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A discussion on the need for coordinated, governed, data-driven computing education initiatives of the future.

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

INFORMATICS (ALSO REFERRED to here as computing or computer science) and information technology (IT) provide the underlying infrastructure for most societal systems and services. Training 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 is maturing, definitive answers to the previous questions are still to come. Over 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 of them have focused on training researchers, while others have focused on engineers, practitioners, or

specialists in particular areas, such as automotive or aerospace. While it is very important to prepare graduates for the labor market with a variety of different skills, it is also crucial to be able to steer the education system in the long term, based on trustable and transparent impact analyses that are only possible through the collection of reliable data about the available curricula.

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 it also challenges data collection and analysis about such programs. Despite these challenges, policymakers and educational administrators aim to compare programs, identify strengths and weaknesses, design model programs, benchmark against the best programs, and design incentives for program improvements.

Important institutions highlight the need for data-driven and institutionalized reasoning and planning over educational agendas, especially for the most impactful jobs on the market, such as IT. For example, the United Nations 2030 Sustainable Development Agenda[a] 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[b]) aims to offer relevant information to help define some concrete plans toward this goal. The IEHE builds on top of data sources from individual European countries 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 more than 20 European countries, the portal offers facilities for exploring the informatics higher education data in Europe with a wide range of indexing options (for example, by country, year, or education 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.** Researchers can, for example, 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; communicate the importance of computer science education to policymakers, industry partners, and the public; and showcase the achievements of their own department or institution.

In this article, 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 (UASs).

» key insights

- **The demand for people skilled in informatics is increasing constantly; therefore, analyzing data about higher education in informatics and assessing its impact on society is of paramount importance.**
- **This article presents the Informatics Europe Higher Education (IEHE) data portal, created to provide the informatics academic community, policymakers, and industry with a complete and reliable picture of the state of informatics higher education in Europe.**
- **As a case study, we analyze the role of universities of applied science as opposed to traditional research universities in five representative European countries, and we show that the first ones have an important role in training a qualified workforce for the European informatics field.**

State of the Art

Open data portals are available in all major countries. The key objective is to make government operations more open and accountable even for laymen and non-educated citizenship. A notable portal example is Data.gov (https://data.gov), where 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) to make EU state-regulated data accessible via direct querying as well as regulated API access.

Other country-level initiatives with comparable objectives and design principles are available in several locations around the world, for example:

- Australia (https://data.gov.au/)
- Japan (https://www.data.go.jp/)
- Brazil (https://dados.gov.br/).

Some are specifically devoted to providing information about education (for instance, https://bit.ly/3rrPjwO and http://ustat.miur.it/opendata/). The main limitation of these initiatives is that they refer to a single country or region.

For the concerns of higher education in informatics, two interesting initiatives are the Computing Research Association's (CRA) Taulbee survey (https://bit.ly/3r8WkCU), which focuses on the path of Ph.D. candidates in the U.S. and Canada from enrollment in a Ph.D. program to their subsequent career after graduation; and the Association for Computing Machinery's (ACM) NDC survey (https://bit.ly/3rl60KA), which focuses on Bachelor's and Master's students in the U.S. Both 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. IEHE is not based on data provided by survey respondents, but instead relies on official data from government agencies in the analyzed countries.

a https://sdgs.un.org/2030agenda
b https://bit.ly/46h9zjO

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 drawn from data in the Data.gov portal—to reflect on the status of national governments' agendas on any number of policy-making issues, for example, 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 by the European Commission[c] among others.

The Informatics Europe Higher Education Data Portal offers facilities for exploring the state of informatics higher education in Europe with a wide range of indexing options.

The IEHE Data Portal

The IEHE Data Portal available at https://bit.ly/46h9zjO offers facilities for exploring the state of informatics higher education in Europe with a wide range of indexing options (for example, by country, educational level, year) as well as possibly manipulating available data using APIs. Next, we briefly describe the organization of IEHE, present the data available, and describe the mechanisms of the data update.

Organization of the data portal. The IEHE was launched in 2019 to create a complete and reliable picture of the state of informatics higher education in Europe so as to be useful to the informatics academic community, policymakers, industry, and other stakeholders. The portal[d] is organized in several interconnected sections which complement each other in explaining the peculiarities of informatics higher education in more than 20 European countries. The first section comprises the statistics of enrolled students and degrees awarded at bachelor's, master's, and doctoral (Ph.D.) levels, including gender distribution in absolute numbers and percentages—both at research universities (RUs) and universities of applied science—covering the last 11 years from 2010/2011 to 2020/2021. The next sections, "Subjects" and "Institutions and Academic Units", list subject names used to identify informatics study programs. They show universities and academic units offering informatics higher education in each country. The latter section includes not only traditional RUs but also UASs 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 that remain inconsistent across Europe. The next two sections, "Academic Titles and Positions" and "Academic Salaries", provide a comparative analysis of some key academic positions—Ph.D. candidate, postdoctoral researcher, and professor—with corresponding employment details and estimated yearly gross salaries in selected countries. Additional sections "Data Sources" and "References" provide background information regarding the sources and methods used to collect the data presented in the IEHE.

Presentation of available dataset and data visualization. One of the most important parts of the portal, which enables comparison across countries and time, is the dataset showing the number of students enrolled and degrees awarded. Currently, it covers the last 11 years, from 2010/2011 to 2020/2021 for 23 European countries, including Germany, Italy, France, the Netherlands, and Spain. A user can choose one of the topics of interest (first-year students, students from all semesters, degrees awarded) and the level of education according to the Bologna system —bachelor, master, or doctoral (Ph.D.). The variables available for each combination of topic and education level are:

- Total number of students
- Ratio, or number of students per 1 million inhabitants
- Number of female students
- Percentage of female students

c https://bit.ly/3ZliC0O

d Prior to the creation of the portal, Informatics Europe produced an annual report inspired by the annual Taulbee survey in the U.S. The first report was published in 2013 and covered five years, from 2008/2009 to 2012/2013.

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, which depicts cross-country and time-series comparisons directly in the EU map and bar-chart graph. By specifying level of education, topic and variable of interest, institution type, country, and year, users can get custom maps and graphs to view recent trends in informatics higher education in Europe.

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."[e] The IEHE follows the definitions and concepts provided by these national agencies and reflects the national situation in the countries considered. Aspects 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 who are active in and knowledgeable about the field from respective countries—to help interpret the statistics available and understand the specificities of the higher education systems in these countries. One of the main challenges in integrating the statistical data is identifying 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 screen the terms and programs and identify which part is pertinent to Informatics.

Another useful feature of the IEHE is the online data visualization tool, which depicts cross-country and time-series comparisons.

Academic salaries, available for 17 countries, are updated based on publicly available information about pay grades and salary scales taken from higher education and research ministries, academic 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 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.

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 UASs as opposed to traditional RUs in five European countries—Germany, the Netherlands, and Switzerland having both types of institutions, and Italy and Spain having only traditional RUs—chosen as they represent around 30% of the total European population.[7] 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.

Case study focus. In this study, we aim to explore two research questions:

- What are the core differences between informatics higher education at traditional RUs and UASs at the bachelor's level?
- How do 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 statistics from 2010/2011 to 2020/2021 academic years, which are available for most countries selected for the analysis except Spain, which is missing data on first-year students enrolled in informatics bachelor's programs between

e https://bit.ly/3PrQJzA

2010/2011 and 2012/2013; and Italy, which is missing data on female first-year students for 2020/2021. On the one hand, the focus of the case study is deliberately generalist to offer a birds-eye view of the possibilities 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—for example, the case for Germany's educational areas[f]—to further inform any connected policy-making process.

Analysis of data. *Core differences between RUs and UASs.* 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 in the field from each country in the EU who had experience with either RUs or UASs.

Available evidence shows the emergence of a rather polarized view of education in both types of institutions, whereby RUs favor research (including applied research) while UASs favor almost exclusively the creation of talent for industrial processes and product development with a core set of theoretical foundations included in their specific programs. A striking finding is that UASs emerged between the 1970s and 1990s and therefore can be considered young and upstarting. The enrollment numbers and success of UASs likely reflect the initial growth phase and promise considerable potential for future organizational learning from the UAS's educational experience.

Bachelor's-level enrollment rates. The number of first-year students has been increasing in all cases except Spain and Germany (Figure 1). Spain (for which data is 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 each year. In German RUs, growth was observed until 2018/2019, but the number of first-year students began declining afterward. To conclude, if it is a consistent new trend or just a temporary de-

f https://bit.ly/46dH3iS

Figure 1. Distribution of first-year students' enrollment growth at RUs and UASs.

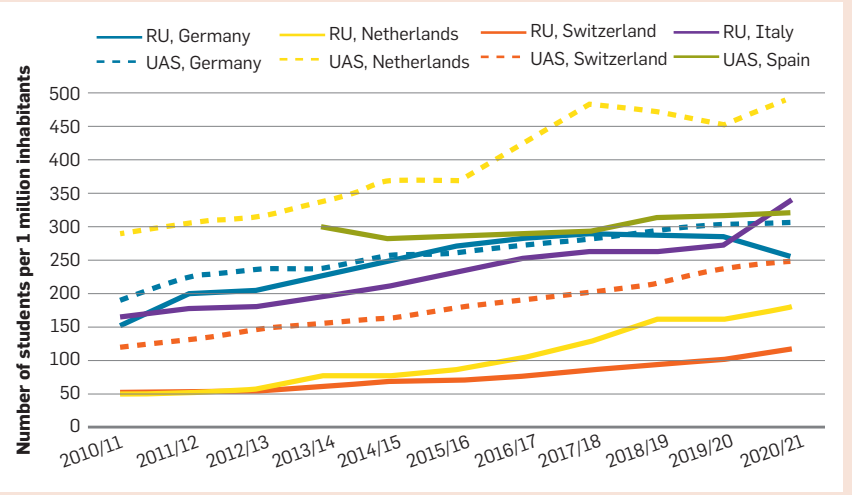


Figure 2. Share of female first-year students' enrollment at RUs and UASs.

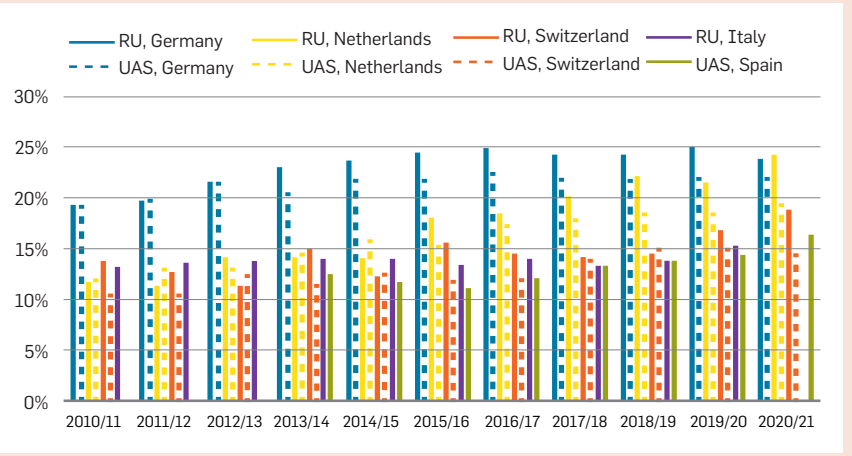
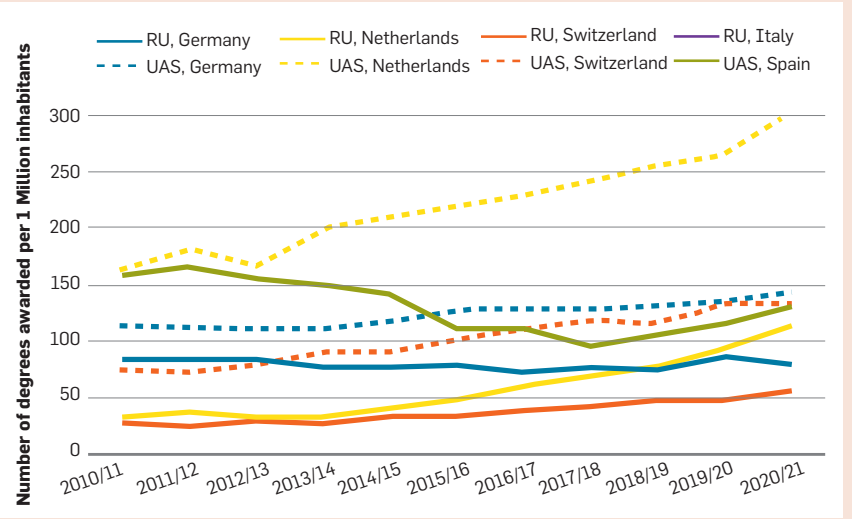


Figure 3. Distribution of informatics bachelor's degrees awarded at RUs and UASs since 2010/2011.



cline, we must continue observing the situation over the next two to three years. When comparing the number of first-year students between RUs and UASs, in Switzerland and the Netherlands, UASs enroll significantly more new students every year than RUs. 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 UASs, 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 UASs do not exist. It shows the importance of UAS educational programs in these countries to train 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.

The share of female first-year bachelor's students enrolled in informatics programs in all countries does not exceed 25% regardless of the institution type (Figure 2). Looking at the last three years, the female share in Germany and the Netherlands is significantly higher than in other countries and has been growing consistently at both RUs and UASs since 2010/2011, especially in the Netherlands (from 12% in 2010/2011 to 24% in 2020/2021 for RUs and from 12% in 2010/2011 to 19% in 2020/2021 for UASs). In Italian and Spanish RUs as well as in Swiss UASs, 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 RUs, the female share was also low and relatively stable until 2018/19; only in the two most recent years has it started to increase slightly.

Bachelor's-level graduation rate. Figure 3 shows the rate of informatics bachelor's degrees awarded per million inhabitants at RUs and UASs since the 2010/2011. In most cases, there has been an increase in the ratio of degrees awarded across years, except for Spanish and German RUs, where a downward trend can be seen, being more marked in the case of Spain from 2011/2012 to 2017/2018. Concretely, Spain has suffered a decrease of around 50% of the graduation rate during this period, while in Germany the decrease is less significant. Comparing RU graduation rates between countries, Spain and Italy have the highest ratio, followed by Germany, the Netherlands, and Switzerland. Nevertheless, if the degrees awarded at UASs are also considered, the Netherlands has the highest ratio, also having the most significant increase across the years, followed by Germany and Switzerland. Regarding the share of informatics bachelor's degrees awarded to women (Figure 4), it does not exceed 22% in any country, regardless of the type of institution. A growing trend is observed in Germany and the Netherlands, in both RUs and UASs, where it reaches 21.7% in the case of UASs. In Italy, the proportion of women remains relatively stable throughout the years studied, although never exceeding 15%. In Spain, a decreasing trend is observed over the years, going from boasting the top ratio in the 2010/11 academic year (21.7%) to less than 15% in 2020/2021. The proportion of women is lowest in Switzerland, not exceeding 13%.

Comparing the ratio between informatics bachelor's graduates and

Figure 4. Share of informatics bachelor's degrees awarded to women at RUs and UASs since 2010/2011.

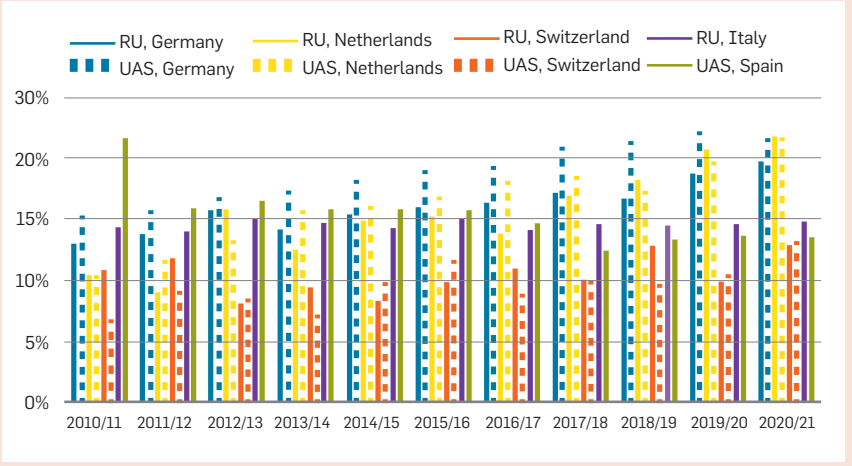
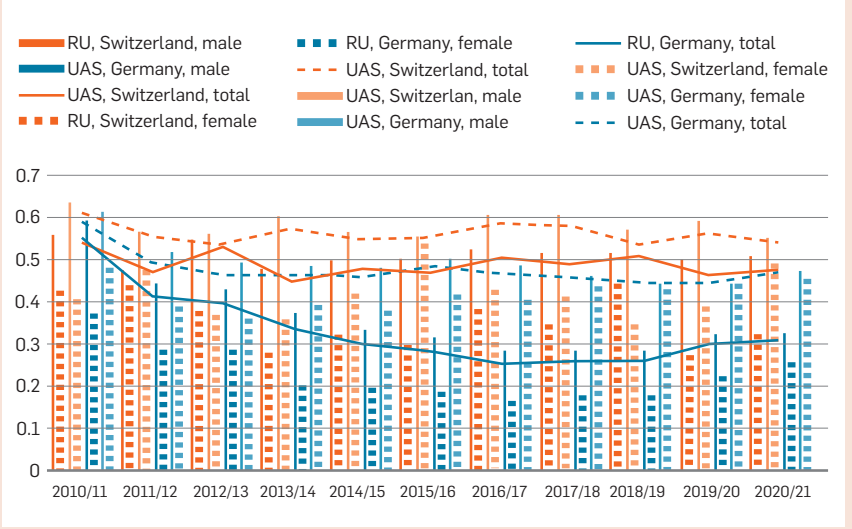


Figure 5. Ratio between informatics bachelor's graduates and new students enrolled at RUs and UASs since 2010/2011 in Germany and Switzerland.



new students enrolled, (Figures 1 and 3) we can see that tendency throughout the years correlates in most of the cases and the number of enrollments is, on average, twice the number of graduates. This indicates the completion rate is, on average, around 50%. Comparing completion rates between two institution types and genders uncovers significant differences between 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 shown in Figure 5, in UASs in Germany and Switzerland have significantly higher ratios than RUs 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 has been decreasing, especially at UASs, where male and female completion rates are becoming almost equal. In other countries, completion rates are almost the same for male and female students, indicating that female students do not have more difficulty completing their studies than male students.

Conclusion

This article 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 policymaking which are equally data-driven. We offer an overview of portals to illustrate such data-driven educational policymaking as well as conducting an initial case study into how such portals and data can be used to apply specific planning and policymaking 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 policymaking, with fewer still and mostly US-based research initiatives showing 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]

Research universities favor research (including applied research) while universities of applied science favor almost exclusively the creation of talent for industrial processes and product development.

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