056

A change of name from Vocational High School to 'Professional High School' in 2007 and the opening up of opportunities for vocational students to progress to Higher Education are part of a government strategy to increase interest in the vocational pathway. Graduates from vocational high schools may enter employment directly or progress on to college courses. Progression of vocational high school graduates to college from the vocational pathway has increased from a rate of 22% in 1990 to 71.1% in 2010.

In 2009, 85% of graduates from General High Schools continued into post-secondary education and 74% from Vocational High Schools. The number of students graduating from different vocational areas is show in Table 3 below.[40]

Vocational Area	Number of students	Percentage
Liberal Arts	20,404	14.3
Social Science	28,401	19.9
Education	459	0.3
Engineering	65,516	45.9
Natural Science	8,938	6.2
Medicine	2,108	1.5
Arts: Sports	15,845	11.1
Special classes	1,108	0.8
TOTAL	142,779	100

Table 3: Students graduating from different vocational areas in 2009

For those on the vocational pathway, progression would normally be to a Junior College (sometimes referred to as a Vocational College) or the country's Polytechnic, which only offers courses within a limited number of vocational areas such as electronics, mechanical engineering and telecommunications. Most Junior Colleges are private and receive only small amounts of government funding whilst the Polytechnic is a public institution with 23 campuses nationwide[41].

The purpose of vocational colleges and the polytechnic is to produce technicians or middle-grade technical experts.[42] Both junior college courses and 2-year polytechnic courses lead to an Industrial Associate degree[43]. The polytechnic also offers 1-year courses, for those with work experience or a

[40] http://eng.krivet.re.kr/eu/ec/prg_euCDAVw.jsp?gn=M06-M060000056

[41] http://www.oecd.org/korea/SBS%20Korea.pdf

[42] http://eng.krivet.re.kr/eu/ec/prg_euCDAVw.jsp?gn=M06-M060000056

[43] http://www.oecd.org/korea/42689417.pdf

technical certificate, to become craftsmen and master craftsmen[44]. The numbers of post-secondary institutions and entry data for 2014 are shown in the following table[45]. It should be noted, however, that students may enter university after taking an Associate degree in a junior college as well as moving directly from an Academic High School.

2014	Number of institutions	Number of entrants	Percentage of total entrants
Vocational College	139	221,750	33.7
University	189	363,655	55.3
Polytechnic	1	14,344	2.2
Open University	1	57,700	8.8
TOTAL	330	657,449	100

Table 4: Entrants to academic and vocational institutions in 2014

What is the content and level of mathematics in STEM technical education for 16-19 year olds and how does this differ across STEM sectors and pathways?

There are a number of mathematics courses offered to students in upper secondary:

- Basic Mathematics
- General Mathematics (Mathematics I and II, Probability and Statistics, Calculus 1 and 2, Geometry and Vectors)
- Advanced Mathematics (Advanced Mathematics I and II)

Mathematics is a compulsory subject for students on both academic and vocational pathways during the first year of upper secondary education but it then becomes optional. Most students in vocational schools would follow a course in Basic Mathematics in their first year whilst students from general schools would normally take modules from the General Mathematics course. The Advanced course is normally taken by science school students and not by general school students.

Students in vocational education generally spend less time on mathematics than those in the academic pathway - 4 and 5 hours per week, respectively [46]. This means that students on different vocational courses will have a similar foundation in mathematics from their first year of upper secondary education but there will be variations afterwards in the content and quantity of mathematics studied. Typically

[44] http://eng.krivet.re.kr/eu/ec/prg_euCDAVw.jsp?gn=M06-M060000056

[45] http://eng.krivet.re.kr/eu/ec/prg_euCDAVw.jsp?gn=M06-M060000056

[46] http://www.oecd.org/korea/42689417.pdf

students on vocational courses spend more time on their vocational subjects and less on core subjects at this stage[47].

Variation in participation, in both in the quantity and type of mathematics studied, between academic and vocational students generally becomes wider in the second year and third years of upper secondary education since the subject is then optional. Participation in mathematics in second and third years also varies between different vocational pathways since this is dependent on the mathematical demands and priorities of occupations in the vocational area.

How is the mathematics provision delivered?

Within the Academic and Vocational High Schools mathematics is a core subject with a defined curriculum. High school teachers in each pathway teach the subject and, although there are seen to be weaknesses in the industrial experience of vocational teachers, their mathematical ability is very high and their general training is considered to be strong. Entry to training for teaching is highly competitive and all teachers in public schools have to undertake a university-level training programme plus a subject-specific Teacher Employment Test before entering the profession[48].

[47] http://www.oecd.org/korea/42689417.pdf

[48]http://c.ymcdn.com/sites/www.amatyc.org/resource/resmgr/educator_feb_2013/sami2013februarymae.pdf

MATHEMATICS AND VOCATIONAL EDUCATION IN SINGAPORE

Introduction

The education system in Singapore is acknowledged internationally as being highly successful with students showing strong performance in mathematics[49]. Singapore also values vocational and technical skills. Since the 1990s the government has focused on developing a strong vocational education system to serve the needs of a knowledge-based economy[50].

Mathematics / numeracy performance in international surveys

PISA 2015 (age 15) [51]	564
TIMSS 2015 Grade 8[52]	621
PIAAC Survey of adult skills 2013[53]**:** **Numeracy ages 16-24** **(Ave numeracy ages 16-65)**	287[54] (257)

Background

Education is compulsory to the end of Primary 6 (normally age 12 years)[55] in Singapore but the majority of students continue in school through the secondary phase and move to 'post-secondary' education at age 16 years. The phases referred to as 'secondary' and 'post-secondary' in Singapore may be therefore considered as broadly equivalent to the lower and upper secondary stages in other countries. An overview of the education system is shown below[56].

49 http://www.oecd.org/countries/singapore/46581101.pdf

50 http://www.ncee.org/programs-affiliates/center-on-international-education-benchmarking/top-performing-countries/singapore-overview/singapore-school-to-work-transition/

51 OECD. (2016). *PISA 2015 Results (Volume I): Excellence and Equity in Education*. Paris: OECD Publishing. DOI: http://dx.doi.org/10.1787/9789264266490-en

52 Mullis, I. V. S., Martin, M. O., Foy, P., & Hooper, M. (2016). *TIMSS 2015 International Results in Mathematics*. CHestnut Hill, MA: TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College / International Association for the Evaluation of Educational Achievement (IEA).

53 Singapore carried out PIAAC survey in 2014/5.

54 Singapore carried out PIAAC survey in 2014/5.

55 http://www.moe.gov.sg/initiatives/compulsory-education/

56 http://www.moe.gov.sg/education/landscape/print/sg-education-landscape-print.pdf

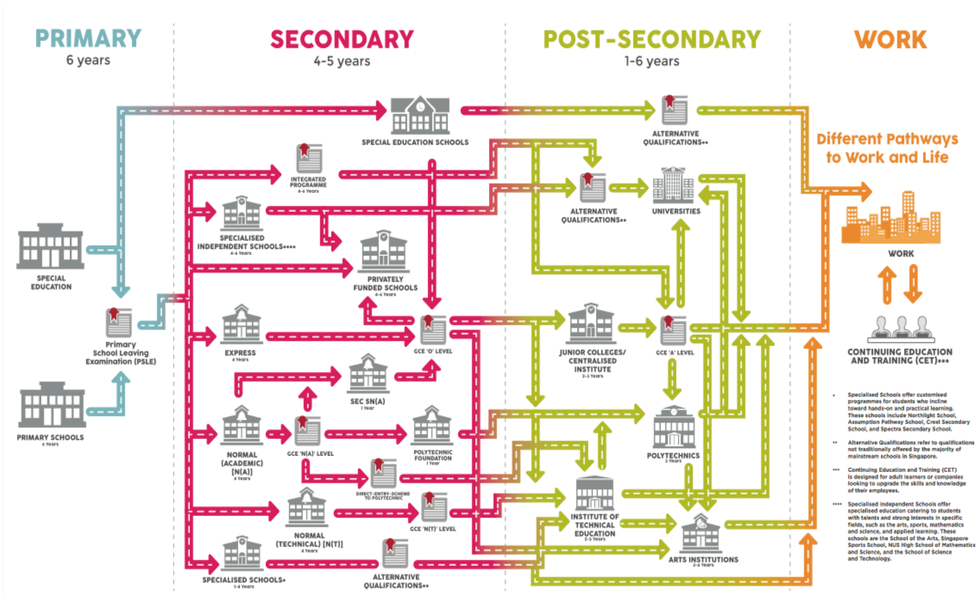

Figure 1: The education system in Singapore
© Ministry of Education, Government of Singapore

There are four main options available to students in 'post-secondary' education, each offered by a different type of organisation:

- Junior Colleges
- Centralised Institute
- Polytechnics
- Institute of Technical Education.

In addition there are two specialist institutions providing courses in the creative arts: the Nanyang Academy of Fine Arts (NAFA) and the LASALLE College of the Arts (LaSalle). There are also a number of schools where an 'integrated programme' is offered that combines the secondary and 'post-secondary' phases, leading to an A-level qualification. Students following this integrated route progress directly to Junior College education without taking O-level examinations at age 16/17 years.

Entry into the different 'post-secondary' options is determined by performance in secondary education. The different 'post-secondary' organisations offer courses that lead to different qualifications and focus on preparing students either for further study, or for progression into employment, as shown in Table 1[57]. The system does, however, make it possible for students to move between pathways.

57 http://www.moe.gov.sg/education/post-secondary/files/post-secondary-brochure.pdf

Type of education	Organisation	Normal course length	Qualification	Main focus
Academic	Junior College	2 years	GCE A levels	Preparation for university or other HE course
	Centralised Institute	3 years	GCE A levels	Preparation for university or other HE course
Vocational	*Polytechnic	3 years	Diploma	Preparation for employment or HE
	Institute of Technical Education	1-3 years	Higher National ITE Certificate (*Higher Nitec*) or National ITE Certificate (*Nitec*)	Preparation for employment or a polytechnic course

*Polytechnics provide a wide range of vocational education leading to the Diploma but also offer some academic courses.

Table 1: Academic and vocational pathways in Singapore

There are five polytechnics in Singapore, currently offering 234 programmes[58], with an emphasis on the areas of Engineering, Games Design, Business and Science[59]. This reflects a focus on STEM subjects that is present across the Singapore education system. The majority of students who study in polytechnics then move into employment, although some progress into higher education. Employment opportunities are readily available and 90% of polytechnic graduates in 2013 found employment within 6 months.

The numbers of students enrolling on polytechnic programmes in the different subject areas offered is shown in Table 2[60] alongside the number of graduates in the same year (2013). These figures indicate the dominance of the Engineering Sciences, followed by Business and Administration, Information Technology and Health Sciences. The overall profile is consistent with the focus on STEM subjects in the Singapore education system, showing that STEM-related subjects account for approximately 63% of the total student intake (16880). Please note that the figures in the table are for a particular year: hence the number of graduates may be greater than the intake, as in the case of Health Sciences.

58 http://www.polytechnic.edu.sg/introduction/available-courses

59 http://www.moe.gov.sg/education/post-secondary/files/post-secondary-brochure.pdf

60 http://www.moe.gov.sg/education/education-statistics-digest/files/esd-2014.pdf

Vocational Area	Intake	Graduates
Applied Arts	2097	1746
Architecture and Building	796	630
Business and Administration	6267	5400
Education	323	262
Engineering Sciences	7655	7016
Health Sciences	2410	2454
Humanities and Social Sciences	756	627
Information Technology	3756	3523
Legal Studies	140	132
Mass Communication and Information Science	661	638
Science and Related Technologies	1602	1469
Services	416	260
TOTAL	26879	24157

Table 2: Polytechnic entrants and graduates by vocational area in 2013

The Institute of Technical Education (ITE) offers two modes of study: a full-time course or a traineeship. There are 103 full-time courses plus a range of 30 traineeship courses[61]. The full-time courses are offered at two different levels (*Higher Nitec* and *Nitec*) with around 45 courses at the *Higher Nitec* level and 58 at the *Nitec* level. Students who successfully complete a *Higher Nitec* or *Nitec* course in ITE may then move on to take a Diploma course at a polytechnic. The main vocational areas and numbers of students entering or graduating in 2013 are shown in Table 3 below.[62] These figures show a similar pattern to the numbers of new enrolments and graduates in the polytechnics, with the largest numbers of students in the areas of Engineering, Business, and Electronics and Information-Communication Technology. The table also indicates that STEM subjects account for approximately 64% of the total intake of vocational students (on Nitec or Higher Nitec courses) in the Institute of Technical Education (9165 students).

Vocational area	Intake	Graduates
Applied and Health Sciences	1219	1058
Business and Services	3916	3387
Design and Media	811	471
Engineering	4413	3420
Electronics and Information-Communication Technology	3533	3085
Hospitality	540	467
TOTAL	14432	11888

Table 3: Institute of Technical Education entrants and graduates by vocational area in 2013

61 https://www.ite.edu.sg/wps/portal/fts

62 http://www.moe.gov.sg/education/education-statistics-digest/files/esd-2014.pdf

The Institute of Technical Education (ITE) was established in 1992 under the Ministry of Education to develop national occupational skills certification and standards. The aims were to enhance Singapore's workforce competitiveness[63] and improve the image of vocational education that existed at the time of being a last resort for low achievers[64]. Three ITE campuses with state of the art equipment were developed and enrolments in vocational education increased significantly, now almost doubling the numbers there were in 1995.

The percentages of each cohort admitted into the three main pathways in 'post-secondary' education are as follows[65].

Pathway	2008	2009	2010	2011	2012	2013
Junior College or Centralised Institute	28.0	27.6	27.5	27.0	27.7	28.2
Institute of Technical Education	20.9	21.1	20.9	21.3	21.2	22.8
Polytechnics	43.0	44.7	45.8	46.5	47.1	46.4

Table 4: Proportions of the cohort entering the three main 'post-secondary' pathways

The overall number of students (any age) enrolled in the three main types of educational organisation in 2013 confirms the dominance of the polytechnics[66] in 'post-secondary' education.

Enrolments	Junior Colleges and Centralised Institute	Polytechnics	Institute of Technical Education
2013	32165	79970	26288

Table 5: Enrolments on the three main 'post-secondary' pathways in 2013

Recently there have been renewed efforts to further strengthen vocational education following a review of ITE and polytechnics by the ASPIRE[67] committee. A series of recommendations, published in August 2014, are being implemented, including: improving career guidance systems, developing clear skills

[63] https://www.ite.edu.sg/wps/portal/iteglobal
[64] http://www.ncee.org/programs-affiliates/center-on-international-education-benchmarking/top-performing-countries/singapore-overview/singapore-school-to-work-transition/
[65] http://www.moe.gov.sg/education/education-statistics-digest/files/esd-2014.pdf
[66] http://www.moe.gov.sg/education/education-statistics-digest/files/esd-2014.pdf
[67] http://www.moe.gov.sg/aspire/aspire-report-online/

frameworks and pathways of progression, strengthening workplace partnerships and expanding apprenticeship opportunities.[68]

What is the content and level of mathematics in STEM technical education for 16-19 year olds and how does this differ across STEM sectors and pathways?

Entry to vocational courses in ITE or a polytechnic depends on performance in secondary education but entry requirements can vary from course to course[69]. Students may therefore enter vocational education with different levels of attainment in mathematics.

The mathematics curriculum within academic secondary education leads towards taking the Singapore-Cambridge GCE O level qualification at age 16/17 years. Students may follow a 4 year Express Course directly to O level, or take a Normal Academic [N(A)] programme for 4 years and study a range of academic subjects before taking an additional year to prepare for the Singapore-Cambridge GCE O level examinations. Alternatively, students may follow a Normal Technical programme [N(T)] for 4 years that includes mathematics, English, Mother Tongue, Computer Applications and some technical options[70]. The mathematics curriculum was extensively reviewed in 2010[71] and in secondary education new mathematics curricula are now being gradually introduced over the period 2013 to 2016 for all levels. The aims and content of these curricula are not identical but do share some common features. The O and N(A) syllabi, however, focus on the needs of students who have an aptitude and interest in mathematics[72] whilst the N(T) syllabus is aimed at preparing students for 'post-secondary' education and their future lives by developing the skills and confidence to use mathematics in problem-solving and decision-making.[73]. Students may, therefore, enter vocational pathways in 'post-secondary' education with different mathematical backgrounds due to following different curricula in the secondary phase.

ITE vocational courses include core modules, specialization modules, life skills modules and elective modules. Mathematics is not a compulsory subject and there are variations in the mathematical content taught within different vocational education courses. The national mathematics curriculum, however, is designed so that students acquire sufficient mathematical and problem-solving skills before entering 'post-secondary' education. A strong foundation from secondary education in academic subjects such as mathematics, which is evidenced by performance in international comparisons such as TIMSS[74] and PISA[75], contributes to perceptions that ITE graduates are highly skilled[76]. Polytechnic Diploma courses may involve vocationally related mathematics and the level and content of this also varies. For example,

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[68] http://www.ncee.org/programs-affiliates/center-on-international-education-benchmarking/top-performing-countries/singapore-overview/singapore-school-to-work-transition/

[69] http://www.moe.gov.sg/education/post-secondary/files/post-secondary-brochure.pdf

[70] http://www.moe.gov.sg/education/secondary/normal/

[71] http://www.moe.gov.sg/education/syllabuses/sciences/

[72] http://www.moe.gov.sg/education/syllabuses/sciences/files/ordinary-and-normal-academic-level-maths-2013.pdf

[73] http://www.moe.gov.sg/education/syllabuses/sciences/files/normal-technical-level-maths-2013.pdf

[74] https://nces.ed.gov/TIMSS/table11_2.asp

[75] http://oecd.org/pisa/keyfindings/pisa-2012-results-overview.pdf

[76] http://www.ncee.org/programs-affiliates/center-on-international-education-benchmarking/top-performing-countries/singapore-overview/singapore-school-to-work-transition/

for the Diploma in Architecture there are no specific mathematics modules but the Diploma in Chemical Engineering includes a range of mathematics modules and the Diploma in Civil Engineering with Business specifies compulsory modules in basic mathematics and engineering mathematics, with an elective module in higher mathematics[77].

Within ITE vocational courses students are expected to achieve a satisfactory level in basic mathematics and acquire any specific mathematical skills required for vocational competence, which varies between vocational areas. The mathematical content within vocational Diploma courses also varies, since there are no generic mathematics modules or any shared mathematics curriculum. There are indications from the outline course content that Engineering Diploma courses, for example, involve a more significant quantity of mathematics than some other STEM programmes[78]. The exact quantity of mathematics within modules and the level of participation with mathematics overall remains unclear without a more detailed examination of each course and syllabus. However, the numbers of students following STEM courses in both ITE and the polytechnics, are substantial, forming approximately 64% and 63% of the totals respectively and this suggests that participation in mathematics overall during 'post-secondary' education may be high, although this will still vary between different vocational courses.

How is the mathematics provision delivered?

Modules within vocational courses are assessed separately, using in-module assignments and end-of module summative assessments with an overall pass mark for the module of 50%. Any specific mathematics modules within a vocational course are subject to the same assessment process. However, vocationally specific mathematics may also form part of module that is not entirely devoted to mathematics. Teachers from the vocational team would normally carry out the teaching of all the modules within a course, including the mathematical content using an integrated approach so that students understand the applications of mathematics in other subjects within their course.

[77] http://www.sp.edu.sg/wps/portal/vp-spws/schcls
[78] http://www.sp.edu.sg/wps/portal/vp-spws/schcls

MATHEMATICS AND VOCATIONAL EDUCATION IN SWITZERLAND

Introduction

Swiss vocational education is recognised internationally as a well-developed and successful system using the 'dual track' (apprenticeship) approach.[79] The system is strongly linked to the needs of the economy and youth unemployment is low.

Mathematics / numeracy performance in international surveys

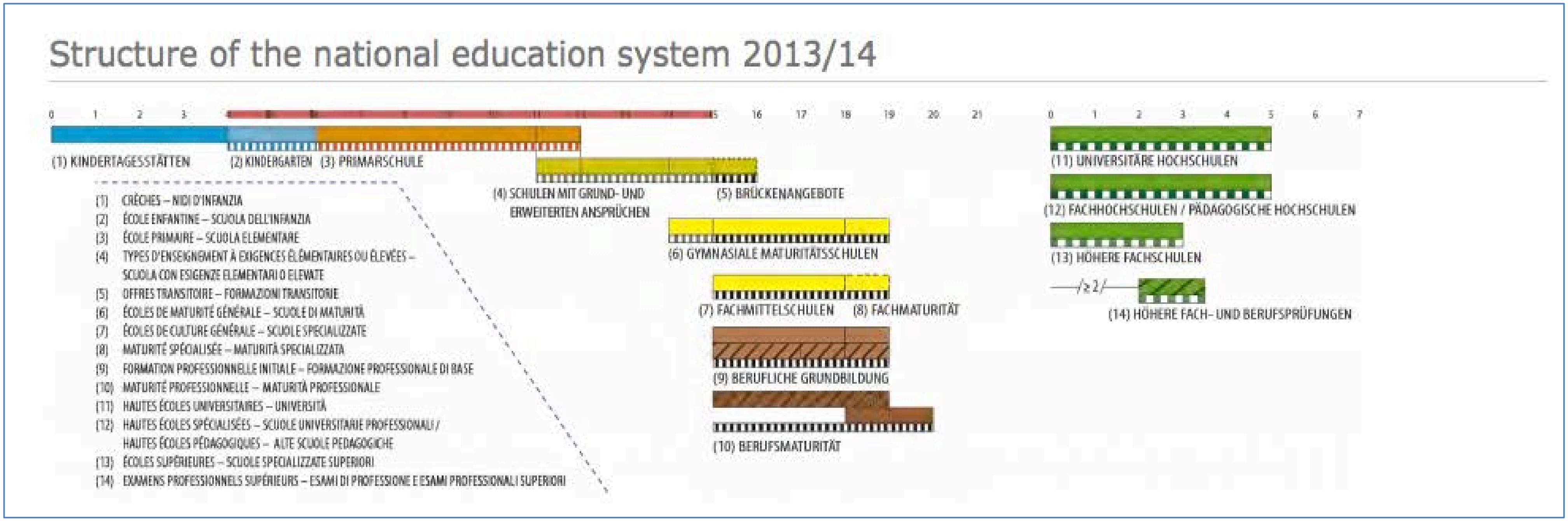
PISA 2015 (age 15)[80]	521
TIMSS 2015 Grade 8[81]	N/A
PIAAC Survey of Adult Skills 2015[82]	N/A

Background

Education is compulsory to age 16 in Switzerland and students may then choose to enter upper secondary education. Nearly 95% of young people hold upper secondary level qualifications.[83] The options available are summarized in Figure 1 below.

[79] Hoffman, N., & Schwartz, R. (2015). *Gold Standard: The Swiss Vocational Education and Training System*. Washington, DC: National Center on Education and the Economy.
80 OECD. (2016). *PISA 2015 Results (Volume I): Excellence and Equity in Education*. Paris: OECD Publishing. DOI: http://dx.doi.org/10.1787/9789264266490-en
[81] Switzerland did not take part in the IEA's TIMSS survey in 2015.
[82] Switzerland did not take part in the OECD's PIAAC skills survey.
[83] http://www.sbfi.admin.ch/berufsbildung/index.html?lang=en

Figure 1: The educational system in Switzerland.
Source: https://webgate.ec.europa.eu/fpfis/mwikis/eurydice/index.php/Switzerland:Overview



There are two main options available to students in upper secondary education[84]:

- General education at a Baccalaureate school or upper secondary specialized school;
- Vocational education (VET) on a 'dual-track' or school-based programme.

Alternatively, some students not yet ready for upper secondary education take a transitional course to prepare for this. Notably the vocational education route attracts most of the annual cohort of students.

The progression of students from their final year of lower secondary education is distributed between these routes as shown in Table 1[85].

	2008	2009	2010	2011	2012
VET	47.8%	47.3%	47.6%	47.5%	45.8%
General education	25.9%	26.3%	26.4%	26.2%	26.5%
Transitional options	14.2%	14.0%	13.8%	13.4%	12.8%
Number in final year of lower-secondary	88,200	85,600	84,500	85,900	84,100

Table 1: Proportions of the cohort entering different routes. Source: Federal Statistical Office (2014)

The Swiss 'dual-track' VET system combines school-based and work-based learning. Students have an apprenticeship with a training company for three or four days a week and attend a vocational school for one or two days a week. An alternative, but less common approach, is to take a VET programme that is entirely school-based, provided usually by a special trade school or commercial school[86]. The majority of the VET students follow the dual-track system.[87] In total, after transitional arrangements and other 'gap' options (such as studying abroad), about two-thirds of each new student cohort that actually enter upper secondary education enroll on VET programmes.[88] Table 2 below shows the distribution between these two approaches for the new student cohorts entering upper secondary education. Note that since some students leave lower secondary and do not immediately enter upper secondary, the cohort sizes do not directly match.

[84] http://www.sbfi.admin.ch/berufsbildung/index.html?lang=en

[85] http://www.sbfi.admin.ch/berufsbildung/index.html?lang=en

[86] https;//swisseducation.educa.ch/en/vocational-education-and-training-0

[87] http://www.sbfi.admin.ch/berufsbildung/index.html?lang=en

[88] State Secretariat for Education, Research and Innovation (SERI) (2016). *Vocational and Professional Education and Training in Switzerland: Facts and figures2016*. Bern: SERI. https://www.sbfi.admin.ch/dam/sbfi/en/dokumente/berufsbildung_inderschweiz-faktenundzahlen2016.pdf.download.pdf/vocational_and_professionaleducationandtraininginswitzerland-fac.pdf

	2008		2009		2010		2011		2012	
Dual-track VET	68,446	89.4%	68,289	89.9%	68,741	89.8%	67,733	90.7%	69,033	89.8%
School-based VET	8,089	10.6%	7,643	10.1%	7,784	10.1%	6,917	9.3%	7,864	10.2%
TOTAL VET	76,535	100%	75,932	100%	76,525	100%	74,650	100%	76,897	100%

Table 2: Students in dual-track and school-based VET routes. Source: Federal Statistical Office (2014)

The Swiss VET system at upper secondary provides students with the skills for a specific occupation but also prepares them for professional education and training (PET) at tertiary level. The curriculum combines qualifications that equip students to carry out an occupational activity with a basic general education and knowledge of social, cultural, economic and environmental issues[89]. The learning content is determined by the ordinances for each VET profession and specific training plans, which provide details of the skills and knowledge required, the number of lessons, the inter-company courses to be attended and the qualification procedures[90]. The general education subjects, such as mathematics, are regulated by the Confederation through the State Secretariat for Education, Research and Innovation (SERI) and by a core curriculum for general education within VET.

There are three main types of qualification that may be achieved in upper secondary vocational education, as shown in the table below[91].

Qualification	Length of course	Purpose/Progression
Federal VET Diploma	3-4 years	Provides the skills for a specific occupation or for progression to PET college courses.
Federal VET Certificate	2 years	Provides the skills for a specific occupation or for the foundation for progression to a VET Diploma course.
Federal Vocational Baccalaureate (FVB)	This is completed in combination with the Federal VET Diploma, either as a 1 year full-time or a 1.5-2 year part-time course.	The combination prepares students for entry to Universities of Applied Sciences or cantonal universities or a Federal Institute of Technology.

Table 3: Main qualifications available in upper secondary VET

[89]https://webgate.ec.europa.eu/fpfis/mwikis/eurydice/index.php/Switzerland:Organisation_of_Vocational_Upper_Secondary_Education
[90] https;//swisseducation.educa.ch/en/vet-learning-objectives-curriculum-and-assessment
[91] http://www.sbfi.admin.ch/berufsbildung/index.html?lang=en

Students who achieve the Federal Vocational Baccalaureate (FVB) may progress to Swiss Universities of Applied Sciences (UAS) or, if they also pass the University Aptitude Test (UAT), may enroll at a cantonal university or one of the two Swiss Federal Institutes of Technology (FIT). Approximately 14% of VET graduates (13.7% in 2012) achieve the Federal Vocational Baccalaureate (FVB) and of these, over 55% enroll on to a UAS degree programme within two years.[92]

Post-compulsory education is the joint responsibility of the cantons and the Confederation[93]. VET programmes are closely matched to the needs of the labour market and youth unemployment is one of the lowest in Europe. There are VET programmes for about 230 different occupations, with the 10 highest number of enrolments in 2013 coming from the following areas[94].

Occupation	**Enrolments**
Commercial employee	14,367
Retail clerk	5,453
Health care worker	3,802
Social care worker	2,914
Electrician	2,178
Cook	1,844
Mechanical engineer	1,654
Draughtsman	1,643
Retail assistant	1,643
Logistician	1,574

Table 4: Enrolments to the 10 most popular VET occupational programmes in 2013

In 2013 the 20 most popular occupations accounted for over 60% of all newly signed apprenticeship contracts. Several STEM-related occupations within the Engineering and Construction areas feature in this list, although commercial work dominates the apprenticeship programme.[95]

What is the content and level of mathematics in STEM technical education for 16-19 year olds and how does this differ across STEM sectors and pathways?

Entry to upper secondary education, including VET, is dependent on successful completion of lower secondary education. Entry to an apprenticeship is by a process of selection determined by the training company and this may involve an assessment of the students' performance in lower-secondary education or an aptitude test. Within lower secondary education there is a core curriculum that includes mathematics (RLP) and this extends into upper secondary education. In vocational education mathematics is part of the general education with each course rather than a separate subject.

[92] http://www.sbfi.admin.ch/berufsbildung/index.html?lang=en

[93] https://webgate.ec.europa.eu/fpfis/mwikis/eurydice/index.php/Switzerland:Overview

[94] http://www.sbfi.admin.ch/berufsbildung/index.html?lang=en

[95] http://www.sbfi.admin.ch/berufsbildung/index.html?lang=en

There are variations in the mathematics taken on different vocational courses, which is intended, since the Swiss approach is to strongly link the course content to the VET ordinances for each profession. Vocational courses in upper secondary education lead to the Federal VET Certificate, the Federal VET Diploma or the Federal Vocational Baccalaureate (FVB) and the mathematics requirements for each of these are different.

The Swiss system performs relatively well in the PISA mathematics. However, comparatively lower levels of competence with mathematics occur most frequently amongst those who take a transitional option but are more frequent in VET than in upper secondary general education.[96] The OECD identify numeracy skills as a weakness in both VET and PET and argue that the high proportion of time spent on practical education in VET as a possible cause (although at the same time, they argue that this emphasis is also a strength of the Swiss system).[97]

How is the mathematics provision delivered?

The focus on practical skills and strong orientation towards the labour market in the Swiss VET system may allow limited time for direct teaching of general academic subjects but mathematics is an important part of the curriculum. Practical training takes up more than half the total instructional time[98] and apprentices typically spend one day a week at the vocational school so students develop mathematics skills in the context of other training rather than taking mathematics as a separate subject.

A similar situation exists after progression from VET into the PET system. There is recognition that numeracy is of increasing importance in professional occupations and that any lack of focus on developing these skills would be a weakness in the VET and PET systems.[99]

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[96] http://skbf-csre.ch/fileadmin/files/pdf/bildungsmonitoring/Swiss_Education_Report_2014.pdf

[97] Fazekas, M., & Field, S. (2013). OECD Reviews of Vocational Education and Training: A Skills beyond School Review of Switzerland doi:http://dx.doi.org/10.1787/9789264062665-en

[98] http://www.oecd.org/edu/skills-beyond-school/A-Skills-Beyond-School-Review-of-the-Netherlands.pdf

[99] http://www.oecd-ilibrary.org/education/skills-beyond-school-review-of-switzerland_9789264062665-en

MATHEMATICS AND VOCATIONAL EDUCATION IN THE NETHERLANDS

Introduction

Vocational education in the Netherlands is of particular interest because the majority of students follow a vocational pathway in upper secondary education and leads to almost double the percentage of any cohort taking vocational programmes than in England[100]. Measures to further improve mathematics standards include the recent introduction of a national basic 'applied numeracy' test into upper secondary education[101] for students on both academic and vocational pathways. The attainment grade in this test appears on a student's diploma but there is no 'pass' level that they must obtain in as a requirement for graduation from upper secondary education.

Mathematics / numeracy performance in international surveys

PISA 2015 (age 15)[102]	512
TIMSS 2015 Grade 8[103]	N/A
PIAAC Survey of Adult Skills 2013: Numeracy ages 16-24 (Ave Numeracy ages 16-65)[104]	285 (280)

Background

In the Netherlands students aged up to 18 years are required to attend school until they attain at least a basic qualification at Level 2 from a general or vocational programme. The options available at different ages are summarised in Figure 1 below.

[100] http://www.cedefop.europa.eu/en/publications-and-resources/publications/8065

[101] http://www.taalenrekenen.nl/referentiekader/niveauopbouw/

[102] OECD. (2016). *PISA 2015 Results (Volume I): Excellence and Equity in Education*. Paris: OECD Publishing. DOI: http://dx.doi.org/10.1787/9789264266490-en

[103] The Netherlands did not take part in TIMSS 2011 or 2015 at Grade 8.

[104] OECD. (2016). *Skills Matter: Further Results from the Survey of Adult Skills*. Paris: OECD Publishing; Additional tables: dx.doi.org/10.1787/888933366463

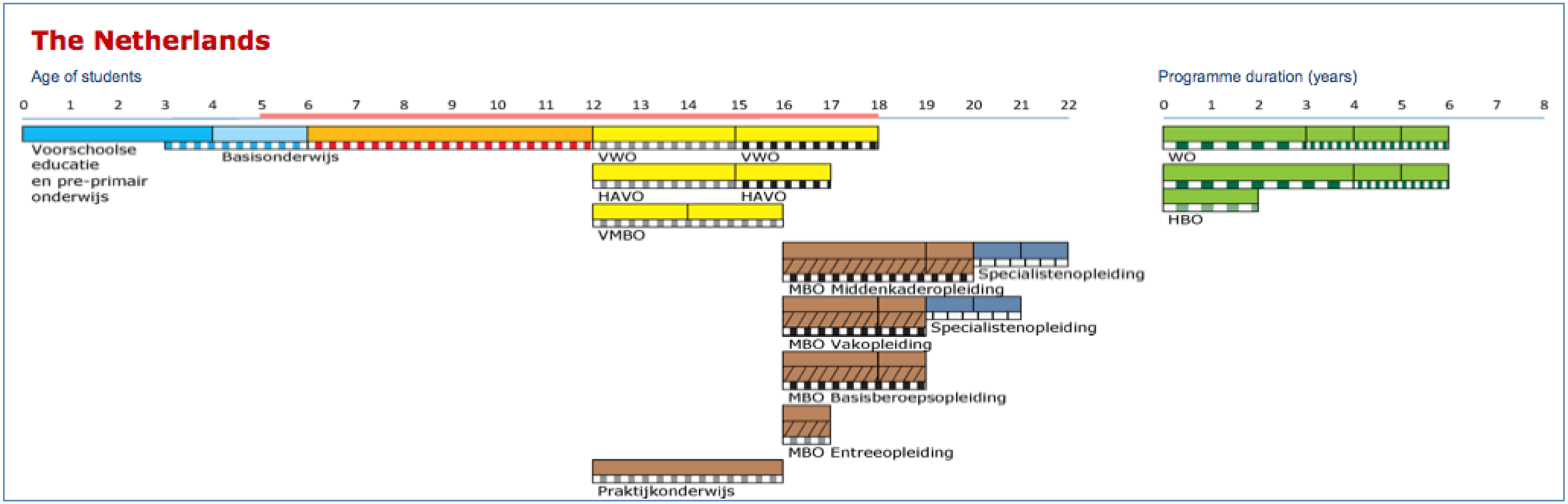

Figure 1: Overview of education in the Netherlands, Eurydice, Nov 2014.

Choices of the type of path are made at an early age. Pre-vocational courses are offered in lower secondary education, generally from age 14 years. Approximately a quarter of students study pre-vocational courses at this stage before entering upper secondary education.[105]

In upper secondary education a student may follow:

- a general education programme (Hoger algemeen voortgezet onderwijs - HAVO)
- a pre-university programme (voorbereidend wetenschappelijk onderwijs - VWO)
- a vocational programme (Middelbaar Beroepsonderwijs - MBO)

General	HAVO	Upper secondary general education	Preparation for higher level professional training
	VWO	Pre-university education	Preparation for university entry
Vocational (MBO)	BOL	Schools-based vocational education	Preparation for further education or the workplace
	BBL	Employer-based vocational education	Preparation for the further education or the workplace

Table 1: Academic and vocational routes available in upper secondary education

MBO programmes may be school-based (BOL) or employer-based (BBL). On a school-based programme (BOL), students spend a minimum of 20% and no more than 60% of the course in work placement. On an employer-based programme (BBL), students combine employment with study in an apprenticeship arrangement, spending at least 60% of the week with the employer.

A large proportion of each student cohort follows the vocational education pathway. In 2011, 69.1% of students in upper secondary education were on vocational programmes (compared to 36.0% in the UK)[106]. The majority of these vocational students (79% in 2011) follow a school-based (BOL) rather than a work-based (BBL) programme[107] although both lead to the same diploma.

Upper secondary vocational education (MBO) is offered at four levels, which correspond to the EQF Levels 1-4 and are briefly outlined in Table 2 below.[108] These incorporate changes starting from year 1 in 2014/15[109].

[105] http://www.cedefop.europa.eu/en/publications-and-resources/publications/8065

[106] http://www.cedefop.europa.eu/en/publications-and-resources/publications/8065

[107] http://www.oecd.org/edu/skills-beyond-school/A-Skills-Beyond-School-Review-of-the-Netherlands.pdf

[108] http://www.cedefop.europa.eu/en/publications-and-resources/publications/8065

[109] http://www.mbo15.nl/node/313

Level	Description	Course length	Purpose
1	Assistant Level	1 year	Training for simple practical work
2	Basic Vocational Training	1-2 years	Basic vocational training to carry out practical work
3	Professional Training	2-3 years	Training to become an independent practitioner, able to work across a range of activities in a vocational area
4	Middle-management or Specialist Training	3 years	Middle management and specialist training

Table 2: Educational levels available on the upper secondary MBO route

The starting level for an individual depends on their prior experience and attainment. At Levels 2 and above there are formal entry requirements, although these were only introduced for Level 2 in 2014. At Level 1 there are no formal entry requirements.

In 2010/11 the distribution of students aged 15-19 years across the MBO programmes at different levels is shown in Table 3[110]:

MBO/EQF Levels	Level 1	Level 2	Level 3	Level 4
Number of students	39,000	62,000	49,000	59,000
% of student cohort	18.7%	29.7%	23.4%	28.2%

Table 3: Distribution of students in the MBO route in 2010/11

A wide range of diplomas (612 in 2014) are offered, based on over 200 (237 in 2014) dossiers of interrelated qualifications[111]. The main vocational areas are:

- engineering and technology
- personal and social services and health care
- business
- agriculture and the natural environment.

[110] http://www.ilo.org/wcmsp5/groups/public/@ed_dialogue/@sector/documents/publication/wcms_344805.pdf
[111] http://www.cedefop.europa.eu/en/publications-and-resources/publications/8065

The VET system is considered to be strong and well-funded.[112] Vocational education is a joint responsibility shared by government, social partners (such as employers and unions) and educational institutions. The business community is involved in both developing qualifications and providing apprenticeships.

The formal VET system prepares students for employment or further education and has a strong link to practice but promotes both general education and personal development[113]. There are multiple tracks and qualifications in upper secondary vocational education and VET is the main supplier of employees to the labour market. Programmes are built around professions and the competencies required.

Unemployment for 15-25s is low. Few graduates of the work-based pathway continue into post-secondary education (6.7% of Level 4 graduates in 2010) although over half of graduates from school-based programmes (60% in 2010) progress to higher vocational education[114]. Higher professional education is available for students who gain a diploma in upper secondary general education at Level 4. About 50% with the MBO Level 4 qualification move into employment and the others progress to higher professional education.[115]

Recent emphasis in last 4 or 5 years has been on efficiency and quality within VET with a revision of the national qualifications structure for the MBO. The new National Qualifications Framework (NLQF) uses the existing levels of learning in the Netherlands and is mapped to the EQF but divides skills into applying knowledge, problem-solving skills, learning and development skills, information skills and communication skills.it also includes a Level zero or Entry Level and makes a distinction between Level 4 and Level 4+.

What is the content and level of mathematics in STEM technical education for 16-19 year olds and how does this differ across STEM sectors and pathways?

For entry to vocational (MBO) programmes the mathematics requirements are different depending on the level of the programme. At MBO level 1 there are no entry requirements but for programmes at MBO levels 2-4, students should have passed the pre-vocational diploma (VMBO) or have proof of a similar level of attainment. Achieving the pre-vocational diploma (VMBO) involves a minimum of 2 years of mathematics in lower secondary education during years 1 and 2 (ages 12-14 years) and 1 or 2 years of science. In some vocational areas, however, students are also required to take mathematics during years 3 and 4 of lower secondary (14-16 years). In Engineering and Technology, for example, students are required to take mathematics and also science, whereas in Agriculture both mathematics and biology are compulsory.

[112] http://www.oecd.org/edu/skills-beyond-school/A-Skills-Beyond-School-Review-of-the-Netherlands.pdf.
[113] http://www.euvetsupport.eu/index.php?id=113
[114] http://www.oecd.org/edu/skills-beyond-school/A-Skills-Beyond-School-Review-of-the-Netherlands.pdf
[115] http://www.cedefop.europa.eu/en/publications-and-resources/publications/8065

Since 2010 basic skills requirements (language and numeracy) have been tightened across the education system to improve quality. Central testing of these skills is now incorporated into both lower and upper secondary education[116], as detailed in the Dutch Literacy and Numeracy Framework (LaNF)[117].

Students in lower secondary education on (pre)vocational courses (VMBO) are now required to take a basic applied numeracy test in year 3 or 4 and repeat this towards the end of their vocational diploma. Other students, on HAVO and VWO courses, take a basic applied numeracy test at the end of their secondary schooling. This has led to extra lessons to prepare students for the test. From 2020, students will fail their pre-vocational education diploma (VMBO) if they do not pass the basic applied numeracy test.

In upper secondary education, mathematics is included within vocational programmes in two ways:

- Specific mathematical knowledge and skills are required to achieve particular occupational competencies. This mathematics is embedded into the vocational learning programme and the mathematical content varies between vocational areas.

- Students are required to work towards the national applied numeracy examination (which started in 2015/2016) as described in the Dutch Literacy and Numeracy Framework (LaNF). This is generally taught as a separate course and the content is the same across all vocational areas. It is linked to the basic numeracy test in lower secondary.

From 2020 onwards, achieving a pass in the national numeracy examination is expected to become a requirement for graduation from upper secondary education for all students, including those on upper secondary vocational programmes (MBO). The emphasis of this national test is on achieving a basic level of functional use of numeracy skills, which may alternatively be referred to as a type of applied numeracy or 'mathematical literacy'. The test may be taken at one of two levels. The lower one is for students on Level 1-3 programmes (and pre-vocational programmes) and the higher level is for those on Level 4 programmes (and the general education programmes HAVO and VWO). The level of test taken depends on the level of the students' vocational programme but not on the vocational area, thereby prescribing a minimum expected level of applied numeracy across vocational areas for these MBO levels. The content domains in the LaNF are Numbers, Proportions, Measurement & Geometry, and Relations (tables, diagrams, graphs).

Despite the national applied numeracy test, the actual amount of mathematics learned on different vocational courses still varies, since in some vocational areas there is more mathematics embedded into the vocational competencies than in others. Even in STEM areas the embedded mathematics content varies. For example, some Engineering and Technology students will learn about trigonometry and logarithms since these are relevant to their particular vocational course, whilst for those training to be laboratory technicians, dilution rates, measurement and statistics are important. In some vocational areas, such as Engineering and Technology, additional mathematics courses are also offered in the final year of MBO to prepare students for higher professional or vocational education. This also applies to

[116] http://www.cedefop.europa.eu/en/publications-and-resources/publications/8065

[117] http://www.taalenrekenen.nl/referentiekader/niveauopbouw/

those intending to become primary school teachers. The mathematical content of these courses varies depending on the progression route and mathematical content of the following course.

There are also concerns about the compatibility of the national applied numeracy test with the mathematics needed in the vocational programmes for VET and that a generic central test will lead towards teaching applied numeracy in VET as a separate and unconnected subject[118].

In 2010 the VET system in the Netherlands became more closely aligned to competency-based training and, as a result, the position of mathematics within vocational education became less visible, since references to mathematics were not always explicit in qualification specifications. Accountability for the development of students' mathematical competencies seemed less clear in this new VET system[119] and this was a concern.

Prior to these changes, in 2008, a Dutch framework for mathematics was developed collaboratively by a group of institutions to make the mathematics within VET more visible and support the teaching and understanding of the subject. This framework supported decisions about levels of mastery in the functional use of mathematics in different contexts. The skills and knowledge required for mathematical literacy at different levels were described but reference was also made to the complexity and familiarity of the context of the problem situation. Both the complexity of the mathematics and the context were used to determine the level of difficulty. Skills, sub-skills, examples of situations and the underlying mathematics were specified for each of four strands:

- Quantity
- Shape and space
- Data handling and uncertainty
- Relationships and change.

With the introduction of the national applied numeracy test this approach to promoting the visibility of numeracy in vocational education has been largely overshadowed by the requirement to develop generic mathematics skills. This has raised the profile of the subject in vocational education but has not strengthened the vocational connections. All students are expected to achieve a defined standard in basic applied numeracy by the end of upper secondary education at their level of study. The numeracy required for this standard is taught across all the vocational streams but the amount of additional mathematics taught within different vocational programmes will vary, depending on how much mathematics is embedded into the vocational competencies.

Although the subject is compulsory until this standard is attained, the results of the Numeracy test at this moment still have no consequences for 'graduation' of the students (at the end of their schooling). The decision to make 'passing the test' a requirement in (pre)vocational education has been postponed by the government, due to disappointing results so far.

[118] http://www.fisme.science.uu.nl/staff/arthur/wijers2010EIMI.pdf
[119] Op. cit.

How is the mathematics provision delivered?

The specific mathematical knowledge and skills required to achieve particular occupational competencies is normally delivered in vocational education using an embedded approach. Teachers have the freedom to decide what mathematics is taught and how to embed this into the vocational programme of learning. There is no separate assessment of this mathematics but it is integrated into vocational assessment as an element present within the relevant work processes.

Students need additional mathematics teaching to be prepared for the standardized test. Since this more general 'basic mathematics' is fairly new to VET and the new standardized computer-based assessment represents a high stakes test, this mathematics is mostly taught separately in dedicated mathematics classes, with a general textbook.

Teachers in vocational education are allowed to teach every subject. New programs and courses for professional development (in-service) aimed at teachers that teach numeracy, have been designed and made available. In pre-service teacher training the teaching course/module on numeracy has changed to be better aligned with the new framework. Some teacher training colleges have a Minor in Numeracy, for teachers of different subjects who want to teach numeracy at (pre)vocational schools.

MATHEMATICS AND VOCATIONAL EDUCATION IN NORWAY

Introduction

The upper secondary VET system in Norway follows a 2+2 model (2 years vocational education followed by 2 year 'apprenticeship' in an enterprise or public institution).[120] The system is well developed and the 'apprenticeship' model has a long history. The VET system is well-respected amongst stakeholders and there is strong cooperation between government and other 'sector' stakeholders nationally and regionally.[121]

Mathematics / numeracy performance in international surveys

PISA 2015 (age 15)[122]	502
TIMSS 2015 Grade 8[123]	487[124]
PIAAC Survey of Adult Skills 2013: Numeracy ages 16-24 (Ave Numeracy ages 16-65)[125]	271 (278)

Background

Below, the Norwegian school system is explained, with emphasis on vocational education programs. Thereafter, some challenges that exist in these programs are presented, and how mathematics is implemented in vocational education is explained.

The Norwegian Education System

Norway has ten years of compulsory education. Students start in Grade 1 when they are six years old, and continue until lower secondary school (Grade 10). Only 2.2% of the students attend private schools, so the focus below is on the education within state schools. The basic structure of the educational system is outlined in Table 1.

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[120] The Norwegian Directorate for Education and Training / ReferNet Norway. (2014). *Norway VET in Europe – Country Report 2014*. Thessaloniki: Cedefop (European Centre for the Development of Vocational Training). http://www.cedefop.europa.eu/en/publications-and-resources/country-reports/vet-in-europe-country-reports

[121] OECD (2011). *OECD reviews of vocational education and training*. Paris: OECD Publishing. (p.43). https://www.oecd.org/edu/skills-beyond-school/LearningForJobsPointersfor%20PolicyDevelopment.pdf

[122] OECD. (2016). *PISA 2015 Results (Volume I): Excellence and Equity in Education*. Paris: OECD Publishing. DOI: http://dx.doi.org/10.1787/9789264266490-en

[123] Mullis, I. V. S., Martin, M. O., Foy, P., & Hooper, M. (2016). *TIMSS 2015 International Results in Mathematics*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College / International Association for the Evaluation of Educational Achievement (IEA).

124 Norway's assessment focus in TIMSS 2015 was Grade 9, but benchmarking data for Grade 8 were also collected. Grade 8 attainment is reported in the table.

125 OECD. (2016). *Skills Matter: Further Results from the Survey of Adult Skills*. Paris: OECD Publishing; Additional tables: dx.doi.org/10.1787/888933366463

School level	Grades	Age
Kindergarten (voluntary)		1-5
Primary School	1-7	6-12
Lower Secondary School	8-10	13-15
Upper Secondary School	> 11	> 16
Vocational Education and Training Programs 2 years school 2 years apprenticeship	Programs for General Studies 3 years	

Table 1: Outline of the Norwegian Education System

The Norwegian education system is based on the principles of education for all, equality and adapted education. Almost all students attend the closest local school, and low, medium and high achievers study together in the same classes. Most students with special needs are integrated into these classes with additional support and aid (The Norwegian Directorate for Education and Training, 2013b).[126]

Students have no options regarding which subjects to study in the compulsory education until Grade 10, with the exception of Foreign Language and Elective Subjects.[127] There exist opportunities to take subjects from upper secondary school while a student is still in lower secondary school[128], but this was done by only 0.4% of students in the school year 2010-2011 (The Norwegian Ministry of Education and Research, 2011)[129]. All of these factors contribute to a compulsory education with a broad range of students in all subjects.

[126] 8.6% of students are identified as having special needs, and receive special education to a lesser or larger extent. 92% of these students participate within a regular class. In total, less than 1% of the students are organized in other ways than regular education. The Norwegian Directorate for Education and Training (2013b). *Statistikknotat 03 2013 Spesialundervisning: opplæring i eller utenfor den ordinære klassen?* [Statistics note 03 2013 Special needs education: within or outside the ordinary class?]. Oslo. Retrieved from http://www.udir.no/Upload/Statistikk/Statistikknotater/Statistikknotat_13_3.pdf?epslanguage=no.

[127] In Norwegian: Valgfag. Elective subjects have a total of 171 hours (2% of the total school time), and students can choose between subjects such as "Physical Activity and Health," "Design and Redesign," "International Cooperation," "Research in Practice," and "Living Heritage."

[128] http://www.udir.no/Regelverk/Rundskriv/2013/Udir-04-2013-Elever-som-tar-fag-fra-videregaende-opplaring-pa-ungdomstrinnet/Oversikt-over-de-nye-bestemmelsene/

[129] The Norwegian Ministry of Education and Research (2011). *Motivasjon - Mestring - Muligheter Ungdomstrinnet* [Motivation - Mastery - Opportunities Lower Secondary Education]. Oslo.

Upper Secondary Education

After ten years of compulsory education, Norwegian students have the right to continue to upper secondary school.[130] In 2012 almost 98% of the students started upper secondary school (The Norwegian Directorate for Education and Training, 2014a)[131].

Upper secondary education is divided into two school types: schools for General Studies and schools for Vocational Education and Training. About 59% of students choose General Studies, and the remaining 41% choose Vocational Education and Training (The Norwegian Directorate for Education and Training, 2014a)[132]. The schools for General Studies have slightly increased their proportions of students in recent years. There are three possible choices within General Studies: (1) Specialization in General Studies, (2) Sports and Physical Education and (3) Music, Dance and Drama. Students on one of these programs will, after completing three years of upper secondary school, obtain a general university and college admission certificate. This certificate is needed for acceptance to further studies at the tertiary level.

Students who attend schools for Vocational Education have the opportunity to continue to study towards a General Studies certificate after their two first years in vocational education, if they take a supplementary year of general studies instead of doing an apprenticeship. Students who do this will be qualified to continue into higher education with the same opportunities as students that have taken general education studies. This supplementary year of general studies is generally regarded as quite hard. Over half of the students who started the supplementary year after two years of vocational education in 2011-12 failed in one or more subjects, and therefore did not receive a General Studies certificate (The Norwegian Directorate for Education and Training, 2013a)[133].

Vocational Education and Training Programmes

For those students who have chosen to attend a school for Vocational Education and Training, there are nine programs: (1) Design, Arts, and Crafts; (2) Media and Communication; (3) Technical and Industrial Production, (4) Building and Construction, (5) Agriculture and fishing, (6) Electrical trades, (7) Health and Youth development, (8) Restaurant and Food Processing, and (9) Service and transport.

These are broad entry programs for vocational education, and they are structured in such a way that students have the opportunity to reselect their education program without much loss of time or need to retake common core subjects (The Norwegian Ministry of Education and Research, 2013a)[134].

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[130] Students have a statutory right to 3 years of upper secondary education. There is no statutory right to an apprenticeship placement. In 2013, 5750 applied but did not get an apprenticeship placement (around 13% of total applicants). These students are entitled to one year of practical school-based training equivalent to the training element of the two-year apprenticeship. Op cit: The Norwegian Directorate for Education and Training / ReferNet Norway. (2014).

[131] The Norwegian Directorate for Education and Training. (2014a). *The Education Mirror 2014*. Oslo.

[132] Op cit.

[133] The Norwegian Directorate for Education and Training. (2013a). *Gjennomføring i videregående opplæring - status per september 2013* [Completion of upper secondary education - status as of September 2013]. Oslo. Retrieved September 15, 2014, from http://www.udir.no/Tilstand/Analyser-og-statistikk/Gjennomforing-i-videregaende-opplaring--- status-per-september-2013/

[134] Op cit.

The main model for vocational training is the 2+2 model, illustrated in Table 2. This is a combination of two years in school, with education and training, and then two years paid in- service training in an enterprise.

Grade	Description	Location
11	Vg1 (Vocational Education year 1)	Upper Secondary School
12	Vg2 (Vocational Education year 2)	
13	Combined Training and Productive Work	Enterprise / Public institution
14		
	Craft certificate is obtained after a final examination	

Table 2: Outline of the 2+2 model for vocational education and training

The subjects in the first two years in Vocational Education are divided into (1) common core subjects, (2) common program subjects and (3) an in-depth study project.[135] In the two first years of Vocational Education, the common core subjects have 588 hours; the common program subjects have 954 hours; and the in-depth study project 421 hours. Students in vocational education are usually organized into classes of 15 students according to their vocational education program, and these 15 students have almost all their lessons together. Mathematics is defined as a common core subject, together with Norwegian, English, Natural Science, Social Science and Physical Education. The Norwegian Directorate for Education and Training (2010a[136]) specified that "the teaching [in the Common Core subjects] should be as relevant as possible; with adaptions towards the different education programs", and this has been perceived as an instruction to connect the common core subjects to the students' vocational context. The common program subjects vary according to the vocational program. For example, students in Technical and Industrial Production will learn about Production, Technical Services, and Documentation and Quality. After their two years of vocational education within school, the students have a two-year apprenticeship period, before they have final examinations and obtain a craft certificate.

Vocational education in Nordic countries such as Norway is often regarded as different and somewhat separated from other kinds of school education. The learning practices in vocational education have been described by the Swedish researcher Lindberg (2003) as different from (1) learning practices in comprehensive education, and (2) practices in the workplace. She characterized the vocational education model in the Nordic countries as a hybrid between practices with most tasks for students in vocational education being "contextualised in the vocation" (p. 162). She observed that much of the work the students do in the workshop is self-instructional and relies on the students being able to read and use books that are used in industry. Tasks were often part of a practice with the aim of producing a product, so learning is not the "only" goal of the activity.

[135] In Norwegian: Prosjekt til fordypning [In-depth study project].
[136] Op cit.

This is also emphasized by Roth (2014), who pointed out that when apprentices are on jobsites, they are treated as workers and not as learners.[137] Also, Høst (2012)[138] reported that students expected their vocational education to be different from usual classroom teaching. The students expressed that they learn most from, and are most interested in, the practical training. Dahlback et al. (2011)[139] have shown that vocational connected practical tasks motivated the students when the common core subjects and the common program subjects were integrated. Dahlback et al. (2011) and Hiim (2013)[140] found that implementing such integration was difficult because of the broad first year in the vocational education programs, and they observed that this was problematic both for the students and their teachers. The teachers often did not have sufficient competences in the wide range of the vocational opportunities, and the students needed to learn small portions from many vocations in the specific vocational education program. In the next section, some issues of vocational education that are discussed in the public debate are elaborated on.

What is the content and level of mathematics in STEM technical education for 16-19 year olds and how does this differ across STEM sectors and pathways?

Students in schools for Vocational Education and Training have a compulsory mathematics course in their first year. Mathematics is the subject for which most students in vocational education have problems getting a pass grade (The Norwegian Ministry of Education and Research, 2010)[141], and this makes the mathematics course important in light of non-completion.

The curriculum gives the students the opportunity to choose between two mathematics courses, 1P-Y and 1T-Y. The course 1P-Y is regarded as the easiest mathematics course, and almost all students (around 95%) in vocational education choose this course (The Norwegian Directorate for Education and Training, 2012). The 1Y-T curriculum is designed as more theoretical, while 1P-Y is meant to be more practical. The course 1P-Y has the same curriculum for all of the nine vocational education programs. This curriculum is identical to 3/5 of the mathematics course for grade 11 students in schools for General Studies. This alignment between curricula for Vocational Education and General Studies came into existence with the 1994 education reform in Norway. Before this reform, the mathematics curriculum in vocational education had been regarded as a tool intended to assist the vocational subjects; it was tailored and connected to the different vocational education programs. With the 1994 reform, the common curriculum across programs increased opportunities for students to change their

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[137] Roth, W.-M. (2014). Rules of bending, bending the rules: the geometry of electrical conduit bending in college and workplace. *Educational Studies in Mathematics, 86*(2), 177-192. doi:10.1007/s10649-011-9376-4

[138] Høst, H. (2012). *Kvalitet i fag- og yrkesopplæringen Fokus på skoleopplæringen: Rapport 2 Forskning på kvalitet i fag- og yrkesopplæringen* [Quality in vocational education and training Focus on schooling: Report 2 Research on quality in vocational education and training] NIFU- rapport (Vol. 21). Oslo: Nordisk institutt for studier av innovasjon, forskning og utdanning.

[139] Dahlback, J., Haaland, G., Hansen, K., & Sylte, A. L. (2011). *Yrkesdidaktisk kunnskapsutvikling og implementering av nye læreplaner (KIP)* [Vocational didactics knowledge development and implimention of new curriculum]. Lillestrøm: Høgskolen i Akershus.

[140] Hiim, H. (2013). *Praksisbasert yrkesutdanning: hvordan utvikle relevant yrkesutdanning for elever og arbeidsliv?* [Practice bases vocational education: how to develop relevant vocational education for students and worklife?]. Oslo: Gyldendal akademisk.

[141] Op cit.

educational program without much time loss. However, there are critical voices that point to the lack of vocational relevance of the common core curricula (e.g. Hiim, 2013)[142].

The competence aims in 1P-Y are the same for all vocational education programs, and divided into three main areas: (1) Numbers and Algebra in Practice, (2) Geometry, and (3) Financial Mathematics (The Norwegian Directorate for Education and Training, 2010b)[143]. Students in General Studies have additional competence aims in (4) Probability and (5) Functions. The complete competence aims[144] for 1P-Y is presented below:

Numbers and algebra

The aims of the studies are to enable students to:

- Estimate answers, calculate practical tasks, with and without technical aids, and evaluate how reasonable the results are
- Interpret, process, evaluate and discuss the mathematical content of written, oral and graphic presentations
- Interpret and use formulas that apply to everyday life, working life and the vocational context
- Calculate with proportions, percentages, percentage points and growth factors
- Deal with proportional and inversely proportional magnitudes in practical contexts

Geometry

The aims of the studies are to enable students to:

- Use similarity, scale and the Pythagorean Theorem in calculations and practical work
- Solve practical problems involving length, angle, area and volume
- Calculate using different measurement units, use different measuring tools and evaluate measurement accuracy
- Interpret and prepare working drawings, maps, sketches and perspective drawings related to working life, art and architecture

Financial mathematics

The aims of the studies are to enable students to:

- Calculate using price indexes, currencies, real wages and nominal wages
- Calculate wages, and compose budgets and accounts using various tools

[142] Op cit.

[143] The Norwegian Directorate for Education and Training. (2010b). *Læreplan i fellesfaget matematikk* [Curriculum in mathematics]. Oslo. See also: : http://www.udir.no/kl06/MAT1- 04/Hele/Kompetansemaal/competence-aims-after-1p-y---vg1-vocational- education-programme?lplang=eng

[144] These are the competence aims until 2012 (The Norwegian Directorate for Education and Training, 2010b). The curriculum had a minor revision in 2013.

- Calculate taxes
- Examine and evaluate consumption and various terms for loans and savings using web-based consumer calculators

The mathematics curriculum does not specify possible connections with regard to the different vocational education programs. But formulations such as "calculate with practical tasks", "interpret and use formulas that apply to day-to-day life and working life", "practical contexts," "practical work", "solve practical problems," and "interpret, make, and use sketches and working drawings for problems from cultural and working life" point toward mathematics used outside the school practice. The connections between the mathematics curriculum and the world outside the school is emphasized in an Act relating to primary and secondary education which says that "the teaching [in the Common Core subjects] should be as relevant as possible; with adaptions toward the students' different education programs" (The Norwegian Directorate for Education and Training, 2010a, our translation).[145] In addition, the objectives of the mathematics curriculum point out that mathematics "can form the basis (…) for participation in working life and recreational activities" (The Norwegian Directorate for Education and Training, 2010b, p. 2)[146]. In the apprenticeship period, the content of the vocational examination is set by the county (regional) trade specific examination board and the examination includes both theoretical knowledge and practical skills[147]. This examination may (or may not) include some mathematics.

Textbooks written for the 1P-Y course claim that they are vocationally connected. But the two major textbook series are written to cover all nine vocational education programs (Engeseth, Heir, Moe, & Kielland, 2013)[148]. Other textbooks are written for a specific vocational education program, but nevertheless they are quite similar to the textbooks for the General Study program.

How is the mathematics provision delivered?

The mathematics course has a total of 84 hours of teaching in the 11th school year, which equals about three 45-minute lessons a week.

To teach mathematics in upper secondary education, including the 1P-Y course, a teacher is required to have at least 60 ECTS[149] points in mathematics (The Norwegian Ministry of Education and Research, 2006)[150]. The 1P-Y course is mostly taught by teachers who teach mathematics at different levels and education programs in upper secondary education. Many teachers with the required formal competence in mathematics are not experienced with the vocational education programs or the students' future

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[145] In Norwegian: Opplæringsloven kapittel 1, andre ledd § 1-3 videregående opplæring: "Opplæringa i fellesfaga skal vere tilpassa dei ulike utdanningsprogramma".

[146] Op cit.

[147] Op cit: The Norwegian Directorate for Education and Training / ReferNet Norway. (2014).

[148] Engeseth, J., Heir, O., Moe, H., & Kielland, G. E. (2013). *Matematikk for yrkesfag* [Mathematics for vocational programmes]. Oslo: Aschehoug;

[149] European *Credit* Transfer and Accumulation System

[150] The Norwegian Ministry of Education and Research. (2006). *Opplæringsforskrifta* [Education Act]. Oslo.

workplaces, and therefore can have difficulties to use vocational contexts in their teaching. Aretorn (2012)[151] reports that teachers of the vocational program Electrical Trades and teachers of mathematics had different kinds of explanations when working with mathematical electricity tasks. The mathematics teachers used more general mathematics-based explanations, while the electricity teachers were more context-specific in their explanations. She points out that, for students, it may be problematic to reconcile such differences. Since 2012, a national training programme for teachers has been in place to encourage general education (including mathematics) to be more oriented towards students' vocational routes.[152]

There are no qualification requirements for enterprise-based trainers[153], although training supervisors are required to have qualifications or experience relevant to the trade.[154]

[151] Aretorn, L. (2012). *Mathematics in the Swedish Upper Secondary School Electricity Program: A study of teacher knowledge.* Licentiate Thesis. Umeå, Sweden: Umeå Universitet

[152] Op cit: The Norwegian Directorate for Education and Training / ReferNet Norway. (2014).

[153] Op cit: OECD (2011). *OECD reviews of vocational education and training*. Paris: OECD Publishing. (p.43).

[154] Op cit: The Norwegian Directorate for Education and Training / ReferNet Norway. (2014).