Informatics for All

Report of the *Informatics for All* Workshop

held on 20th February 2019 in Brussels, Belgium

Informatics for All Coalition

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Preface

Informatics for All is a Coalition formed by ACM Europe, CEPIS and Informatics Europe. In recent years, this group has undertaken considerable work to determine the state of Informatics education at school level across Europe and to articulate in broad terms a vision that will support developments for Europe. The intention of this Workshop was to move to a new level and widen the discussion. One aspect of this was to receive feedback and guidance but it was also intended that the Workshop should address mechanisms to chart a way ahead that will benefit all the countries of Europe.

The concept of *Informatics for All* has been set out in the paper *Informatics for all: The Strategy*[1]. In short, the aim is to promote Informatics as a foundational discipline, with a two-tier strategy being devised. The two-tier strategy involves: seeing Informatics as a separate disciple to be taught to some meaningful level to all students and to have a status that reflects an importance and relevance at least as strong as mathematics, the sciences or language; but also to have Informatics integrated into the teaching of other disciplines in such a way that it leads to a deeper and more relevant educational experience.

The agenda for the Workshop took the form of: an introductory session with a number of presentations on school-level developments in Informatics education from participants from various countries across Europe. Details of these are included in the Annex. This was followed by sessions of group work involving brainstorming to identify the major challenges associated with achieving the goals of *Informatics for All*. A selection was made to identify the most important challenges for further group discussion. Finally, the closing session discussed the elements of an Action Plan that would chart a way forward on how the challenges might be addressed and communicated to stakeholders. The Action Plan was subsequently prepared by the Coalition members and is attached here.

There were 50 attendees, all with considerable expertise and track record in computing education, from across Europe.

March 2019

[1] https://dl.acm.org/citation.cfm?id=3185594

1. Identifying Major Challenges

In discussing the major challenges associated with realizing *Informatics for All,* the attendees were divided into five groups. The challenges identified by the five groups are summarised below.

Group 1

- Getting well educated teacher workforce.
- Developing a body of knowledge for everyone and how to identify what that is.
- How to get politicians on board –how to practically engage them.

Group 2

- Communicating about what Informatics is – to all stakeholders.
- Developing the content and curricula learning materials on the basis of appropriate research.
- Teacher training and re-training.
- Young people must be taught from early age.
- Ensuring at least all students leave primary/secondary school with basic confidence in informatics – including the ethical aspects and its impact on society.

Group 3

- How to communicate the identified challenges?
- Outline relevance and role of informatics – some stakeholders who have stake in deciding to do not understand our goals.
- Motivate students to study informatics and motivating teachers.
- Developing curricula – sharing best practices across Europe.
- Developing quality teaching workforce and methods, with a special focus on 'open source'.

Group 4

- Define what is the nature of Informatics – curricula and what does it mean.
- Who will be the teachers – training and targets?
- Reaching out to stakeholders conveying why Informatics is important.

Group 5

- Communicating how Informatics can solve key issues, enabling digital transformation.
- Teacher training.
- How to fit Informatics into curriculum – what courses will have to be sacrificed/reduced?
- Understanding how children will best learn.
- Finding industry representatives.

2. Addressing Selected Challenges

The following challenges were seen as being of major importance and were selected for further discussion in five groups:

1. communicating the message curriculum (for all levels)
2. teacher education
3. curriculum
4. teaching methods and pedagogy
5. advocacy

The groups were asked to identify action points that would feed into the creation of an Action Plan for *Informatics for All*.

2.1 Communicating the Message

The message that should be conveyed is that Informatics is a key subject of which every child should have a broad understanding. Informatics can help solve a wide range of real-world problems, e.g. intelligent cars can reduce pollution, or robot physiotherapists (see Maja Matarić: https://www.bcs.org/category/19075).
It should be noted that this message does need to be tailored to the audience, e.g. "industry-relevance" is positive in some cultures and more negative in others.

Note that codeweek.eu has 2.7M participants, and in some countries more girls than boys. There's also the maker movement, which again appeals to girls if the tasks are suitable. The Barefoot findings that teaching computing improves Mathematics scores (96% of teachers) and English (69%) are potentially significant. See (https://www.btplc.com/Purposefulbusiness/Techliteracy/IPSOS-full.pdf page 34)

It was felt that the Informatics for All Coalition members should curate a collection of useful arguments and analogies, so that people didn't have to explain the message from scratch. For instance: Informatics doesn't just explain the current, digital, world, it lets us change it; if we only taught reading, not writing, there'd be no new literature to read; Barefoot as above.

For the different stakeholders, the following challenges and messages were identified:

for the **media,** the challenge was noting that they would treat the field in a marginal sort of way. The messages to them were: that the teaching of Informatics is crucial because of the extensive digitisation and job requirements. Informatics has to be seen as a major subject that is universal, to be used within all disciplines and essential for society.

for **politicians,** the challenge was that there would be a requirement for funding and they would be pressurised to make decisions about this. Yet they were likely to be unclear about distinctions between digital skills and expertise in Informatics; it would be important to clarify that Informatics should be seen as at least as important as other disciplines such as mathematics, that Informatics should be a mandatory subject for all students and that it can help with a deeper understanding of other subjects. It has a crucial role in addressing matters such as data protection, big data, and cyber security but is also vital for economic growth.

for **the EU commission,** the challenge was to convince them to recognise the importance of Informatics. They could have vital roles in funding and in bringing together people from the member states.

for **OECD,** the challenge was to convince them of the importance of Informatics and the message was to include Informatics as an essential component of the PISA assessments

for **parents and the general public,** the challenge is that they often perceive Informatics as unimportant, and even difficult. The message to them can include information about careers and salaries as well as excitement about shaping the world of the future.

for **students**, the challenge is that there is a perception that Informatics is hard. Consequently, motivating them is the real challenge. So, in the teaching process, the relevance of Informatics to their future careers can be mentioned, as well as the use of Informatics in tackling the challenges of today's world, e.g. climate change. Informatics is a multi-faceted subject with many applications.

for **girls,** the challenges are often the gender imbalance accompanied by the suggestion that they should not study Informatics**.** The messages to them are that they can become engaged; there are applications that would be of great interest to them and often very challenging. There are interesting career prospects for them. And they have a vital role in the development of a balanced and fair society.

for **teachers**, the challenge to them is to make the subject exciting for pupils and there is ample scope for this. Evidence – based approaches can be used to convince and excite.

for **school leaders** the challenge is that the curriculum is crowded and Informatics has to be accommodated. Moreover, if Informatics is seen as a hard topic, there are issues for them about accountability through league tables. In response the messages are: use technology to make curricular delivery more efficient; teach Informatics within other subjects as well as stand-alone; promote teaching methods which have been proved to be effective.

for **employers,** the challenge is convincing them that within education every attempt is made to maintain independence, and not promoting one employer's agenda over others. The messages to them are to exercise social responsibility by ensuring a qualified workforce that can contribute to economic growth

2.2 Teacher Education

To start the discussion on Teacher Education a number of basic questions were identified:

- What should be assumed about the background of the teachers, and which teachers?
- Should consideration be given to alternative paths for teachers?
- How to engage children, how to motivate them and are there pedagogical issues here?

In connection with this topic there were a number of important issues. There is already a shortage of math/science teachers; many graduates in these subjects go to industry. Graduates with an Informatics background tend to go to industry first. In many countries now, teaching is not well respected or regarded. In terms of training teachers, it should be observed that in some countries, pre-service training, no matter what the topic, is sometimes regulated by the "education research department".

In considering answers to these questions, much will depend on the grade level of teachers; for instance, primary teachers are generalists. Bootstrapping is one approach, i.e. training in-service teachers of science, mathematics, etc.
Some Informatics graduates will return from industry but they typically need training in pedagogy, etc. Re-skilling teachers is another significant approach.

Adopting the bootstrapping approach tends to be a short-term solution, but often problematic in the long term. Basically, Informatics teachers need to possess good Informatics content knowledge.

One example of transition in Slovakia involved initially teaching mathematics teachers about Informatics on Saturdays. This was followed by providing sessions in higher education for the pre-service math teachers.

In this process, research is important. Teachers need time to prepare their teaching programmes properly and this will typically require, back-and-forth proofreading; in so doing they need to read what has been done/researched and be given the opportunity to implement new ideas. Much support can be provided through professional development, scaffolding, and supplying resources. Fundamentally, the status of teachers in the country should be improved.

In thinking about an action plan, a number of suggestions emerged:

- Define standards (with priorities to identify the core knowledge needed for a teacher to get a broader view of the field)

- Note that content knowledge is good but teachers need to also convey a way of thinking (abstraction)

- Teach progressively, core concepts, using evidence-based efficient activities and recognised didactical principles

Thought might be given to the possibility of ACM designing a teacher programme, but recognising the existence of, for instance, CSTA, BCS or code.org offerings.

In the course of discussion about Teacher Education some observations were made:

- An interesting report has just been published in the US. It provides some recommendations on the topic at hand: “Priming the Computer Science Teacher Pump” http://computingteacher.org/2018

- There will be a workshop involving among others IFIP TC3 in June in Paris: https://wikis.univ-lille1.fr/computationalteaching/wiki/actions/2019/eiah19_en/home

- The Didapro conference will bring together French speaking researchers every two years or so. The next one will be next academic year in Lille. See: http://didapro.org/7/

2.3 Curriculum

Some key questions were identified:

1. Do we need guidelines? A framework? A detailed curriculum?
2. How can we make the curriculum *for all*?
3. How to promote gender equality?
4. What content to specify?
5. Are we looking at all levels of education?

The following sub areas were further discussed.

Guidelines

Guidelines are required rather than a detailed curriculum because:

- the detailed content depends on the context and country, and
- quite detailed content specifications already exist that might be drawn on e.g. CSTA.

Starting level? It was generally agreed that Informatics can be introduced at elementary level/kindergarten provided that appropriate pedagogy and approaches are used. More research is needed to clarify which approaches are most appropriate. However, in the past, simple floor turtles or robots have been used appropriately with very young children to develop key ideas in Informatics

Content

This should address:

- Foundations of Informatics – incorporating both theoretical and experimental/practical elements at all levels.
- A "*spiral*" approach covering concepts, terminology and practical examples. This means concepts are introduced early but with practical examples and games rather than technical terms. As the curriculum spirals up to higher levels, the earlier concepts are further clarified with suitable terminology. Furthermore, new, more complex concepts come in. The context for the concepts and examples also spirals, becoming gradually more complex and varied and therefore appropriate/relevant for the age range.
- Current developments, e.g. AI, robotics, because:
  - they can be inspirational/motivational
  - they can be suited to the particular context
  - examples can be developed to cater for diversity (gender awareness in specifying the range of examples).
- Use well-established terms e.g. algorithm. Computational thinking is considered problematic owing to widely different interpretations and perhaps best avoided.

Assessment

Assessment is closely linked to the curriculum. Key action points to be considered:

- PISA. The Program for International Student Assessment (PISA) is not supported by all European countries but many consider it to provide a benchmark and would follow their recommendations and develop curricula accordingly. There are moves already to incorporate Informatics into PISA. There is more work to be done to ensure that these are incorporated appropriately. In particular, computational thinking has been discussed.

- EQF levels. The European Qualifications Framework is also controversial and is not necessarily helpful in all countries or at all levels. However, it will be useful to feed into that framework to consider how to ensure that Informatics assessment levels are appropriate.

2.4 Teaching methods

A key goal for teaching is to build a groundswell of interest, motivation and enthusiasm. In considering this, some assumptions are made for the purpose of this discussion:

- It is assumed that teachers have acquired content knowledge
- The context for projects should take into account diversity and social impact
- The expertise is in *Informatics* education, not in Technology Enhanced Learning nor in General Education. Whatever is recommended, needs to be less valid if "computer science / informatics" is replaced by the name of any other subject
- If there is too much focus on technology, teachers may associate the subject with the technology.

In pursuit of this the main challenges are to:

- Identify what the good teaching methods are and, where appropriate, develop new methods.
- Get the results out, e.g. to www.clearinghouse.edu.tum.de i.e. a clearinghouse
- Produce a list of characteristics of good teaching material ("things to enable teachers to teach the subject matter")
- Produce material written in the language of instruction, developed in contact with practitioners, and accompanied with an assessment method.

There is an important issue with the (natural and programming) language of instruction. For instance, a lot of amount of money was invested, e.g., in Italy, to properly translate code.org's material. The problem is no easier once students leave primary school. Translating language constructs (or even the method calls) inevitably leads to problems once students get out of the sandbox.

Programming / coding is a very good way of "getting hands dirty" and getting instantaneous feedback - even though this feedback is very harsh ("wrong!"). Even Unplugged involves programming an agent (usually some other student). We do not know how to properly give feedback to programming assignments, in particular on a larger scale. Greater focus has to be on the process of designing programs / solving problems.

2.5 Advocacy

The concept of advocacy is basically about communication and convincing stakeholders; thus, it includes engaging politicians, industry and universities. So, it would be desirable to make contact with universities and industry to share plan and get their agreement / approval. It would also be important to target politicians / policy makers and for this there were different groupings: European, national and regional. In some countries approach would have to be regional from the outset, as in many countries education systems are run independently in smaller regions.

Messaging to the different groups will be different depending on the audience. But what should the messages be: there should be information and a plan to convince them that

Informatics in school education is important, and there should also be information on how to make it happen.

The arguments for focussing attention on Europe initially are: no country wants to be left behind so if we work at a European level first it might be possible to get more countries on board; this would also imply that there would be fewer people for the Informatics for All coalition to target and speak to (initially). Evidence from the UK experience highlights the importance of getting different stakeholders engaged and informed (e.g. computing societies, teacher associations etc.) before approaching politicians. Within Europe, there is no one voice for Informatics; this is on the basis of having tried before but unsuccessfully.

One possible immediate approach is to make a plan and customise it to the situation in every country -- taking into account the differences in each country. There would be a need for guidelines for each country to develop (or customise) the plan. One consideration is: is there a different approach for different levels of politicians, different sectors (e.g. industry, university)?

The *Informatics for All Coalition* should approach companies and ask them to endorse the Informatics for All strategy / initiative / action plan. Ideally companies should be seen as one consortium, a representative body - so that it's not just one company voice. But it's important to have industry at the table. The policy challenge is not just for education policy makers; the policy challenges need to reference the skills gap, innovation / growth, job creation and diversity. Wider groups need to be targeted, with innovation, enterprise, job creation and diversity all being part of the conversation. The arguments for Informatics relate to labour market but also to the societal impact - giving young people the skills and knowledge to participate in future society.

Education change takes time – for example see Seymour Papert, Mindstorms. There are dangers / challenges of pushing for change too fast / too soon. But politicians tend to want quick wins (during their term of office). There is a need for a plan that includes a long-term vision, but short-term wins, and medium-term actions.

There is a need for champions from across all sectors. But support networks are also desirable, e.g. the EU School Net, CAS (CAS EU).

Diversity

Gender imbalance in Informatics at school level is a persistent problem in the west. In India and other countries in Asia the culture is different and there are often far higher female participation rates. Early exposure is key; but the critical time for girls is early adolescence due to considerations such as peer pressure, lack of role models, misinformation from parents, and career guidance. On the basis of evidence from the AP Principles Course in the US, the manner in which Informatics is presented in the curriculum and the terminology used are important factors.

In charting a way ahead, it would be important to make diversity a priority: for industry it is important to have the necessary buy-in (a common challenge) and for society at large it is also vital. Within the concept of 'Informatics for All' diversity is guaranteed but the topic must be presented in a manner that is attractive and appealing to girls. One aspect of this is recognition of the role of the programmer, with programming being the basis of the innovation chain, and crucial to the profile of the Informatics professional.

The current developments in artificial intelligence could resonate with policy makers leading to attention to ethics, social responsibility, applications to the wider workforce and sectors (law, health etc.)

3 Towards an Action Plan

In the final session there was discussion about how to reach out to stakeholders and to involve people in the various countries. Making use of the media – television, radio, news outlets etc. - could be very valuable. In advance of this it would be important to compile a list of good arguments / analogies for communicating the importance of informatics and to showcase good practices – the comment was specifically about countries that are doing well. This can have an impact on countries that are less advanced. Appealing to the competitiveness of different countries may help to push them to move faster.

It must be important to urge engagement in respective countries by helping them set up local events and activities. Setting up 'Tech clusters' - associations bringing together academia, industry and policy makers with teachers for instance – can be valuable so that provide their input can be provided. The Informatics for All Coalition can offer to come and put an international touch on it.

In all this activity it has to be stressed that teachers are key stakeholders and it must be important to engage them with *Informatics for All* and to keep them engaged. Drawing attention to existing course or professional development material can be useful. Moreover, there should be a special emphasis on politicians who are also needed, as they will not come to us.

Finally, three important observations:

- There is a need for an Informatics for All website to act as a focus for activity
- The need to build on the existing Steering Group and to have a more broadly-based network of organisations to help spread our message and signing up to the join the Coalition
- The Informatics for All Committee should embark on the preparation of an Action Plan based on the outcome of this Workshop. In so doing, account should be taken of achieving meaningful results in a defined timescale.

ANNEXES

A1. Workshop Attendees

Andor Abonyi-Tóth, Michal Armoni, Paolo Atzeni, Irene Bell, Miles Berry, Torsten Brinda, Luís Caires, Michael E. Caspersen, Paolo Ciancarini, Claire Conneely, James Davenport, Bart Demoen, Georgi Dimitrov, Panagiota Fatourou, Nuno Feixa Rodrigues, Marie-Claire Forgue, Judith Gal-Ezer, Olivier Goletti, Jürg Gutknecht, Wendy Hall, Chris Hankin, Helen Harth, Győző Horváth, Alexa Joyce, Linda Keane, Claude Kirchner, Michael Kolling, Jan Lepeltak, Ulrik Lorck, Robert McLaughlin, Kim Mens, Marios Miltiadou, Enrico Nardelli, Pierre Paradinas, Ernesto Pimentel, Pierfranco Ravotto, Alexander Riedl, Sindre Rosvik, Branislav Rovan, Robert Schnabel, Davide Storti, Maciej Syslo, Austeja Trinkunaite, Jan Vahrenhold, Ivo Van Horebeek, Ángel Velázquez Iturbide, Thierry Vieville, Mary Webb, Ali Yazici

A2. Information gathering

To provide a certain context for the Workshop, a number of initial presentations were made, reflecting developments in a range of countries across Europe. Certain restrictions (regarding length, etc) were placed on presenters, namely a time slot of 5 minutes plus at most an additional 5 minutes for questions; supplementary material could also be supplied.

The slides for these presentations (and possibly supporting material) are available at:
https://drive.google.com/open?id=1Yyur5PaT8jAglgpcNv0U3DS_j6kGOk46

An outline on each presentation follows:

Denmark *Michael Caspersen*

Within Denmark there has been an emerging political awareness of the role of Informatics education. It began in January 2016 with input from the World Economic Forum's annual meeting in Davos and has developed so that in March 2019 the Danish government will host its first Digital Summit.

A strategy based on the concepts of specialization and integration within *Informatics for All* has been adopted at all educational levels from primary school through to higher education. A new Informatics trial subject is to be launched in K-9, where students at all grade levels are to receive on the average two Informatics lessons per week.

Within this trial, four competence areas are envisaged, namely

1. Computational empowerment
   Critical, reflective and constructive examination and understanding of possibilities and consequences of digital artefacts.
   This involves attention to an analysis of technology – intention and use; evaluation; redesign.

2. Digital design and design processes
   Organization and implementation of iterative and incremental design processes considering the context of future use.
   Study here is seen to involve problem framing, ideation, prototyping and argumentation.

3. Computational thinking
   Analysis, modelling and structuring of data and data processes. This involves study of data, algorithms, structuring and modelling

4. Technological knowledge and skills
   'Mastery' of digital technologies (computer systems and networks), associated languages and programming.
   More specifically this involves attention to programming, computer systems, networks and security.

For further reading on the concept of Computational Empowerment see [Ive].

France *Pierre Paradinas*

The history of computing education at school level in France goes back many years. But around 2010-2014 there was a new start. In 2010 a decision was taken to introduce a new specialization on Informatics and scientific computing into the science strand of the senior year at school.

And again, a report from «*French Académie des Sciences*» in 2012 mention: It's urgent to not wait!

In 2015 Informatics was introduced in a number of ways:

- For pupils aged 6 to 7: an introduction to Informatics devices
- For pupils aged 7 to 10 years old: some instruction on media and information, algorithms and Informatics as a tool, and
- In middle school: the teaching of Informatics in mathematics and technologies, this covering analogue and digital information, algorithms and programs, networks, application design and development, simulation and programming in Scratch

In 2018 there was a new announcement about new reforms within the Baccalaureate:

- A general course covering the Internet, data structures, social networks, embedded systems and digital photography would be included for all sophomores and this would have a weighting on one and a half hours per week «*Sciences numériques et technologie*»;
- A more traditional Informatics course – 4 hours per week for juniors and 6 hours per week for seniors – would be introduced «*Numériques et sciences informatiques*».

Moreover, there would be a new examination (CAPES) allowing teachers to be qualified as Informatics teachers for middle school.

Germany *Torsten Brinda, Johannes Magenheim and Christine Bescherer*

To quote (with very slight adjustments) from [Bri] the authors quoted from [IFIP] what they saw as their main challenges:

- A lack of a clear understanding of Computer Science / Informatics as a school subject
- The need for Computer Science / Informatics as a distinct subject in school curricula is controversial and poorly understood
- Computational thinking, a core component of Computer Science / Informatics, is considered to be important in 21st century skills, but due to its complexity, it is difficult to implement in schools
- The development of Computer Science / Informatics school curricula is impeded by insufficient empirical evidence of student learning in order to support content

definition and sequencing
- Previous ICT curricula deliveries poorly prepared students for Computer Science / Informatics in further / higher education or professional employment
- Integrating Computer Science / Informatics across other subjects in school curricula has been ineffective
- Teacher professional development in a newly introduced Computer Science / Informatics subject is a challenge in quality and quantity
- Identifying and allocating the additional resources for teaching Computer Science / Informatics is a challenge

The authors also articulated some lessons learned and made some recommendations. In a shortened form these included:
- Make sure Ministries are reached with recommendations
- Provide some concrete recommendations, how to overcome the problem of limited resources concerning time, etc
- Decide on a qualification framework for teachers, who teach Computer Science; maybe also for those, who have to integrate CS aspects in the ordinary teaching of their subject
- Make recommendations available in different languages
- The organization and content-related linking of formal and informal educational offers is of great importance

Further details can be obtained from [Bri] where each of the challenges is explained in more detail.

Israel *Michal Armoni*

In Israel Computer Science is taught in

- Primary school starting from the 4th grade (about 9-10 years old) as a mandatory subject and is currently implemented in about 400 out of about 1800 schools. The syllabus covers: programming in Scratch in the 4th grade; Scratch and mBlocks (robotics) in 5th grade; and advanced programming in Scratch in 6th grade. Currently, teachers are not trained and there is little professional development for them.

- Junior high school (covering 7th to 9th grade) and is currently taught in 270 schools out of about 1000, as part of an elective STEM program for excellent students. It is planned to become a mandatory subject in the future. There is an introduction to algorithmics using Scratch in the 7th grade; advanced algorithmics using Python in development for the 8th grade; and for the 9th grade there are plans to develop a course on cyber security and cryptography with a final project. The teachers involved with this are mainly high school CS teachers and there is basic professional development.

- High school (covering 10th to 12th grade) where it is elective in almost all schools. The syllabus includes 540 hrs of computer science and another 540 hrs of software engineering. The computer science program includes mandatory modules (covering algorithmics, object-oriented programming using Java or C sharp, and data structures) and two flexible modules. The first is usually project based, and it addresses topics such as assembly language programming, web programming and logic programming. The second elective module is an advanced one, offering topics such as computational models and operations research. The software engineering program offers several tracks (mobile embedded systems, cyber defense systems, web services, operating systems, expert systems and graphics systems and information systems). The teachers at this level are all trained and they have a CS background.

Poland *Maciej M. Syslo*

The history of computing education in Poland dates back to 1965 but there have been significant changes in the school system in the period 1993-2017 with a major change in 2016 when a new government was installed and in 2017 when a new informatics curriculum was introduced in primary schools. There is a unified set of aims in the new curriculum, these having to be addressed in a spiral fashion through the 3 levels of education in K-12. The unified aims are:

1. Understanding and analysis of problems
2. Programming and problem solving by using computers and other digital devices
3. Using computers, digital devices, and computer networks
4. Developing social competences
5. Observing law and security principles and regulations

The challenges now are

- How to motivate and engage students through 12 years of informatics education
- The role of coding (programming) – when and how to start
- When and how to switch from visual to textual programming, more professional programming
- The core assumption: computer science classes should be about computer science: concepts, methods, algorithms, computational thinking, then computational thinking used in other areas of education

The report of the UNESCO / IFIP TC3 Meeting at OCCE in June 2018, Linz, Austria includes further perspectives from Poland.

Portugal *Luis Caires*

Although the history of Informatics education at school level dates back to the 1990s, it was in 2015 that a serious discussion started about the need to integrate earlier initiatives into the basic and secondary education, so leading to the current set of curricula development efforts. In this work the key actors are the Ministry of Education, the Minister of Higher Education, Science and Technology, Agencia Ciencia Viva (the Live Science Agency), the National Science Foundation, INCODE 2030 (see later), the academic community from the universities and ANPRI (the informatics Teachers Association).

INCODE 2030 is the Portuguese National Digital Competences Initiative. The main elements of this are

Inclusion
Making sure that the whole population has equal access to digital technologies to obtain information, communicate, and interact with others

Education
Educating the younger population by stimulating and reinforcing digital literacy and digital skills at all levels of schooling and as part of lifelong learning

Qualification
Qualifying the working population by providing them with the knowledge they need to become part of a labour market that relies heavily on digital skills

Specialisation
Promoting specialization in digital technologies and applications to improve employability and create higher added value in the economy

Research
Providing the conditions for the production of new knowledge and an active participation in international R&D networks and programmes.

The INCODE recommendations for the schools curriculum include, and to quote (with very slight changes)

- Interpreting, producing and evaluating various kinds and forms of content, which will help students to understand diverse forms of cultural communication and to build their personal identity
- Ability to use digital tools to collect, integrate and organize information, to assist creative processes, to communicate and to socialize, while developing a critical perspective
- Exposure to computational thinking from 1st grade on, using simple programming languages such as Scratch and simple robotics, as well as more abstract concepts such as simple algorithms
- Integration with interdisciplinary teaching models that exploit logical, analytical, and critical thinking, experimentation and problem solving
- Launch plot introductory programming initiatives in the 1st cycle as pedagogical projects proposed by schools
- Continue this track through the 12 years, progressing in the algorithmic complexity and programming languages used

As far as the current curriculum is concerned this is centred around four pillars, namely digital citizenship, search and research, communicate and collaborate, and create and innovate. Of these the create and innovate pillar involves (and again to quote, with very slight modification)

- Formulate everyday situations and problem solutions in terms of computational thinking and programming
- Develop digital artifacts that combine narratives with multimodal content such as music, video, and other
- Create algorithms and/or programs that use mathematical, logical or geometric concepts in calculations with objects such as sequences, patterns and regularities
- Construct interactive programs, simulating natural processes or phenomena related to the environment
- Create algorithms and / or programs that involve interaction with virtual or tangible objects and the context (e.g. create simple games)

In the meantime, there are a number of currently open initiatives, some of which will support education e.g. targeting the education of teaching staff, the development of educational materials and content, and dissemination.

UK (England mainly) *James Davenport*

The Royal Society (the UK's national Science Academy) reports:

- Shut down or restart: the way forward for computing in UK schools [UK1]
- After the reboot: computing education in UK schools [UK2]

are highly significant in the development of schools computing. There is also a very important grassroots movement with around 29,000 members: Computing At School (CAS): see https://computingatschool.org.uk
The Government's response to [UK2] was to announce a £100M investment in computing

education in UK schools. In England, £84M have gone to a new National Centre for Computing Education: https://teachcomputing.org/

England: In England the school curriculum is organised in "Key Stages" or KS. KS 1 and 2 are generally taught in primary schools (up to 11), and the rest in secondary schools (though there are local variations). KS3 lasts to roughly age 14. KS1-3 have no significant choice elements, and, since 2014, computing is a compulsory part of the national curriculum in KS1-3, and is a statutory entitlement (albeit not always delivered) up to KS4 (roughly 16), where students have a choice of 6 (or more) subjects to take to ae England-wide examination (GCSE). At KS5, students aiming for university will normally study three subjects to the England-wide A-level examinations, though other routes exist. The curriculum ensures that, by age 11, all pupils:

- Can understand and apply the fundamental principles and concepts of computer science, including abstraction, logic, algorithms and data representation
- Can analyse problems in computational terms, and have repeated practical experience of writing computer programs in order to solve such problems
- Can evaluate and apply information technology, including new or unfamiliar technologies, analytically to solve problems
- Are responsible, competent, confident and creative users of information and communication technology
- Design, write and debug programs that accomplish specific goals, including controlling or simulating physical systems; solve problems by decomposing them into smaller parts
- Use sequence, selection, and repetition in programs; work with variables and various forms of input and output
- Use logic to explain how some simple algorithms work and to detect and correct errors in algorithms and programs
- Understand computer networks including the Internet; how they can provide multiple services, such as …
- Use search technologies effectively, and be discerning in evaluating digital content
- Select, use and combine a variety of software (including Internet services)
- Use technology safely, respectfully and responsibly; recognize acceptable / unacceptable behaviours; identify a range of ways to report concerns about content and contact

And by KS3 they should be able to:

- Design, use and evaluate computational abstractions that model the state and behaviours of real-world …
- Understand several key algorithms that reflect computational thinking; compare the utility of alternative algorithms
- Use two or more programming languages, at least one of which is textual, to solve a variety of computational problems; make appropriate use of data structures; design and develop modular programs that use procedures or functions
- Understand simple Boolean logic and some of its uses in circuits and programming; understand how numbers can be represented in binary, and be able to carry out simple operations on binary numbers
- Understand the hardware and software components that make up computer systems, and how they communicate with one another and with other systems
- Understand how instructions are stored and executed within a computer system; understand how data of various types (including text, sounds and pictures) can be represented and manipulated digitally, in the form of binary digits
- Understand creative projects that involve selecting, using, and combining multiple applications, preferably across a range of devices, to achieve challenging goals, including collecting and analyzing date and meeting the needs of known users
- Create, re-use, revise and re-purpose digital artifacts for a given audience, with

attention to trustworthiness, design and usability
- Understand a range of ways to use technology safely, respectfully, responsibly and securely, including protecting content, contact and conduct and know how to report concerns

Has this been a success? About 25,000 students per year study Computer Science. However only 9685 took A levels in 2018, which is insufficient to make it a prerequisite for University entrance (about 19,000 per year study Computer Science at university). In connection with this presentation, [UK3] is also relevant.

Northern Ireland (*by Irene Bell*): January 2017 saw the dissolution of the devolved government in Northern Ireland. This has slowed the pace of discussion and progress of computing in Northern Ireland. However, Computing At School (CAS) has worked with Council for Curriculum Examinations and Assessment (CCEA), industry and fellow educators to continue offering professional development to teachers and ensuring that progression within the curriculum continues to be made. This professional development has ranged from teachers working from Foundation Stage through to GCE ‘A’-level. The curriculum is grouped under the Key Stages of Foundation stage, KS1 and KS2 for pupils aged 5 to 11, KS3 for pupils aged 11-13, GCSE is described as KS4 and GCE as KS5.
The Northern Ireland Curriculum is underpinned by the development of skills and capabilities and incorporates ‘Cross-Curricular Skills’ (CCS) and ‘Thinking Skills and Personal Capabilities’ (TSPC).
Using ICT (Information and Communications Technology), along with Communication and Using Mathematics, is one of the three statutory Cross-Curricular Skills that form part of the Northern Ireland Foundation Stage Curriculum http://ccea.org.uk/curriculum/foundation_stage and the Northern Ireland Key Stage 1 and 2 Curriculum http://ccea.org.uk/curriculum/key_stage_1_2 .
The Digital Skills curriculum for primary schools in Northern Ireland is delivered through three strands
- Becoming a Digital Citizen
- Becoming a Digital Worker
- Becoming a Digital Maker

These can be accessed at http://ccea.org.uk/digitalskills/primary. It is within the ‘Becoming a Digital Maker’ strand that the elements of programming, computational thinking and computing are housed. Logical and structured options include pupils exploring coding and programming through interaction with different types of languages and devices and ‘Digital Problem Solving’ within Creative Technology Options specifically addresses programming and computational thinking.
The curriculum assessment requirements for Using ICT are set out under the headings of Explore, Express, Exchange, Evaluate and Exhibit referred to as the 5E’s.

United States *Bobby Schnabel*

A short history capturing the major steps and influences in the development of Computer Science education at school level was presented.

The Computer Science Teachers Association had been formed in 2004, the ACM Education Policy Committee in 2006 and around 2010 the National Science Foundation launched an initiative to train 10k teachers of Computer Science.

Around that time there had been a lack of awareness both at state level and at national level of the scale of the demand for jobs in computing. Computer Science itself was struggling for recognition and inclusion in STEM legislation and policy, and there was very little Computer

Science in pre-university education.

Several events had a transformative effect on the situation

- In 2009 the concept of the annual Computer Science Education Week was created and this had the support of the US Congress
- A report entitled Running on Empty [RoE] was published by the ACM Education Policy Committee and this captured the state of Computer Science education in each of the states; this received a significant attention including in the US Congress
- Around 2010, industry became involved through the *Computing in the Core* consortium
- The College Board launched their Advanced Placement CS Principles course in 2016/17; this was several years in gestation

Then

- code.org was launched, the hour of code was launched and integrated into Computer Science Education Week by code.org
- In 2016 the *CS for All* initiative was launched by the Obama administration
- The CS Advanced Placement Exam Enrollments grew from 20, 000 in 2007 to around 136,000 in 2018
- The majority of US states have adopted standards / requirements for computer science education at school level

The lessons from this development are that progress is indeed possible. But it needs dedicated leadership. In the US the inclusion of industry was a very important, indeed a key, factor in complementing the education sector.

A3. Additional comments

To provide a more complete view of the discussions of the day, there follows a number of additional comments that arose.

Information literacy started in the high schools. But research has shown that those who took Informatics at high school were more interested in pursuing it in higher education. There is evidence of new developments in primary and middle school being rushed and implemented quickly, and of a curriculum being developed by a single person (no team involved; academics not consulted). These programs have typically not been successful with teacher resources being of poor quality and teachers being unprepared (e.g. just 30 hours of professional development).

Some challenges in introducing Informatics into the school curriculum include: finding space in the curriculum for Informatics (at the expense of other subjects?); making choices between Informatics and other discipline areas -- what to prioritise; allocating hours for Informatics since these have to come from other subjects; the professional development of teachers. The subject is changing so quickly, it is challenging to prepare the teachers in time. There has to be a balance between making changes (at appropriate pace) and the rapid evolution of the field. And in devising curricula it is desirable that theoretical aspects and practical aspects of the discipline should be intertwined.

The concept of an Informatics teacher community has to be recognised and utilised. Grassroots efforts, e.g. Scratch conferences, can play an important role. Moreover, there is an opportunity to re-use resources that are already well established and translate them; focus then instead in-country on teacher professional development and resourcing.

How Informatics is taught at university is important. The fact that it is taught from the beginning is on occasion used as an argument for waiting till university to start study of Informatics. But in other subject areas the teachers also often assume no knowledge (e.g. Mathematics).

The role of Ministry of Education staff (and councils) in influencing government has to be considered as they often don't change over time (e.g. in Poland the Council of the Ministry of Education chair has occupied this role for 25 years). There could be merit in having a stable (permanent), professional body (non -political) to advise government on Informatics education including such matters as teacher professional development.

If providing a definition of Informatics, it should accommodate the important topics of: inference and abstraction; analysis; and the mechanisation of a mathematical process. It also possesses a strong body of knowledge; perhaps a different definition is needed for different audiences (e.g. politicians, policy makers, students, teachers, parents etc.) How can we (academics) convince politicians that Informatics is important, especially at a time of education reform when there is potential for change / new space in the curriculum? It was noted that industry cannot be used to influence in some European countries.

A major challenge from an education point of view is pedagogy - do we really understand how students learn? How does their progression develop? There has been less research in Informatics education compared to other fields. And how much time should be allocated to Informatics in the school timetable?

Some students in the UK are being told not to take Computer Science before university, as their course material is likely to be repeated later in the university curriculum. The same is an issue in US. The point was then made that the main idea of primary and secondary school is to "prepare students for life" and not as much for university only - many people do not continue their education. For this reason, the possible curriculum repetition is not a key priority to address.

One commented that Informatics in high school is only meant to expose students to the discipline, so they may choose whether to continue with the subject at a later stage.

In Italy the key goal is to find more Informatics students, as well as to make sure that the subject is understood and recognised in other fields – several senior political representatives have to be 'educated' in what Informatics is.

In Poland 40.000 graduates began studying Informatics related topics – and the results was that half of them quit, which also points to making better preparatory courses available.

In Israel they did an experiment where students who had taken courses in calculus, and some who had not, were given the same new calculus course material. While the students who had already been exposed to calculus did not achieve better results than their classmates, they did turn out more motivated and engaged. In this case, the repetition of content did not seem to be an issue but instead had a positive effect on the students' development.

When focusing on setting teaching goals for Informatics, these should not be set too high, as too high expectations may lower number of students

Introducing learning with technology in kindergartens is also something that stakeholders should explore. At the same time, there is a risk in introducing Informatics too early, at too high a level.

Within TC3 of IFIP, they have been looking at curriculum for many years and came up with a list of key challenges - the full report is on their website –see [IFIP]. Key challenge identified was a lack of clear understanding of Informatics as an academic discipline. Among policy makers, teachers as well as academics this presents an underlying challenge.

A key issue is also that many people do not understand that Informatics is fundamental for explaining the digital reality around us – without Informatics digitalisation is not possible. Yet the subject is not as established as more traditional fields – Informatics is not mainstream in science. This feeds into the notion that Informatics should be introduced in schools very early on, so that it forms part of their general basic knowledge.
It seemed desirable to focus on 'demystifying' the concept of algorithms, which is one of the key areas that many are not knowledgeable about and may make Informatics less relatable.

A key priority highlighted among the participants was how to properly disseminate the Coalition's message – it is not easy to get attention in media.

In terms of stakeholders, parents of students as well as their career advisors are important to look at.

The need for finding allies outside of the Informatics field was highlighted – industry was also noted as essential for helping to push message.

It was said that in England enough thought had not been given to how every child should benefit from exposure to certain subjects, including Informatics – instead the focus has been purely to prepare students for their careers.

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