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## **A digital tool for teaching, learning and assessment in Mathematics and Sciences**

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Approved by the Joint Teaching Committee at its meeting on 13 and 14 February 2020 - Brussels

## A digital tool for teaching, learning and assessment in mathematics and sciences

### Background

The characteristics of the technological tool to be used for mathematics was previously defined in the document 2010-D-571-en-2. The document authorises a group of experts to continually revise the recommendations of which particular tool to use.

Since the original document was published, yet another revision of the mathematics syllabus has taken place. The new syllabus, although being neutral to any particular choice of technology, puts more emphasis on the use of technology. This is both reflected in the specific content, such as programming and algorithms, as well as the recommended activities on digital competence as related to mathematics.

Recent developments within the European Schools system express a commitment to promoting digital competence, such as the adoption of the Digital Education Vision Policy which states the aim that ***“Every pupil and student develops throughout his/her European School education the digital competence to foster confident, critical, responsible and creative use of, and engagement with, digital technologies for learning, at work, and for participation in society.”***

Teachers are also encouraged to use collaborative tools and to exchange resources, for example through the use of Office365. In this way, good practices can be shared throughout the European Schools system.

The current technological tool in use, in the form of a calculator, satisfies the requirements in the original document. These requirements are mainly formulated in terms of functionality. Limited reference is made to teaching and learning in this document. The choice of the current tool was a good one at the time and it has in many ways served the system well.

Among the negative aspects that have been raised by teachers is that the current tool compensates for the lack of understanding rather than helps understanding. Some teachers have reported cases where pupils write a sequence of keys pressed as their solution in a test. This means that, at least for some pupils, the tool, while being useful in assessment, is not equally useful in learning. Given the proportions of time being spent on learning and on assessment, the learning aspect should be better reflected in the choice of technological tool.

An inherent disadvantage of a hardware-based tool is that it's not easily upgradable. Even if it's possible to update the software for a given hardware, one can expect new hardware versions to be released during the 10-year life-cycle of a syllabus, possibly resulting in several different versions of the tool in the same classroom. With a software-based tool, everyone would always have the same version installed. A natural consequence of running software on more general hardware such as a computer, tablet or smartphone, is that you can also run other software on it, both for mathematics and other subjects.

The group of experts responsible for the choice of technological tool updated the recommended tool to be used in May 2019, taking into consideration , *inter alia*, all of the above mentioned aspects. Based on a analysis of a comparative use of various technological tools in class (see annex 2), the group proposed the use of GeoGebra as digital tool for teaching, learning and assessment in mathematics and physics.<sup>1</sup> For the other sciences subjects, it may be used for teaching, learning or assessment depending on the needs.

## 1. Why GeoGebra?

GeoGebra, created in 2001, is an interactive geometry, algebra, statistics and calculus application (CAS), intended for learning and teaching mathematics and sciences from primary school to university level.

GeoGebra, created in 2001, is an interactive geometry, algebra, statistics and calculus application (CAS), intended for learning and teaching mathematics and sciences from primary school to university level. GeoGebra is also used as a tool for research. GeoGebra itself is the subject of much research in the education sciences. This research shows its pedagogical interest.

Some features of GeoGebra are:

- Free for non-commercial use and open-source.
- Available in all European languages.
- Available on multiple platforms, including Windows, macOS, Linux, ChromeOS, iOS and Android.
- Possible to run online and offline as a desktop or mobile device application.
- Can be embedded into Office365.

A comparative use of various technological tools in class was made by some maths teachers (see Annex 2) under the supervision of the Experts Working Group. This comparative study is based on the different content areas in mathematics. In particular, and after analysis, this comparison allowed the WG to develop its conclusions as to the possible use of only one tool in the classroom from 2020-2021, namely "**GeoGebra**".

## 2. GeoGebra in teaching

GeoGebra can be used by the teacher in all areas of the syllabus. It satisfies the subject-related characteristics in the document. as well as having more features. It has its own scripting language (GGBScript) and is also compatible with JavaScript, a widely used programming language. This feature can, besides demonstrating concepts related to programming, be used to create interactive resources called applets, such as interactive e-books and online self-correcting homework assignments.

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<sup>1</sup> See Memo 2019-05-M-9

It is possible to publish notes and embed audio, images and video content. All these resources can be shared amongst colleagues. There already exists more than 1 million applets that teachers can use as they are or adapt to their specific needs. Illustrations from GeoGebra can be exported as images in a wide range of formats.

### 3. GeoGebra in learning

For the pupils, GeoGebra offers the possibility to visualise and explore various mathematical concepts and thus discover relations between different mathematical representations. It can be used for interactive self-assessment and repeated practice of tasks in order to build familiarity with concepts, for example matching a line to an equation. GeoGebra could also be of benefit for educational support, mainly in the areas of calculation and geometry.

### 4. GeoGebra in assessment

In assessment, GeoGebra can replace the use of a calculator, and it can be run both with and without CAS (computer algebra system). Having a more interactive tool opens up the possibility of creating more investigative, rich and open problems stimulating creative problem solving (this could also correspond to some remarks from the previous BaccaLaureate Presidency).

GeoGebra has a test-mode which can block other applications on the device. This function works differently on different platforms.

For larger exams, a possibility would be to use school-owned devices or some kind of MDM (mobile device management system). The latter could provide a framework for using devices in other subjects as well.

### 5. Proposal for the use of GeoGebra in classrooms and for examination

In May 2019, the Experts Working Group in charge of the technological tool already recommended, to the schools, the following:

- *To accompany the new mathematics syllabuses for secondary year **s4** of the European Schools, with effect from the beginning of the 2019-2020 school year in September 2019, a **non-graphing and non-programmable scientific calculator** (the model used in s3 may be sufficient).*
- *To accompany the mathematics syllabuses for secondary years **s5, s6 and s7** of the European Schools, with effect from the beginning of the 2019-2020 school year in September 2019, **TI-Nspire CAS software, version 4.5.1.12 or higher**. The calculators authorised and supporting this software are the **TI-Nspire CX CAS (version 4.5.1.12) and the TI-Nspire CX II-T CAS (version 5.0.0.1683 or higher)**.*

The Experts Working Group had also drawn the attention of the schools to the following recommendations:

*For the 2019-2020 school year, the group of experts recommends that teachers use in year s4 (just like for year s1 moreover) GeoGebra software (open source application, free of charge, multilingual, multiplatform and with an exam mode) or any other software offering the same functionalities. Time for information about and training in the GeoGebra software program has been scheduled for the next centralised training course to be organised in autumn 2019.*

*This recommendation also applies to students' use of this same software for work in dedicated ICT rooms or 'ordinary' classrooms on hardware, tablet or computer, made available by the school. This recommendation is in line with the learning objectives of the new syllabuses and will be applicable immediately, subject to approval by the Joint Teaching Committee at its October 2019 meeting of the new document specifying the characteristics of the technological tool (ref. 2019-05-D-22<sup>2</sup>).*

*This recommendation also takes account of the future introduction of the syllabuses for years s5 to s7, which will lead to use of this type of software, contributing in particular to the development of students' digital competence.*

*Finally, and for harmonisation purposes, the group of experts recommends use of a single software program in the school. Reasons for using any complementary software will need to be justified by the difficulty of solving a given problem with the 'generalist' software chosen.*

Following up on the recommendations of the Experts Working Group made in May 2019, and based on the justification above concerning the decision to choose GeoGebra as software linked to the Mathematics and Physics syllabuses, the Experts Working Group also proposes the following gradual implementation of the use of GeoGebra in classrooms and for examinations in the European Schools and the Accredited Schools.

### Proposal for Classroom only

	19-20	20-21 <sup>3</sup>	21-22	22-23	23-24
<b>S1-S3<sup>4</sup></b>	Scientific calculator <sup>5</sup> and GeoGebra	Scientific calculator and GeoGebra	Scientific calculator and GeoGebra	Scientific calculator and GeoGebra	Scientific calculator and GeoGebra
<b>S4</b>	Scientific calculator and GeoGebra	Scientific calculator and GeoGebra	Scientific calculator and GeoGebra	Scientific calculator and GeoGebra	Scientific calculator and GeoGebra
<b>S5</b>	TI-Nspire	Scientific calculator and GeoGebra	GeoGebra	GeoGebra	GeoGebra
<b>S6</b>	TI-Nspire	TI-Nspire	GeoGebra	GeoGebra	GeoGebra
<b>S7</b>	TI-Nspire	TI-Nspire	TI-Nspire	GeoGebra	GeoGebra

<sup>2</sup> This document is now this present document and has a new reference: 2020-01-D-76-en-1.

<sup>3</sup> S5 Entry into force.

<sup>4</sup> For S1-S3, GeoGebra can be introduced by teachers in ICT room or with share devices in class room.

<sup>5</sup> A non-graphing and non-programmable scientific calculator.

## Proposal for Examination only

	19-20	20-21	21-22	22-23	23-24
<b>S1-S3</b>	<i>Scientific calculator</i>	<i>Scientific calculator</i>	<i>Scientific calculator</i>	<i>Scientific calculator</i>	<i>Scientific calculator</i>
<b>S4</b>	<i>Scientific calculator</i>	<i>Scientific calculator</i>	<i>Scientific calculator</i>	<i>Scientific calculator</i>	<i>Scientific calculator</i>
<b>S5</b>	<i>TI-Nspire</i>	<i>Scientific calculator</i>	<i>GeoGebra*</i>	<i>GeoGebra</i>	<i>GeoGebra</i>
<b>S6</b>	<i>TI-Nspire</i>	<i>TI-Nspire</i>	<i>GeoGebra*</i>	<i>GeoGebra</i>	<i>GeoGebra</i>
<b>S7</b>	<i>TI-Nspire</i>	<i>TI-Nspire</i>	<i>TI-Nspire</i>	<i>GeoGebra</i>	<i>GeoGebra</i>

**\*Only June examinations.**

With the introduction of the new Mathematics and Physics S5 syllabuses next school year 2020-2021, and after consideration, the Experts WG has revised its decision fractionally and suggests postponing, for one year, the introduction of GeoGebra for the examination – only for this particular year. It remains compulsory to use it during the lessons but not for the examination next year in S5. It will be compulsory in the second semester tests of the school year 2021-2022 for S5 and S6.

It is also strongly recommended that the pupils have the occasion to train themselves with the application. To this end it is recommended that pupils have their own device in order to take ownership of the software GeoGebra, and for the examination.

The reasons for postponing the move to GeoGebra from the original schedule are:

- To organise properly the decentralised in-service training of mathematics and physics teachers and to allow time for the schools to organise the follow-up inside the school (with the help of the subject referent/coordinator).
- To allow time for the European schools and the Accredited schools to find, amongst their mathematics or physics teachers, a super key user<sup>6</sup> and supervisors to oversee the exams and to train them properly for the examinations in June 2022 (N.B. this is the responsibility of the school). For this date, the schools must also arrange for some devices in reserve for the examination day (e.g. min. 3% of the total number of pupils passing the exam).
- To train pupils properly during classroom for at least nearly two school years.
- To allow time for the Experts working group to continue its analysis on the “exam mode” and to develop proper guidelines for the “Examination mode” and the implementation for the S5, S6 examinations and for the Baccalaureate, in respect to the technical constraints of the schools.

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<sup>6</sup> As it was the case for the implementation of the TI-Nspire, the super key user is the appropriate person who will be in charge to help his/her colleagues with the tool and of the organization of the training for the new teachers and the supervisors.

Before making their recommendations concerning the use of GeoGebra, the “Experts Working Group” took into consideration several things:

- The implementation of the 8 key competences and particularly the Digital competence.
- The fact that GeoGebra is simply a tool that should replace another tool. In this case, the TI-Nspire CAS (for diverse reasons already explained above).
- This new tool is a software and is
  - Free for non-commercial use and open-source.
  - Available in all European languages.
  - Available on multiple platforms, including Windows, macOS, Linux, ChromeOS, iOS and Android.
  - Possible to run online and offline as a desktop or mobile device application. When it runs offline, there will be no impact on the Wi-Fi or on the IT structure of the school. Pupils will not have access to any resources of the schools. The application can be downloaded at home by the pupils.
  - Can be embedded into Office365.
- This tool should be used by both European and Accredited Schools.
- The remarks of the IT-PEDA and IT-ADM, both of which are working on the development of “Guidelines for pedagogical use of mobile devices in the European schools” (see document 2020-01-D-14 – for approval in February 2020).
- The lack of actual financial and human resources and the time needed to manage and secure properly a fleet of school owned devices.

## 6. Proposals

Considering the present document in its entirety (considerations, recommendations, proposals, ...), here are the proposals made by the Experts Working Group:

The “Experts Working Group in charge of the technological tool” recommends, for the next school year 2020-2021, to accompany the entry into force of the new Mathematics and Physics S5 syllabuses, with the following:

1. That teachers use GeoGebra software in year **S5** (just like for year S1) (open source application, free of charge, multilingual, multiplatform and with an exam mode).

To avoid any impact on the Wi-Fi or on the IT structure of the school, the software could be used in offline mode.

Time for information about and teachers training in the GeoGebra software program has been scheduled for the next decentralised training course to be organised in spring 2020.

2. Considering the recommendations made by the IT-PEDA and IT-ADM Working Groups, and their conclusions concerning the pedagogical use of devices in the European schools, **pupils** in year **S5** must bring their own device to use the application GeoGebra in classroom – at least in offline mode - from next school year. The Experts Working Group proposed some minimal technical recommendations for such devices (see Annex 1), and if the “Guidelines for pedagogical use of mobile devices in the ES” (2020-01-D-14) is approved, recommends to the schools to take it into account.
3. The decision of the Experts WG will have no financial impact on the European Schools budget for the next school year.

### **Opinion of the Board of Secondary Inspectors:**

The Board of Secondary Inspectors gave a favorable opinion on the document and its proposals and recommendations as well as in particular on the proposals 1 and 2 above. The Board also recommended the Joint Teaching Committee to approve it with an entry into force in September 2020, to be in line with the entry into force of the new Mathematics and Physics S5 syllabuses.

### **Decision of the Joint Teaching Committee:**

The Joint Teaching Committee approved the document with its proposals and recommendations as well as in particular on the proposals 1 and 2 above with an entry into force in September 2020, to be in line with the entry into force of the new Mathematics and Physics S5 syllabuses.



## Annex 1

### **Minimum recommendations for devices running GeoGebra in the classroom / examination**

GeoGebra can run on several devices (tablet or laptop) offline or online. The group of experts does not specify a model. However, the group recommends at least the following, for adequate use of GeoGebra (these are minimum specifications, but the choice of more powerful devices would allow for more diverse and in-depth uses):

- Operating system: any operating system supporting GeoGebra (e.g. Linux, Windows 10, Mac OS X, ChromeOS, iOS, Android)
- Minimum RAM: 1 GB (for an Android tablet), 4 GB (for a laptop)
- Minimum storage: 16 GB (for a tablet), 32 GB (for a laptop)
- Screen size and resolution: 7" can be allowed provided a good display resolution (minimum 720 p), but at least 9" for comfortable viewing with minimum 1080 p. resolution;

## Annex 2

### Comparative use of various technological tools in class

#### Numbers

	GeoGebra 6 (GG 6) or Tablet App	TI Nspire CX CAS	TI83	NumWorks
Surds	Approx or exact (CAS)	Exact + approx with different keys	Exact + approx in different mode	Exact + both at the same time
Fractions	Exact + approx.	Exact + approx with different keys	Exact + approx in different mode	Exact + both at the same time
Prime factors	Command	3 keys	No	12 keys
Complex numbers	Yes	Yes	Yes	Yes

#### Algebra

	GG 6 or Tablet App	TI Nspire CX CAS	TI83	NumWorks
Expanding and reducing	CAS command	3 keys	No	No
Factoring	CAS command	3 keys	No	No
Solving	CAS command or graphically	Easy	No	2nde degree : exact Others : approx

#### Calculus

	GG 6 or Tablet App	TI Nspire CX CAS	TI83	NumWorks
Table of values of functions	No	Yes	Yes	Yes
Derivative number	Yes	Yes	Yes	Yes
Derivative function	Yes	Yes	Drawing only	Drawing only
Integral	Approx by default exact with CAS	Exact	Approx	Approx
Sequences	Spreadsheet	Yes	Switch from functions	Yes

#### Geometry

	GG 6 or Tablet App	TI Nspire CX CAS	TI83	NumWorks
Placing points	Easy	On grid	No geometry	No geometry
Drawing lines	Easy	Easy from equation	No geometry	No geometry
Complex figures	Easy	Hard	No geometry	No geometry

## Statistics

	GG 6 or Tablet App	TI Nspire CX CAS	T183	NumWorks
1 variable	Spreadsheet and specific tools	Spreadsheet + specific commands	Specific tool	Specific tool
2 variables				
Regressions				

## Probabilities

	GG 6 or Tablet App	TI Nspire CX CAS	T183	NumWorks
Binomial law	Specific tool	Specific commands in menu	Specific commands in menu	Specific tool with values and graphs
Normal law				
Other laws				

## General

	GG 6 or Tablet App	TI Nspire CX CAS	T183	NumWorks
Ease of use	Easier on laptop than tablet	Good	Old fashioned	Good
Exam mode	Yes	Yes	Yes	Yes
Screen quality	Depends on device	Average	Old fashioned	Good
Battery life	Depends on device	Not so good	Good	Good
Weight and size	Depends on device	Heavier	Lighter	Lighter
Cross platform / emulators	Yes	Proprietary emulator	Proprietary emulator	Free and open-source, web and smartphones
Public price (Amazon Belgium, 07/12)	Free app + device	120 €	75 €	80 €