Who are today's astronomy students?

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We compare the level of general astronomical knowledge among 3rd-grade high-school students declaring their interest in astronomy to the level of the same knowledge among newly recruited astronomy students. Then, we discuss the observed differences between astronomy students at different Polish universities. Finally, we provide recommendations for improving the process of passing knowledge from academic teachers to the students.

1 Introduction

Each year, more than one hundred high school alumni start astronomy studies at Polish universities. What is their understanding of the Universe we live in? What is their knowledge of basic astronomical facts? Are the candidates for astronomy those high-school students whose knowledge of the Universe is the highest? How efficient is the University recruitment system in selecting the best candidates for the studies? And finally, how well are we, the faculty members, prepared to pass knowledge to the new generation of students?

The first attempt to quantify the level of the high-school students' understanding of the Universe was made by Muciek et al. (1991, 1994). In 1989, those authors carried out a survey among 994 students from five high schools in Bydgoszcz, Poland (two lyceums and three technical lyceums). Their survey had a form of a questionnaire which consisted of 20 sentences (see Muciek et al., 1991; Molenda-Żakowicz & Kołmański, 2019a,b) which had to be verified by the high-school students to be true or false. The respondents could also select the 'I do not know' option which was counted as an incorrect verification. The maximum score in that questionnaire was 20 points.

In 2018, Molenda-Żakowicz & Kołmański (2019a,b) repeated that survey among 959 students from nine high schools in seven Polish cities, adopting the same methodology of evaluation of their answers as in Muciek et al. (1991, 1994). As a result they showed that, although the mean level of astronomical knowledge among high school students seems to be higher than 30 years ago (we note that these two surveys targeted quite different populations which is why a direct comparison of their results is rather difficult), the problems noticed by Muciek et al. (1991, 1994), i.e., that fact the girls' score is noticeably lower than the boys', have not disappeared. Moreover, Molenda-Żakowicz & Kołmański (2019a,b) identified new issues, for example the fact that high-school students in small towns get a significantly lower score compared to the score of high-school students from bigger cities.

In this paper, we focus on those 3rd grade high-school students of the 3-years-long lyceums who have declared an interest in astronomy, and who as such can be considered as potential candidates for astronomy studies at university. We compare the properties of that sample with the properties of the sample of the just-recruited

	N	$N_{\rm M}$	$N_{\rm F}$	$\tilde{X}$	$\tilde{M}$	$\tilde{F}$
high-schools: summary	96	60	36	16	16	14
universities: total	111	63	48	16	17	14.5
UW	23	15	8	17	18	16
UJ	22	13	9	16	17	15
UWr	49	28	21	16	16.5	14
UAM	17	7	10	14	17	10

Tab. 1: Summary of the results of the survey carried out among high-school students from seven lyceums and astronomy students from four Universities. The columns contain: the type of the sample, the total number of respondents (N), the number of male ($N_{\rm M}$) and female ($N_{\rm F}$) respondents, the median of the good answers in the whole sample ($\tilde{X}$), and in the male ($\tilde{M}$) and female ($\tilde{F}$) sub-samples.

students of astronomy in order to address the questions related to finding an optimal approach to passing knowledge to the new generation.

2 Description of the sample

2.1 High schools

Among the 317 surveyed 3rd-grade high-school students from LO[1] I in Gorlice, LO III in Kalisz, LO I in Kołobrzeg, LO I in Sulęcin, and LOs V and XIII in Wrocław, only 96 declared their interest in astronomy (hereafter 'high-school students'). Table 1 provides the basic statistics of the responses collected from that sample, i.e. the number of respondents and their median scores. We note that although the median of the correct verifications of the sentences in the questionnaire (hereafter 'good answers') provided by the whole population (16) is higher than the level of 15, which was adopted by Muciek et al. (1991) as the lower limit of the 'elementary astronomical culture of every high-school alumnus', the median score of the female students (14) is two points lower than the score of the male students (16).

A more detailed illustration of the statistical properties of that sample is provided in the left panel of Fig. 1 which shows box plots containing good answers provided by the male and female high-school students. In that figure, each box contains 50% of the respective measurements; the remaining 50% are indicated with horizontal lines and the outlying points, with dots. The median values are indicated with a vertical line in each box. The thick red line at the value of 7 indicates the level below which the respondent's astronomical knowledge is considered to be very low, while the thick green line at the value of 15, the level above which the respondent's astronomical knowledge is considered to be satisfactory (cf. Muciek et al. (1991)).

2.2 Universities

In order to see if the properties of the surveyed high-school students are reproduced in the population of the present astronomy students, in 2019 we carried out the

[1] LO = *liceum ogólnokształcące*, a general-education high-school/lyceum.

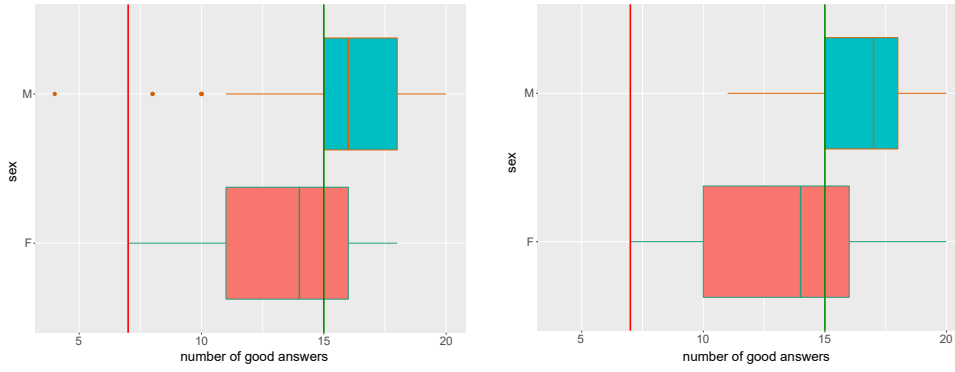

Fig. 1: The box plots of the good answers provided by 96 high-school students (left panel) and 111 astronomy students (right panel). The red box refers to women, the blue to men. Each box contains 50% of the measurements. The remaining 50% measurements are indicated with horizontal lines. Outlying points are indicated with dots. The median values are shown as a vertical line in each box. The red line at the value of 7 indicates the level below which the respondent's astronomical knowledge is considered to be very low. The green line at the value of 15, the level above which the respondent's astronomical knowledge is satisfactory.

same survey among 111 just-recruited students of astronomy at four Polish universities: the University of Warsaw (UW), Warszawa, the Jagiellonian University (UJ), Kraków, the University of Wrocław (UWr), Wrocław, and the Adam Mickiewicz University (UAM), Poznań. In the remaining part of this paper that groups is called 'astronomy students'. We note that the Mikołaj Kopernik University (UMK) in Toruń did not participate in our survey, and that at the UWr the survey was conducted also in 2018.

As shown in tab. 1 and Fig. 1, the median scores of the male and female astronomy students are only slightly higher than the scores achieved by the male and female high-school students. That means that when recruiting astronomy students, we do not select the best high-school alumni but rather those who are just slightly better than an average high-school student vaguely interested in astronomy.

A more detailed outlook on the analysed sample is provided in Fig. 2 and the bottom part of tab. 1, which provides the median scores of the male and female astronomy students at each university. We find that the median scores of the male students do not change significantly from one university to another. At the same time, the scores of the female students seem to be correlated with the rank of the University (see, e.g., Perspektywy, 2019), i.e. the higher the university rank, the better are its female students. As a result, when it comes to calculating the median level of knowledge of all astronomy students at a given university, the most important factor affecting the result is the level of knowledge of the female students.

An even more detailed overview is provided in Fig. 3 which shows how the scores of the male and female astronomy students at different universities depend on the population of the city where their high school are located (the number of citizens and the categories of cities were adopted from Central Statistical Office, 2019). The conclusions which can be drawn from Fig. 3 are less certain due to the size of the analysed sample. However, the first observation which can be made is that there are

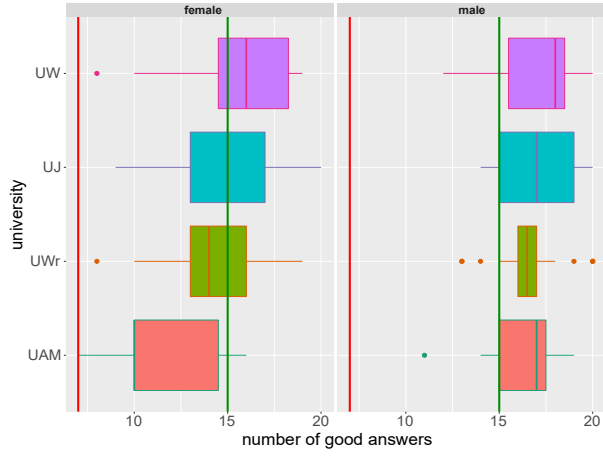

Fig. 2: Box plots of the good answers provided by the male and female students of astronomy at the four universities which participated in this survey. The meaning of lines and symbols is the same as in Fig. 1.

noticeably fewer male students (5) coming from high schools in cities whose population is smaller than 10,000 than there are female students (9). That observation may be an artefact resulting from an analysis of a very small sample or a fact related to the known phenomenon of unequal migration of men and women from villages and small towns to the big cities or abroad (see, e.g., Duda-Mikulin, 2013; Krzyworzeka, 2018), in this case, via the university .

Fig. 3 shows also that at the UW, the number of astronomy students from cities with a population less than 50,000 is negligible (one person) while at the other universities the fraction of students from small and very small cities is significantly higher.

Another observation, based on Fig. 4, is that while UW, UJ, and UWr recruit students from relatively distant cities, in UAM, most of the students come either from Poznań or from the local area. Further studies, which are planned by us for the next years, may answer if the reported observations are real effects.

3 Summary and conclusions

In 2018 and 2019, at four Polish universities, we carried out a survey consisting of a questionnaire of 20 sentences which correctness had to be verified. Each correct verification added one point to the total score. As a result of that study, we found that when the knowledge of the 1st-year astronomy students (in this paper: 'astronomy students') is compared to the knowledge of the 3rd grade high-school students declaring their interest in astronomy (in this paper: 'high-school students'), the difference between their scores is smaller than might be expected.

Our investigation showed that the median score of the astronomy students (16 points), which is only slightly higher than the low level of the satisfactory score set to 15 by Muciek et al. (1991), is the same as the median score of the high-school students, and that the difference between the median score of men and women, in

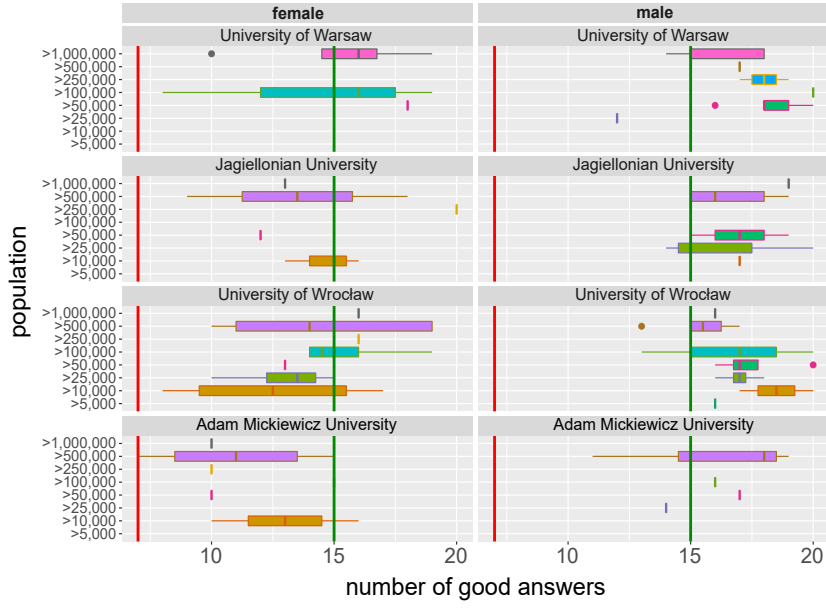

Fig. 3: Box plots of the good answers provided by the male and female students of astronomy. The vertical axis provides information about the population of the cities in which the students' high schools were located. The meaning of lines and symbols is the same as in Fig. 1.

favour of the men, first noticed by Muciek et al. (1991), still persists.

Therefore, we concluded that the astronomy students in Poland may be only slightly better equipped for those studies than an average, but interested in astronomy, high-school student who plans to become an astronomy student, and that still a lot of work has to be done to improve the results obtained by the female students.

We noticed also that when it comes to astronomy students at different universities, there are significant differences in their median scores. Interestingly enough, the median score of the male population at each university is rather constant and close to 17, but there is a clear trend in the female population. We found that the best-performing women attend the highest-rank university in Poland, i.e., the UW. Answering the question whether this situation is a consequence of an efficient recruitment algorithm used at the UW, or there are other factors which influence the median scores, is interesting, however, beyond the scope of this paper.

Our final remark is that the teaching programme at the first year of astronomy studies should take into account that fact, that the level of astronomical knowledge and understanding of the Universe among the 1st-year students may be lower than might be expected. For example, our survey showed that almost 50% the 1st-year astronomy students did not know if the full Moon is closer or further from the Sun than the Earth. Such flaws are easy to correct during the basic courses of astronomy, providing the teacher knows that such relatively obvious facts, which should have been taught at school, need repetition or additional explanation.

Therefore, in order to facilitate the process of passing knowledge from the aca-

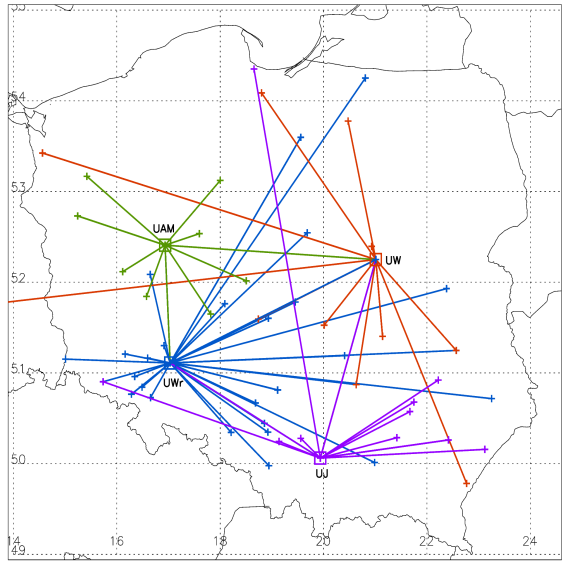

Fig. 4: Locations of high schools attended by the astronomy students. Red lines and symbols: students at the UW, purple: students at the UJ, blue: students at the UWr, and green: students at the UAM. The red line reaching beyond the plot indicates a city in Germany. The number of students originating from the same city as the attended university is 9 (39%) at the UW, 6 (27%) at the UJ, 12 (24%) at the UWr, and 6 (35%) at the UAM.

demic teachers to the students, we recommend carrying out the questionnaire used in our survey (see Muciek et al., 1991; Molenda-Żakowicz & Kołmański, 2019a,b) at the beginning of each 1st year 'Introduction to Astronomy' course (or similar) and then, based on its results, efficiently filling in the gaps in the students' knowledge.

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