ATHÉNA – a pre-university study programme for physics and mathematics at the University of Geneva

Andreas Müller*, Camille Bonvin, Anna Sfyrla*****

This programme really gives a good sense of what studying is like, and prepares us for the student experience in terms of the subject matter itself as well as life on campus. (Athéna student, 17)

Even if I don't know what to do after high school, the programme motivated me to look more into physics studies, that door remains open. (Athéna student, 19)

Logo ATHÉNA

Abstract

Athena (named after the ancient Greek goddess of wisdom) is a pre-university study programme for mathematics and physics organised by the Faculty of Science at the University of Geneva. It targets students enrolled in the final or penultimate year of Secondary level II (senior high school), giving them an opportunity to explore and discover university-level studies in mathematics and physics. The programme aims to enhance students' interest for the physical and mathematical sciences by introducing them to new topics, all while giving them a taste for student life at university. It also seeks to promote scientific careers to young students, especially to young women, as well as improving the transition between Secondary II and university.

1. What is Athena?[1]

Young people often display disaffection as well as negative emotions and attitudes towards "hard" sciences at school, and even more so towards careers in these fields. This is a considerable challenge at both international[2] and Swiss[3] levels and has deep repercussions for society. To quote, "there is a lot of work to be done […] to improve the attitudes of students, particularly girls, towards scientific subjects, studies and careers".[4] These observations are supported by a report of the Swiss Federal Council,[5] which states a worrying lack in Switzerland of people trained in the natural sciences, mathematics, and related fields. The report also underlines the particularly low proportion of women in these fields in Switzerland. Fig 1 indicates the number of women relative to the number of men at different stages of education and professional careers (gender ratio, GR). At the end of high school, the ratio is considerably greater than 1 (GR ≈ 1.4). Yet it decreases rapidly, for example, in physics studies (GR = 0.29 in Geneva). The Athena programme, organised by the physics and mathematics departments within the Faculty of Science at the University of Geneva, seeks to address these well-known problems by (*i*) attracting more young people towards studies in these fields, and by (*ii*) offering targeted support for girls (young women).

Since the academic year 2015/16, high school students have been invited to join mathematics and physics classes at the University of Geneva.[6] This opportunity for early studies is co-ordinated by Camille Bonvin and was initiated by Michele Maggiore and Andreas Müller from the physics department at the Faculty of Science. They drew inspiration from a project in Germany, where a similar initiative ("Frühstudium") had been pioneered by the University of Cologne[7] and then, with the support of a large foundation,[8] turned into a country-wide programme involving more than 60 universities.[9]

1 The present contribution is based on a previous arXiv document of one of the authors.

2 Sjøberg, S./Schreiner, C. (2011): A Comparative View on Adolescents' Attitudes towards Science. In: Bauer, M.W./Shukla, R./Allum, N. (Eds.): The Culture of Science – How the Public Relates to Science Across the Globe. New York.

3 Federal Council of Switzerland (2010): Pénurie de spécialistes MINT en Suisse. Rapport du Conseil fédéral. Bern: Federal Council, *http://www.sbfi.admin.ch/dokumentation/00335/01737/01738/index.html* based on the in-depth study by Gehrig, M., Gardiol, L. & Schaerrer, M. (2010): Der MINT-Fachkräftemangel in der Schweiz. Bern: Staatssekretariat für Bildung und Forschung SBF *http://www.sbf.admin.ch/htm/dokumentation/publikationen/uni/MINT_Schlussbericht.pdf*; 25/7/2014; Börlin, J., Beerenwinkel, A. & Labudde, P. (2014): Das MINT-Nachwuchsbarometer. Zürich: Schweizerische Akademie der Technischen Wissenschaften (SATW); Dutrévis, M., Soussi, S. & Genoud, S. (2017): Les attitudes et aspirations scientifiques des filles et des garçons à Genève. Genève: DIP/SRED.

4 Dutrévis, M., Soussi, S. & Genoud, S. (2017): Les attitudes et aspirations scientifiques des filles et des garçons à Genève. Genève: DIP/SRED.

5 Federal Council of Switzerland (2010): *loc. cit.*

6 Athéna (2020): Athéna - Programme d'Études Anticipées. Geneva: University of Geneva, Faculty of Science. *https://www.unige.ch/sciences/fr/faculteetcite/programme-athena/*

7 Halbritter, U. (2011): Ein Jahrzehnt Frühstudium an der Universität Köln. Beiträge zur Hochschulforschung, 33(1), 70–80.

8 Telekom-Stiftung (2022): Frühstudium in Deutschland – Vom Klassenzimmer in den Hörsaal / Early College – From the classroom to the auditorium: Bonn: Deutsche Telekom-Stiftung; *https://www.telekom-stiftung.de/aktivitaeten/fruehstudium* and *https://www.telekom-stiftung.de/en/activities/early-college*.

9 Deutsche Telekom-Stiftung (2018): Frühstudium in Deutschland (Befragung 2018). Bonn: Deutsche Telekom-Stiftung; *https://www.telekom-stiftung.de/sites/default/files/files/media/publications/Umfrage_Frühstudium_2018.pdf*.

The main aim is to offer students the option to discover and explore mathematics and physics studies in a stress-free environment that is perhaps somewhat off the beaten track and free from self-beliefs and gender stereotypes that prevent young women especially from considering careers in physics or mathematics.[10] The students enrolled in the Athena programme choose a course from a pre-determined list to follow during the autumn semester. The students are mentored by tutors (undergraduates, postgraduates, doctoral students, or young researchers). In the case of female students, special emphasis is placed on recruiting female tutors. The study groups are however mixed. Thanks to the tutors, the programme includes targeted support for the young students, enabling them to develop a more positive and "resilient" self-concept when faced with the intrinsic difficulty of the class content. The tutors also act as role models, known personally to the students. The female tutors mentoring female students, in particular, are a living demonstration of how to overcome gender stereotypes.

Each participant who demonstrates serious involvement in the programme receives a certificate of participation. Athena students are also free to pass examinations and, in case of success and subsequent enrolment at UNIGE, can have their course credit recognised.

Note that Athena, as a programme taking place *at university*, with its aims of providing encouragement and stress-free exploration of university-level studies, and being free of charge, is quite different from "advanced placement" programmes as, e.g., in the United States, offering college-level courses and examinations *at high school*, with a clear objective of providing distinction, and credit and placement for later college studies, and subject to a charge for exams.[11]

The Athena programme is in its seventh year at the moment of the writing of this report (for a few statistics, see the Table 1). This is thanks to considerable support from the physics and mathematics departments, the Faculty of Science, and the Dean's office at the University of Geneva, as well as to the encouraging and fruitful cooperation with the Department of Public Education of the Canton of Geneva.

2. Bringing an idea to life – practical considerations

Admission: The programme is open to all students in public or private schools following a "maturité" (upper high school) curriculum or any other curriculum

10 Federal Council of Switzerland (2010): *loc. cit.*

11 College Board (2022): What Is AP? New York: College Board; *https://apstudents.collegeboard.org/what-is-ap*.

* Institut Universitaire de Formation des Enseignants (IUFE), Pavillon d'Uni Mail (IUFE), Boulevard du Pont d'Arve 40, 1211 Genève.
E-mail: *andreas.mueller@unige.ch*
www.researchgate.net/profile/Andreas-Mueller-13
(currrrently under reconstruction)
ORCID: 000-0001-8556-2333

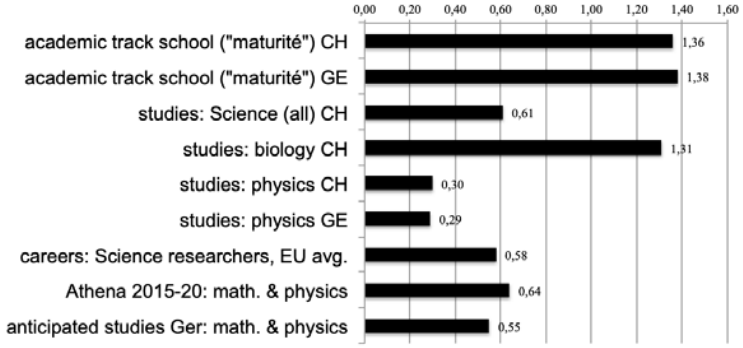
Andreas Müller, Dr. rer. nat., is full professor of science education at the Faculty of Science at the University of Geneva. Studies in Heidelberg, Grenoble, and Göttingen (Ger, F), Doctoral degree at Max-Planck-Institute of Nuclear Physics, Heidelberg, 1990. Habilitation at Institute of Physics Education/University of Gießen (Ger) 1996. Former positions: 10/1997–11/1999 Postdoc at the Institut für Pädagogik der Naturwissenschaften (IPN), Kiel, 12/1999–7/2010 Chair of Physics and Physics Education, University Koblenz-Landau (Ger). Member of: Swiss Physical Society (Board Member for Physics Education), Swiss Association of Science Education (DiNat), European Physical Society/Physics Education Board. Editorial and reviewer activities in international peer-reviewed journals, Expertise and Interest in science (especially: physics) education and science teacher education, physics/science of everyday phenomena, improvement of general interest for and understanding of physics/science.
Foto: Andreas Müller

** Université de Genève, Département de Physique Théorique, 24, quai Ernest Ansermet, 1211 Genève 4.
E-mail: *camille.bonvin@unige.ch*
https://cosmology.unige.ch/users/camille-bonvin
ORCID: 0000-0002-5318-4064

Camille Bonvin, Dr. ès Sc., is a cosmologist and associate professor at the University of Geneva. She obtained her PhD in June 2008 at the University of Geneva. She then spent two years (2008–2010) as a post-doctoral researcher at the Commissariat à l'énergie atomique (CEA) in Saclay, near Paris. From 2010 to 2014 she obtained a Herchel-Smith fellowship to work at the University of Cambridge UK, sharing her time between the Kavli Institute for Cosmology Cambridge (KICC) and the Department of Applied Mathematics and Theoretical Physics (DAMTP). She was also a junior research fellow at King's College Cambridge. From 2014 to 2016 she was a fellow at CERN. In 2016 she obtained an Eccellenza Professorial Fellowships from the Swiss National Science Foundation (formerly professeur boursier) to build her group at the University of Geneva. She was then appointed as an associate professor in 2020. In 2019 she obtained an ERC consolidator grant for the project LSSgrav: "Testing the law of gravity with novel large-scale structure observables". Scientific interests include: cosmology, in particular the study of the large-scale structure of the Universe and its use to test the theory of gravity and understand the nature of dark energy.
Foto: Camille Bonvin

*** Université de Genève, DPNC, Rue de l'Ecole-De-Médecine 20, 1205 Genève.
E-mail: *anna.sfyrla@unige.ch*
https://dpnc.unige.ch/~sfyrla/index.html
ORCID: 0000-0002-3003-9905

Anna Sfyrla, Dr. ès Sc., is a high energy physicist and associate professor at the University of Geneva. She works at the ATLAS and FASER experiments of the CERN LHC and searches for physics beyond the Standard Model. Besides her research, she is engaged in actions related to education, outreach and promotion of equal opportunities in academia.
Foto: Anna Sfyrla



Comments: (*i*) high school "maturité": young women are a majority! (comparable values at Geneva and Swiss levels); (*ii*) study choice, physics: young women "disappear" (from a comfortable majority GR ≈ 1.4 at "maturité" level, to a pronounced minority for physics, GR ≈ 0.3); (*iii*) study choice, natural sciences/biology: these values numbers show that it does not make sense to group biology, physics, etc. as "Sciences", because GR (as well as many other indicators) is completely different for physics and biology; (*iv*) careers (Swiss value GR = 0.61 is very close to EU average value): a value very similar to that of that of overall Science studies; (*v*) Athena: more than twice as large as the value for study choice; young women are interested in an exploratory programme such as Athena in a far greater proportion than currently enrolling in physics studies (the numbers are similar for mathematics).

Figure 1. Ratio of number of women to number of men (gender ratio, GR) at different stages of education and professional careers.[12]

Table 1. Basic data for the first six editions of Athena (data for the current academic year 2021/22 are not yet available).

	2015–16	2016–17	2017–18	2018–19	2019–20	2020–21
candidacies	110	85	75	70	87	57
admissions	78	74	72	64	82	56
certificates	86%	85%	79%	61%	72%	73%
credits	45%	27%	21%	28%	15%	32%

that gives access to university studies. Participation is offered completely free of charge to the students. Decisions to admit students to the programme are based on their grades and teachers' assessment. Consent is also required from the school principal, from their teacher in the subject concerned and, in the case of minors, from their parents or legal guardians. The candidate students are informed of the decision in the month of June, for admission in September.

Programme: The students selected for the Athena programme follow one or two courses at UNIGE. In principle, the courses are chosen by the students (see Table 2).

The Athena classes take place during school hours. Consequently, the students will miss certain hours of their regular high school lessons. However, thanks to active collaboration with school leadership teams, the schedule of Athena classes is designed to have as little impact on high school hours as possible. In particular, the time-tabling constraints are as follows:

- The school time-table must be designed in advance, taking into account the inclusion of the university course(s) selected by the student.
- Efforts are made to preserve the best interests of the student – their strength or weakness in a given subject – when deciding which subjects they will miss; this is determined by the school leadership, in consultation with the time-tabling office.
- Nevertheless, after their students' timetables are fixed (often during July), a high school may come to ask the Athena organizers to change the assigned course that turns out to be incompatible with their time-table. This has almost always proved possible.

School leadership can opt not to release a student from a particular class. For example, they typically refuse to release a student from laboratory sessions in the elective subjects of biology or chemistry, laboratory hours being very strongly constrained by a lack of available space. This can lead to a student not being able to follow the Athena class they had originally foreseen and having to take another instead. Such cases are determined in co-ordination with the Athena organizing team and suitable arrangements have always been agreed upon with relative ease.

In consultation with their tutor, the Athena commission for the relevant department and the leadership of their school, a participant can withdraw from the programme. This decision has no influence on subsequent admission to UNIGE.

Certificates, examinations: At the end of the course, the certificates of participation are distributed at a ceremony dedicated to the Athenians, in the company of their families and teachers. Athena students also have the option to sit examinations for university-level course credit. If they pass the exams, the credits thus acquired count towards their bache-

Table 2. Courses available currently in the Athena programme (there are year-to-year variations; e.g. there were two more advanced courses (probability and statistics; electrodynamics) in the beginning, with a self-test examination needed for entry, which are not proposed anymore).

Physics	**Mathematics**
– Physics laboratory 1	– Elementary methods
– Mathematical methods for physicists 1	– Introduction to logic and set theory
– Introduction to environmental physics	
– General Astronomy	

12 European Commission. Directorate-General for Research and Innovation (2021): She Figures 2021 – Gender in Research and Innovation. Luxembourg: Publications Office of the European Union; *https://data.europa.eu/doi/10.2777/06090*; Office Fédérale de Statistique (OfS) (2021): OFS Numbers: px-x-1502040100_103, px-x-1502040100_106. Neuchâtel: OfS. *https://www.pxweb.bfs.admin.ch/pxweb/de/px-x-1502040100_103/*; Deutsche Telekom-Stiftung (2018): *loc. cit.*

lor's degrees should they choose to enrol at UNIGE in physics or mathematics. However, in the spirit of exploration and discovery that is at the heart of the Athena programme, participating in examinations is neither expected nor mandatory.

To give the Athena programme a reliable framework, all the procedures have been formalised in a set of organisational rules, and a committee has been set up to carry out the programme.

3. Schools' perspectives

The proposal to launch the Athena programme for Geneva high school students was immediately and strongly welcomed by the association of principals of Geneva high schools (*Conférence des directeurs/directrices du Collège de Genève*). The idea was perceived as relevant and attractive, and the concept of offering particularly interested high school students the opportunity to follow a course or two at university level was deemed to have potential for encouraging the next generation, especially young women. In this way, the programme fits very well in the Canton of Geneva Department of Public Education's action plan for mathematics and natural sciences.[13]

For the *Collège de Genève*, it was obviously important to ensure a smooth integration of the programme with the curricula and timetables of participating students. The small number of problems that arose were quickly solved thanks to close co-operation with the participating schools (see above).

Since the very start of the programme, all students wanting to take part and who had received the approval of their school leadership teams have been able to follow Athena courses at UNIGE. Some have stopped part-way through. There have been various reasons for these dropouts: difficulty catching up after a period of illness, course content being very different from expectations, a lack of prerequisite knowledge, *etc*. Nevertheless, a large majority of students taking part have successfully completed the programme. Indeed, ≈ 70% to almost 90% obtained a certificate of participation. The rate of withdrawal from the programme ranges around 15–20%, which seems – given the exploratory and tentative nature of the programme – completely acceptable. In summary, the Athena programme is very well perceived by high school leadership teams, who seek to support the enrolled students as much as possible.

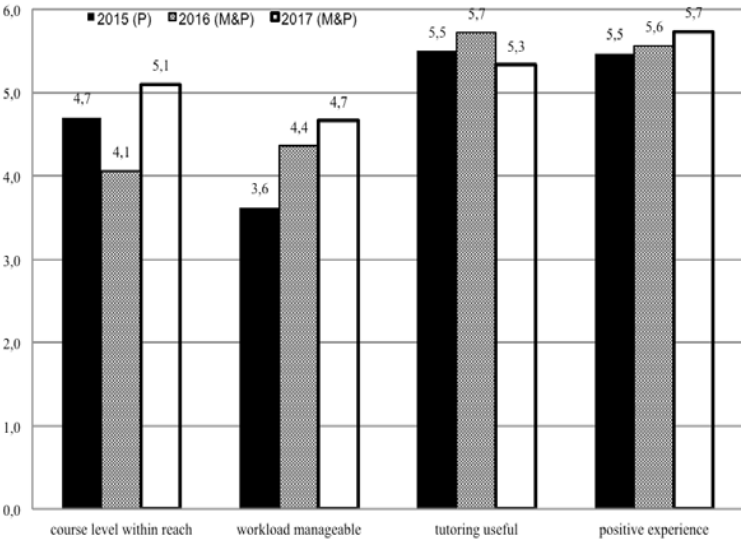


Figure 2. Perception of the educational offer, by year.

4. Evaluation

How well does Athena achieve its objectives? The followings results are based on data collected at enrolment, as well as on a more detailed evaluation of the first three editions of Athena in the period 2015/16 – 2017/18. In total, more than 400 students took part in 6 years (data from the current year are not yet available), on average 60–80 students per year (with almost 60 participants even in the main year of the Covid restrictions, 2020/21). Initially there was roughly a 50%–50% split between mathematics and physics, with a slight shift towards physics over the years.

As for the specific objective of encouraging young woman for mathematics and physics, the gender ratio over 6 years is GR = N_F/N_M = 0.64 (see Fig. 1). This value is still considerably below that of the target population ("maturité" level, overall GR ≈ 1.4), yet it is much higher than for physics studies at university level (both CH average and Geneva: GR ≈ 0.3). Note also, that generalizing statements like "Girls are much less interested in Science" etc. are quite misleading: while for Science in general GR ≈ 0.6, this value mixes very different cases like biology (GR ≈ 1.3) and physics (GR more than 4 times smaller than for biology). Speaking of "Science interest" in general, and regarding girls and women in particular, thus conceals very large differences and does not make sense.

The in-depth evaluation with the questionnaire, from which a selection of results is presented below, sought to evaluate the Athena programme's objectives in a targeted way. It was adapted from a questionnaire that had previously served to evaluate the early-study programme in Germany.[14] All of the assessment questions used a scale ranging from 1 (least positive opinion) to 6

13 Département de l'Instruction publique, de la culture et du sport (2015): "Plan d'action mathématiques et sciences de la nature"; https://edu.ge.ch/site/msn/presentation/.

14 Deutsche Telekom-Stiftung (2018): *loc. cit.*

Table 3. Athena student testimonials.

Atmosphere, perspectives
What pleased me the most is that I now have a better idea of university life: the hours, the atmosphere, the classes, the expectations of the lecturers…
I appreciated not being under pressure. Learning concepts without any negative repercussions in case of failing the exam made the learning more enjoyable. (17, f)
The option to discover the system and to understand how the university works – helps avoid making mistakes in choosing a future path. Opens new horizons. (17, m)
This programme gives a really good insight into what studying is like and prepares us for the university experience in terms of the subject itself and life on campus. (18, f)
Learning
The Athena programme is really very interesting. Surrounded by kind students, I learned a huge amount about mathematics and physics. (16, f)
It is very interesting to discover a maths class at the University of Geneva before being able to come here. This helps me put in place a method for work. In fact, I was able to notice certain mistakes to be avoided in the way I work. (18, m)

(most positive opinion). Overall, the students have a very positive view of their participation in the Athena programme (see Fig. 2, rightmost column), with an average "grade" between 5.5 and 5.7. There was no gender difference regarding this or any of the following points.

Three questions were about the difficulty level and the workload of the courses, and the support available from the tutors as specific characteristics of the educational offer (see Fig. 2). In response to the item "the level of the course was achievable for me", the degree of agreement was acceptable (between 4 and 5; it improved by certain adjustments made between the 2016/17 and 2017/18 editions of the programme). The perception of the workload was also improved over the years by organisational adjustments. However, the standard deviations (not presented here) show a considerable variation among the sample: for many participants, the workload is perceived as very heavy. Given these indicators of the workload and the difficulty of the courses, it is encouraging to note the very positive perception of the tutor support.

It is also important to know whether participating in the Athena programme has an impact on the students' school results, whether positive (by stimulation) or negative (by overloading). A few questions thus dealt with these aspects (on a scale from –2 = very negative impact, through 0 = no impact, to +2 =very positive impact). In the subject corresponding to their Athena studies (physics or mathematics), the students generally perceive the impact on their school results as positive (+0.8). For other school subjects, the programme is perceived as having almost no impact (–0.1). This result is all the more important given the heavy perceived workload (see above).

Comparing with the German programme,[15] the following aspects are worth noting. First, enrolment there is almost by a factor of 10 lower (math: 6; physics: 5; average over participating universities) than in Athena (see Table 1). This is consistent with the different objectives (and more selective admission) of the German programme, see below. Second, there is a very high level of satisfaction in both programmes, with the value for Athena even being slightly higher (Germany: 5.05[16], Athena: > 5.5). Third, the German programme reports a fraction of participants obtaining credits (i.e. passing the exam) for their course of choice larger than 40% (among 27 universities where data are available),[17] while Athena is somewhat below this value (rather 20%–30%, see Table 1[18]). Fourth, the gender ratio in Geneva is higher than in the German programme (GR = 0.55). We interpret these points as consistent with Athena's objectives, i.e., a focus on stress-free exploration, and course success (credits) as an option of secondary importance.

These quantitative results are complemented by a few qualitative comments, obtained in an "open answers" section included in the questionnaire, such as those at the beginning of Sect. 1, or the examples in Table 3, and which provide further evidence the Athena programme is indeed perceived by students in accord with its objectives.

5. Conclusions

From a look on a few perspectives from recent research and expert reports a consistent image emerges of why and how anticipated study programmes can help young people for the critical transition phase from high school to university.[19]

According to a large-sample study ($N > 6000$ students; $N = 60$ universities) by a German centre for research on higher education, a large majority of students expresses

15 Deutsche Telekom-Stiftung (2018): *loc. cit.;* Solzbacher, C. (2008): Frühstudium – Schüler an die Universität. Empirische Studie (Deutsche Telekom Stiftung, Bonn).

16 Obtained by transforming the German „grade scale" (best to worst: 1 to 6) to the one used here (6 to 1).

17 Deutsche Telekom-Stiftung (2018): *loc. cit.*

18 Certain values (gender ratio, sitting of examinations) display considerable year-to-year variation – a topic of further investigation.

19 For further background and another example regarding that issue see also the contribution on a mathematics bridging course by Giamarchi *et al.* starting on page 76 of this issue.

considerable lack of information when beginning their university studies; only roughly ⅓ of students say they had sufficient information about the studying conditions and level requirements for their discipline (36%, 32%, respectively); for mathematics and science this percentage was even lower.[20] This is consistent with an in-depth study specifically on student dropout in physics, where lack of information and false expectations were major reasons to quit.[21] Similar findings are also reported from the United States, concluding that realistic expectations are an important factor for a successful transition into university after school; moreover this study provided evidence that anticipated study programs have indeed to the potential to improve this transition.[22]

Consequently, Heublein *et al.*[23] also emphasize the importance of schools and universities drawing attention to offers like Athena as sources of experience and information. This is certainly one of the points where the close cooperation of the two "worlds" as described in Sect. 3 gains its full importance.

By way of conclusion, and in light of this background and the data and experience with seven editions of the Athena programme, it is safe to say that it has gone beyond the "proof of concept" stage. Indeed, in 2016 Athena won the Credit Suisse Award for Best Teaching.[24] The offer continues to this day, to the satisfaction of students and of the *Conférence des directrices et directeurs du Collège de Genève*. A report co-authored by Madeleine Rousset Grenon, member of the latter commission till 2017, with a focus on the collaboration with and the perspective of schools is available in French and German.[25] Interviews with three female Athena students confirm the positive perception of the programme.[26] Since this year there is an offer of a continuation of the programme, called Athena plus, which gives a first overview of the research carried out at the University of Geneva, and in which students read and work on a scientific paper with the help of a tutor. There are four topics on offer: particle physics (Higgs boson and its recent discovery); theoretical physics (gravitational redshift and its measurement); applied physics (coexistence of several possible climates for given external conditions); quantum matter physics (super-conductivity).

Participants of the Athena programme, especially young women among them, benefit from this opportunity through its various facets: encouragement (for studies in physics and mathematics), stimulation (the courses and their content, the contacts, the immersion), and a welcoming atmosphere. Continuous feedback from and discussion with all partners (students, schools, university) will be help to further improve and extend in the future. ■

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20 Heublein, U., *et al.* (2017): Zwischen Studienerwartungen und Studienwirklichkeit. Hannover: Deutsches Zentrum für Hochschul-und Wissenschaftsforschung (DZHW).

21 Albrecht, A. (2011): Längsschnittstudie Identifikation von Risikofaktoren für einen erfolgreichen Studieneinstieg in das Fach Physik. Dissertation, Freie Universität Berlin.

22 Bailey, Th.; Hughes, K.; Karp, M. (2002): What role can dual enrollment programs play in easing the transition between high school and postsecondary education? Paper commissioned for «Preparing America's Future: The High School Symposium». Washington: Office of Vocational and Adult Education; *https://files.eric.ed.gov/fulltext/ED465090.pdf*.

23 Heublein, U., *et al.* (2017): *loc. cit.*

24 Le Journal de l'UNIGE (124, 17/11–1/12(2016) : Le programme Athéna récompensé pour son enseignement novateur. *https://www.unige.ch/lejournal/numeros/124/article5/*

25 Müller, A., & Rousset-Grenon, M. (2020): ATHENA – un programme d'études anticipées pour les élèves des écoles de maturité à l'université de Genève ; ATHENA – Frühstudium an der Universität Genf für Schülerinnen und Schüler an Gymnasien. Gymnasium Helveticum, 74(4), 24.

26 Golubeva, E., Lei, S., Nguyen; H.T., Lirot, M. (5/2020). SwissMAP Perspectives. Journal of The National Centre of Competence in Research "SwissMAP – The Mathematics of Physics" (Special Edition: Outreach & Education), 38–41. *https://www.nccr-swissmap.ch/application/files/2415/9128/8586/Perspectives2020_Lt.pdf*.