Informatics Higher Education in Europe: A Data Portal and Case-Study

ELISABETTA DI NITTO, Politecnico di Milano, Italy
ISMAEL GARCÍA-VAREA, Universidad de Castilla-La Mancha, Spain
MEHDI JAZAYERI, Universita' della Svizzera Italiana, Switzerland
DAMIAN A. TAMBURRI, Politecnico di Milano, Italy
SVETLANA TIKHONENKO, Informatics Europe, Switzerland

In a context where the demand for people skilled in Informatics is increasing constantly, analyzing data about higher education in Informatics and assessing their impact on society is of paramount importance. The goal of this paper is to offer —by way of case-study research— a data-driven perspective over how Informatics education can be studied and improved in a data driven-fashion. We present the Informatics Europe Higher Education data portal (IEHE), the first European integrated portal of educational data. The portal was created with the aim of providing the Informatics academic community, policymakers, industry and other stakeholders a complete and reliable picture of the state of Informatics higher education in Europe. In addition, as a case study, we analyze the role of Universities of Applied Science as opposed to traditional Research Universities in five representative European countries.

CCS Concepts: • **Social and professional topics → Computing education programs**; **Model curricula**.

Additional Key Words and Phrases: Computer Science Higher Education, Research Universities, Universities of Applied Science, Bachelor's Enrollment, Bachelor's Graduates, Graduation Rate

ACM Reference Format:
Elisabetta Di Nitto, Ismael García-Varea, Mehdi Jazayeri, Damian A. Tamburri, and Svetlana Tikhonenko. 2024. Informatics Higher Education in Europe: A Data Portal and Case-Study. 1, 1 (February 2024), 10 pages. https://doi.org/10.1145/nnnnnnn.nnnnnnn

1 INTRODUCTION

Informatics (also called Computing or Computer Science) and Information Technology nowadays provide the underlying infrastructure for most societal systems and services. Training of computing professionals who can imagine, design, build, and maintain such systems is, thus, an important goal of society. But what is the right training path? What are the skills to be taught considering the variety of jobs that are available on the market? Even if the body of disciplines around Informatics and Information Technologies are becoming more and more mature, a definitive answer to the above questions is still to come.

In the past 50+ years, Informatics education programs have been created and have evolved in different ways. Depending on the specific circumstances occurring in a particular country, such as the state of the economy and the proclivity toward innovation, different and even contradictory goals have been set for these educational programs. Some

Authors' addresses: Elisabetta Di Nitto, elisabetta.dinitto@polimi.it, Politecnico di Milano, Piazza Leonardo da Vinci 32, Milano, Italy; Ismael García-Varea, ismael.garcia@uclm.es, Universidad de Castilla-La Mancha, Campus Univ., s/n, Albacete, Spain; Mehdi Jazayeri, mehdi.jazayeri@usi.ch, Universita' della Svizzera Italiana, Via Buffi, 13, Lugano, Switzerland; Damian A. Tamburri, damianandrew.tamburri@polimi.it, Politecnico di Milano, Piazza Leonardo da Vinci 32, Milano, Italy; Svetlana Tikhonenko, svetlana.tikhonenko@informatics-europe.org, Informatics Europe, Binzmühlestrasse, 14, Zürich, Switzerland.

Manuscript submitted to ACM

of them have been focusing on training researchers, others engineers, others practitioners or specialists in particular areas, such as automotive or aerospace. While it is very important to make graduates available to the labor market with a variety of different skills, at the same time, it is crucial to be able to steer the education system in the long term, based on trustable and transparent impact analyses that are only possible if reliable data concerning the available curricula are collected.

Within Europe, the differences in culture, language, traditions, and histories, have certainly contributed to the formation of a diverse set of programs. This diversity can be a strength, but poses challenges to data collection and analysis about such programs. Despite these challenges, policy makers and educational administrators have the goal of comparing programs, identifying weaknesses and strengths, designing model programs, bench-marking against the best programs and designing incentives for program improvements.

Important institutions highlight the need for data-driven and institutionalized reasoning and planning over educational agendas, especially so for the most impactful jobs on the market, such as Information Technology. For example, the United Nations 2030 sustainable development agenda[1] mentions the need for “equitable and universal access to quality education" as a key —yet unachievable— driver for sustainability. The Informatics Europe Higher Education data portal (IEHE[2]) aims at offering relevant information to help defining some concrete plans toward this goal.

The IEHE builds on top of the individual European countries data sources to create the first pan-European integrated portal of educational data. Integrating quantitative and qualitative data obtained from numerous national statistical agencies and educational offices from over 20 European countries, the portal offers facilities for exploring the Informatics higher education data in Europe with a wide range of indexing options (e.g., by country, year, or educational level) as well as the possibility of manipulating and visualizing available data using Application Programmer Interfaces (APIs). The data is updated every year and is available for stakeholders to examine and analyze. Members of Informatics Europe have been using the data portal to compare their situation with that of other countries in several ways, for example:

- Benchmarking against other countries: The data portal provides a variety of indicators and metrics related to informatics higher education, such as student enrollment, degrees awarded, academic salaries, and gender balance. Members can use these indicators to benchmark their own situation against that of other countries, and identify areas where they may need to improve.
- Identifying best practices from other countries: For example, researchers can look at countries that have high numbers of female computer science students and investigate the policies and programs that may have contributed to this [6].
- Developing policies and strategies: The data portal can also help members to develop policies and strategies related to Computer Science education. For example, they can use the data to identify trends and challenges in the field and develop strategies to address them [3].
- Advocacy and outreach: Members can use the data portal to inform their advocacy and outreach efforts. They can use the data to communicate the importance of Computer Science education to policymakers, industry partners, and the general public, and to showcase the achievements of their own department or institution.

In this paper, we present the data portal and use part of it to reflect on the role of “traditional” research-oriented universities compared to those known as Universities of Applied Science.

[1] https://sdgs.un.org/2030agenda
[2] https://www.informatics-europe.org/data/higher-education/

The rest of this paper is organized as follows. In Sec. 2, we present an overview of available higher education data portals. Sec. 3 describes the IEHE. A case study to reflect the role of Research Universities compared to Universities of Applied Science across Europe is depicted in Sec. 4. Finally, in Sec. 5 we offer some concluding remarks.

2 STATE OF THE ART

Open Data portals are available nowadays in all major countries. The key objective is to make government operations more open and accountable even for laymen and non-educated citizenship. Notable examples of portals are https://data.gov wherefore all data produced or exchanged by government bodies or non-governmental agencies funded by the U.S. government can be accessed and potentially downloaded or retrieved via APIs. At a similar level and exactly in the same vein, the European Union (EU) offers the EU open data portal —https://data.europa.eu— that provides EU state-regulated data, accessible via direct querying as well as regulated API access.

Other country-level initiatives have comparable objectives and design principles and are available in several locations around the world, for example: (a) Australia (https://data.gov.au/); (b) Japan (https://www.data.go.jp/); (c) Brazil (https://dados.gov.br/) and more. Some of them are specifically devoted to providing information about education, see for instance, https://data-nces.opendata.arcgis.com/, and http://ustat.miur.it/opendata/. The main limitation of these initiatives is that they refer to a single country or geographical area.

For what concerns higher education in Informatics, two interesting initiatives are the Taulbee survey by CRA (https://cra.org/resources/taulbee-survey/), which is focusing on PhD candidates in the U.S. and Canada and on their path from their enrollment in a PhD program to their subsequent career after graduation, and the NDC survey by ACM (https://www.acm.org/education/ndc-study), which is focusing on Bachelor's and Master's students in the U.S. Both such initiatives have been a source of inspiration for the IEHE, which, however, tries to focus on a larger set of countries, covering most of Europe, and is not based on data provided by the respondents of a survey, but, instead, relies on official data provided by the governmental agencies in the analyzed countries.

From an education research or general research perspective, several papers have obtained data from the aforementioned portals —mostly focused on the U.S. population and drawing from data available on the https://data.gov portal— to reflect on the status of national governments' agendas on any number of policy-making issues, e.g., the role of race in Informatics higher education in the U.S. [5], on gender demographics [1], or enrollment trend analysis against diversity and inclusion practices [2]. For what concerns Europe, analyses on the challenges faced by Europe in education, as well as the definition of new objectives and corresponding key performance indicators are made available, among the others, by the European Commission.[3]

3 THE IE HIGHER EDUCATION DATA PORTAL

The Informatics Europe (IE) Higher Education Data Portal —namely, the IEHE https://www.informatics-europe.org/data/higher-education/— offers facilities for exploring the state of Informatics higher education in Europe with a wide range of indexing options (e.g., by country, by educational level, by year) as well as possibly manipulating available data using APIs. Below, we briefly describe the organization of IEHE, present the data available and mechanisms of the data update.

[3] https://commission.europa.eu/education/policy-educational-issues_en

3.1 Organization of the data portal

The IEHE was launched in 2019 with the goal of creating a complete and reliable picture of the state of Informatics higher education in Europe so as be of use to the Informatics academic community, policymakers, industry and other stakeholders. The portal [4] is organized in several interconnected sections which complement each other in explaining the peculiarities of Informatics higher education in over 20 European countries. The first section comprises the statistics of students enrolled and degrees awarded at Bachelor's, Master's and Doctoral (PhD) level, including gender distribution in absolute numbers and percentages, both at Research Universities and Universities of Applied Science, covering the last 11 years from 2010/11 to 2020/21. The next sections —"Subjects" and "Institutions and Academic Units"— list subject names that were used to identify Informatics study programs and show universities and academic units offering Informatics higher education in each country. The latter section includes not only traditional Research Universities (RU) but also Universities of Applied Science (UAS) for the countries where these institutions exist and offer undergraduate studies in Informatics. Some background on the specifics of the higher education systems in each country can be found in the section "Higher education systems" helping to grasp various rules, modes of recruitment, the role of universities, the status of faculties and other essential ingredients of the structure of higher education which is still not uniform across Europe. The next two sections —"Academic Titles and Positions" and "Academic Salaries"— provide the comparative analysis of some key academic positions —PhD Candidate, Postdoctoral Researcher and Professor— with corresponding employment details and estimated yearly gross salaries in selected countries. The additional sections —"Data Sources" and "References"— provide the background information regarding the sources and methods used to collect the data presented in the IEHE.

3.2 Presentation of available dataset and data visualization

One of the most important parts of the portal allowing to make cross-country and time series comparisons is the dataset showing the numbers of students enrolled and degrees awarded. Currently, it covers the last 11 years from 2010/11 to 2020/21 for 23 European countries, including the largest ones like Germany, Italy, France, the Netherlands and Spain. A user can choose one of the topics of interest —Students in first year, Students in all semesters, Degrees awarded— and the level of education according to the Bologna system —Bachelor, Master, or Doctoral (PhD). The variables available for each combination of topic and education level are:

- total number of students,
- ratio, or the number of students per 1 Million inhabitants,
- number of female students,
- percentage of female students.

These variables can be shown combined for all types of institutions or separately for RU and UAS for the countries where these institutions exist. Missing values are indicated as n.a. (data is not available at all) or tbp (data will be published in the next round of updates). For each country, the data is complemented by a footnote explaining the numbers given and any notable changes to the coverage of data through the years.

Another useful feature of the IEHE is the online data visualization tool depicting cross-country and time series comparisons directly in the EU map and bar chart graph. By specifying a level of education, topic and variable of

[4]Previous to the creation of the portal, Informatics Europe produced an annual paper report inspired by the annual Taulbee survey in the U.S. The first report was published in 2013 and covered 5 years from 2008/09 to 2012/13.

interest, type of institution, country and year, users can get maps and graphs and see recent trends in Informatics higher education in Europe tailored to their needs.

3.3 Mechanisms for updating the data portal

The portal is annually updated with the most recent data at the end of the year. In the interest of reliability, the IEHE uses data from countries where a solid and reasonably complete picture could be drawn from official sources such as national statistical offices, educational agencies or ministries. The full list of sources can be found in the IEHE section "Data Sources" [5]. The IEHE follows the definitions and concepts provided by these national agencies and reflects the national situation in the countries considered. Those aspects that are not exposed by the consulted agencies are not part of the IEHE dataset. Since each national data repository has its own structure and quite often provides all supporting information in the national language, Informatics Europe consults with its members —academics, active and knowledgeable in the Informatics field from respective countries— who help to interpret the statistics available and who understand the specificities of these countries' higher education systems. One of the main challenges in integrating the statistical data is the identification of terms used to define the Informatics discipline in different countries. A good dozen terms (presented in the IEHE section "Subjects") are used to denote what is fundamentally the same discipline, and the role of national experts here is to help with screening the terms and programs and identifying which part of them is pertinent to the Informatics field.

Academic salaries, available for selected 17 countries, are updated based on the publicly available information about pay grades and salary scales taken from higher education and research ministries, academics associations, unions, or directly from the universities. In few exceptions, when salaries are not regulated by the national governments, salary information is collected and updated by interviewing representatives of several relevant institutions. In each case, a preliminary consultation with the knowledgeable academics from the field is an obligatory step in data processing, making it a reliable and trustworthy source of Informatics higher education information in Europe.

4 CASE-STUDY: RESEARCH UNIVERSITIES VS UNIVERSITIES OF APPLIED SCIENCE

As a case study of the IEHE portal, in this section we analyze the role of Universities of Applied Science (UAS) as opposed to traditional Research Universities (RU) in five European countries. The considered countries are Germany, the Netherlands, and Switzerland having both types of institutions; Italy and Spain having only traditional RU. They have been chosen for the analysis as they represent around 30% of the total European population [7] and, therefore, the findings in terms of similarities and differences in their higher education profiles in Informatics can be considered significant enough to represent the situation in Europe.

4.1 Case study focus

In this study, we aim to explore two research questions: *RQ1: what are the core differences between the Informatics higher education at traditional RU and UAS at Bachelor's level?* and *RQ2: how do the Informatics Bachelor's enrollment and graduation rates differ between the two types of institutions in Europe, paying special attention to gender diversity?* The study covers the statistics from 2010/11 to 2020/21 academic years, which are available for most countries selected for the analysis except Spain which is missing the data on first-year students enrolled at Informatics Bachelor's programs in 2010/11-2012/13 and Italy missing the data on female first-year students in 2020/21. On the one hand, the focus of

[5] https://www.informatics-europe.org/data-portal/?page=data-sources.html

our case-study is deliberately generalist to give a birds-eye view over the potentials of the approach suggested in this paper. On the other hand, the same focus for a specific Informatics educational problem does not preclude digging deeper into more specific instances —e.g. the case for Germany educational areas[6]— to further inform any connected policy-making process.

4.2 Analysis of data

4.2.1 Core differences between RU and UAS. To offer an overview of the qualitative differences between the types of educational organizations reported using the key characteristics for higher-education, we used qualitative interview data drawn from renowned professors from the Informatics field from each country in the EU with experience with either RU or UAS respectively.

Available evidence shows the emergence of a rather polarized view of education in both types of institutions whereby RU favor research (including applied research) while UAS favor almost exclusively the creation of talent for industrial processes and product development with a core basic set of theoretical foundations being included into their own specific programs. A striking finding is that UAS emerged in the early 70'-90's and therefore can be considered young and upstarting. The enrollment numbers and success of UAS probably reflect the initial growth phase and promise considerable potential for future organizational learning from the UAS educational experience.

4.2.2 Enrollment rates at Bachelor's level. In all cases except Spain and Germany the number of first-year students has been increasing (see Fig. 1). Spain (for which the data are not available for the first three academic years) shows a steady situation because it is reaching the maximum (cap) number of available positions in the field every year. In German RU, the growth was observed until 2018/19 but afterward the number of first-year students started to decline. To conclude if it is a consistent new trend or just a temporary decline, we will have to continue observing the situation in the next two-three years. When comparing the number of first-year students between RU and UAS, in Switzerland and the Netherlands, UAS enroll significantly more new students every year than RU. In Germany the numbers appear to be equal. Another remarkable finding is the huge number of new students enrolled in Informatics Bachelor's programs at Dutch and German UAS which is almost twice as high (in the case of the Netherlands) and equal (in the case of Germany) compared to the number of new students enrolled in Italy and Spain where UAS do not exist. It shows the importance of UAS educational programs in these countries for training the qualified workforce in the Informatics field. A related issue is that in Italy and Spain, the number of students accepted in Informatics each year is capped. The impact of this policy is to limit the universities' capacity to produce graduates once the cap is reached.

Considering the share of female first-year Bachelor's students enrolled in Informatics programs, see Fig. 2, in all countries it does not exceed 25% regardless of the institution type. Looking at last three years, in Germany and the Netherlands, the female share is significantly higher than in other countries and it is also constantly growing at both RU and UAS since 2010/11, especially in the Netherlands (from 12% in 2010/11 to 24% in 2020/21 for RU and from 12% in 2010/11 to 19% in 2020/21 for UAS). In Italian and Spanish RU as well as in Swiss UAS, the share of female first-year Bachelor's students enrolled in Informatics programs is extremely low, not exceeding 16% and remains relatively stable across years. In Swiss RU, the female share was also low and relatively stable until 2018/19 and only in two most recent years has it started to increase slightly.

[6] https://eurydice.eacea.ec.europa.eu/national-education-systems/germany/overview

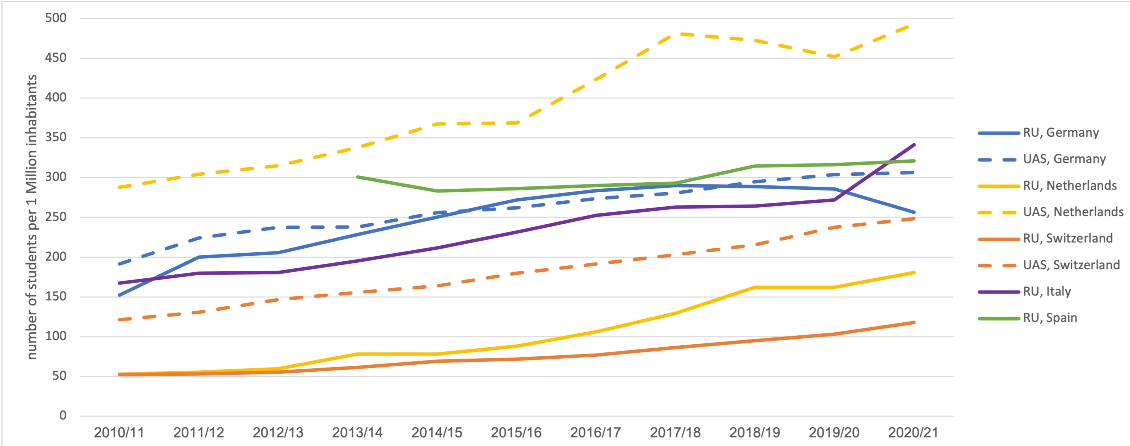

Fig. 1. Distribution of first-year students enrollment growth at RU and UAS.

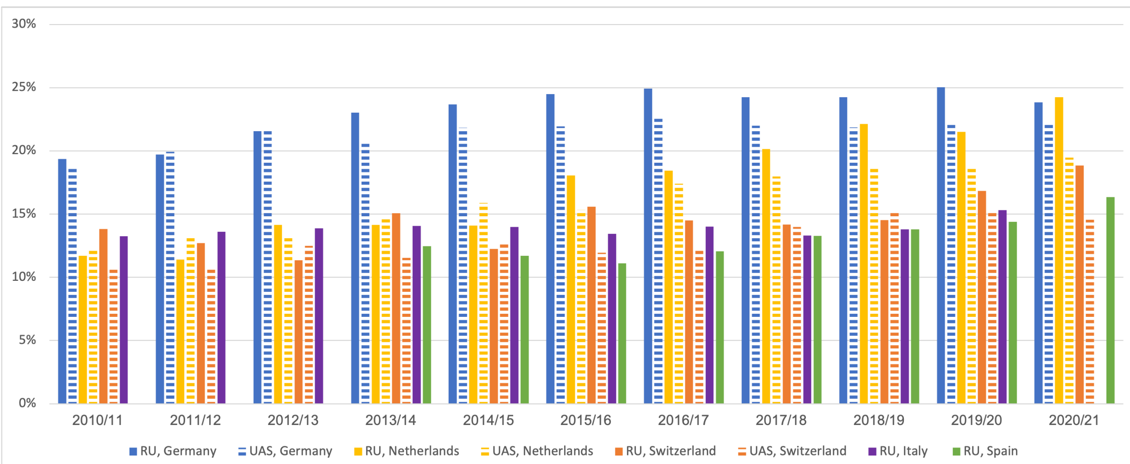

Fig. 2. Share of female first-year students enrollment at RU and UAS.

4.2.3 Graduation rate at Bachelor's level. Fig. 3 shows the rate of Informatics Bachelor's degrees awarded per million of inhabitants at RU and UAS since the 2010/11, for the five countries under study. In most of the cases, there has been an increase in the ratio of degrees awarded across years, with the exception of Spanish and German RU where a downward trend can be seen, being more marked in the case of Spain from 2011/12 to 2017/18. Concretely, Spain has suffered a decrease of around 50% of the graduation rate along this period, while in Germany this decrease is less significant. Comparing the graduation rate between countries in the case of RU, Spain and Italy have the highest ratio, followed by Germany, the Netherlands and Switzerland. Nevertheless, if the degrees awarded at UAS are also considered, the Netherlands has the highest ratio, also having the most significant increase across the years, followed by Germany, and Switzerland.

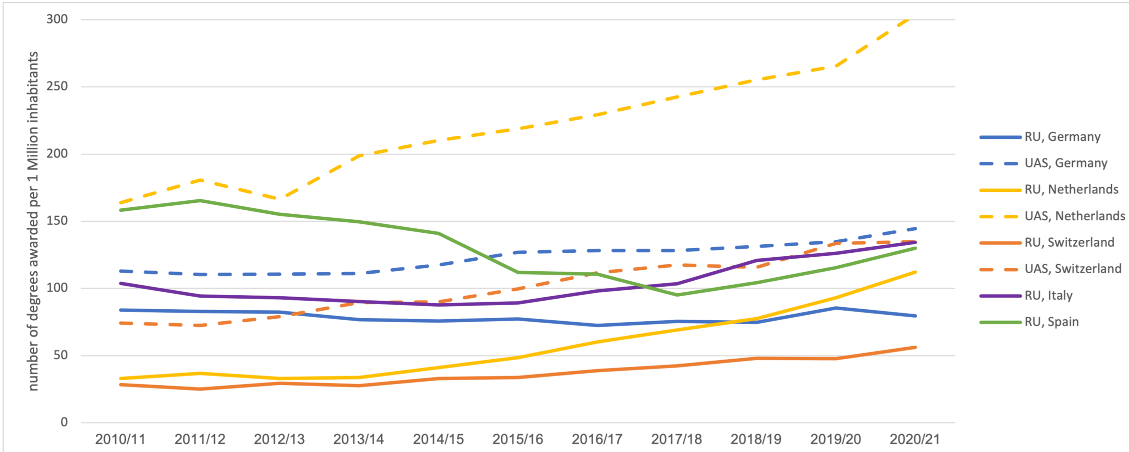

Fig. 3. Distribution of Informatics Bachelor's degrees awarded at RU and UAS since 2010/11.

Regarding the share of Informatics Bachelor's degrees awarded to women (see Fig. 4), we can see that in all countries it does not exceed 22%, regardless of the type of institution. A growing trend is observed in the case of Germany and the Netherlands, in both RU and UAS, where it reaches 21.7% in the case of UAS. In Italy, the proportion of women remains relatively stable throughout the years studied, although not exceeding 15%. In Spain a decreasing trend is observed over the years, going from being the country with the best ratio in the 2010/11 academic year (with a ratio of 21.7%) to reach less than 15% in 2020/21. In Switzerland, the proportion of women is the lowest, not exceeding 13%.

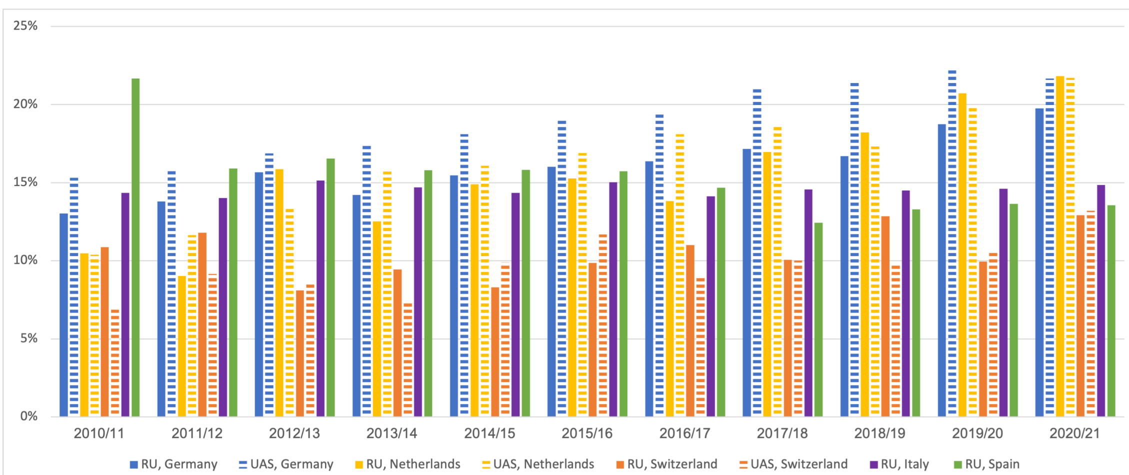

Fig. 4. Share of Informatics Bachelor's degrees awarded to women at RU and UAS since 2010/11.

Comparing the ratio between Informatics Bachelor's graduates and new students enrolled (see Figs. 1 and 3) we can see that the tendency throughout the years correlates in most of the cases and that the number of enrollments is, on average, twice the number of graduates. That indicates that the completion rate is, on average, around 50%. Comparing the completion rates between two institution types and genders, significant differences can be seen in two countries - Germany and Switzerland. To estimate it, we computed the ratio between the number of degrees awarded and the number of students starting their studies in Bachelor's programs for each year. The higher the ratio, the higher the completion rate. As it's shown in Fig. 5, in Germany and Switzerland UAS have significantly higher ratios than RU across all years. Considering gender differences, female students have lower completion rates than male students at both types of institutions. However, in Germany this gap is decreasing across years, especially at UAS where the male and female completion rates are becoming almost equal. In other countries, the completion rates are almost the same for male and female students indicating that female students do not have more difficulties in completing their studies than male students.

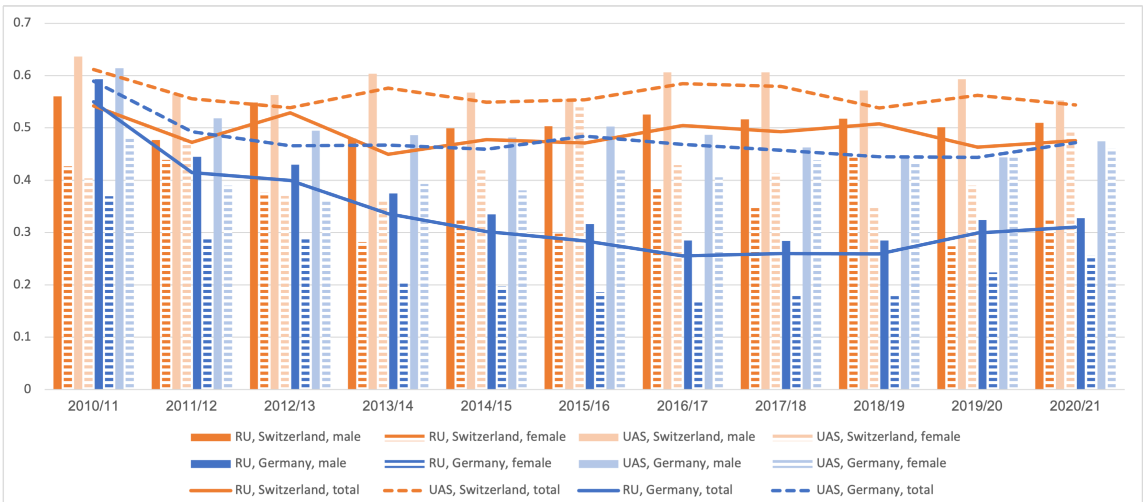

Fig. 5. Ratio between Informatics Bachelor's graduates and new students enrolled at RU and UAS since 2010/11 in Germany and Switzerland.

5 CONCLUDING REMARKS

This paper elaborates and discusses the need for coordinated and governed Computing Education initiatives of the future, a need that shall be steered in a data-driven fashion, with planning and policy-making which are equally data-driven. We give an overview of portals to illustrate such data-driven educational policy-making as well as conducting an initial case-study into how such portals and data can be used to apply specific planning and policy-making scenarios.

Overall, stemming from our initial investigation, one fact emerges: the existence and proliferation of data portals around the globe is increasing in interest, potential use, and potential impact on the practices and policies that regulate even the most basic processes of our society. While education is not different and must be paid due attention, only a few countries have fully-instrumented data portals for data-driven (educational) planning and policy-making, with fewer still and mostly US-based research initiatives to show the value of such data-driven approaches.

We conclude that the future agenda in education and training calls for a more structured approach, one that benefits from such data-driven and multi-criteria decision-making [4].

ACKNOWLEDGMENTS

The authors would like to thank the Informatics Europe (IE) association for collecting the data. Bertrand Meyer came up with the idea of collecting pan-European data and directed the data collection effort for Informatics Europe. He passed on that role to Mehdi Jazayeri in 2014. The data portal was implemented with the help of the group of Professor Cesare Pautasso at the University of Lugano and it is regularly updated by Svetlana Tikhonenko. Many people, including the authors of this manuscript, helped with the identification and interpretation of official data sources from IE member countries.

REFERENCES

[1] Douglas Baumann, Susanne E. Hambrusch, and Jennifer Neville. 2011. Gender demographics trends and changes in U.S. CS departments. *Commun. ACM* 54, 11 (2011), 38–42. https://dl.acm.org/doi/10.1145/2018396.2018410

[2] Vinton G. Cerf and Maggie Johnson. 2016. Enrollments Explode! But Diversity Students Are Leaving.... *Commun. ACM* 59, 4 (March 2016), 7. https://doi.org/10.1145/2898431

[3] European Commission, European Education, and Culture Executive Agency. 2022. *Informatics education at school in Europe*. Publications Office of the European Union. https://data.europa.eu/doi/10.2797/268406

[4] Dedire Dubois, Michel Grabisch, François Modave, and Henri Prade. 2001. Relating Decision with Uncertainty in Multi-criteria Decision Making Models. In *International Journal of Intelligent Systems*, Vol. 15. Wiley, 967–979.

[5] Mark Guzdial. 2020. Talking about Race in CS Education. *Commun. ACM* 64, 1 (Dec. 2020), 10–11. https://doi.org/10.1145/3433921

[6] Letizia Jaccheri. 2022. Gender Issues in Computer Science Research, Education, and Society. In *Proceedings of the 27th ACM Conference on on Innovation and Technology in Computer Science Education Vol. 1* (Dublin, Ireland) *(ITiCSE '22)*. Association for Computing Machinery, New York, NY, USA, 4. https://doi.org/10.1145/3502718.3534204

[7] United Nations: Department of Economic and Social Affairs. Population Division. 2019. *World Population Prospects*. https://population.un.org/wpp