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The Cosmic Trail

Learning astronomy by walking

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Innehållsförteckning

The pedagogical idea

The project aims to engage astronomy students in the contents of selected courses by encouraging them to complement their theoretical knowledge with real-life experiences, in the form of interactive walking trails. In astronomy, it is evidently very hard, perhaps impossible, to find a true physical representation of the time and length scales of the Universe. The cosmic trail will serve as a tool for students to hone their intuition of a notoriously unintuitive cosmos by connecting theory with the experience of real-life length scales. Furthermore, the completion of the walking trails requires the students to answer questions and solve puzzles related to the subject of the course in which the trail is implemented, which will further help them to tie the subject matter to their physical experience.

Wrapping one's brain around the time and length scales of the Universe is notoriously hard. Who can honestly claim that they have a good grasp of just how long 13.8 billion years (the age of the Universe) really is, or how far a distance of 100 000 light years (≈ 9.5e20 m, i.e. nearly a thousand-billion-billion meters; the length scale of the Milky Way galaxy) is? Because of the mind-boggling numbers used in astronomy – far detached from the length and time scales of everyday life – it is very common for astronomy students (even up to the MSc level and beyond) to harbour serious misconceptions about the typical distances between astronomical objects, their relative sizes, the time required to travel or send signals to various destinations in space, the duration of recorded history compared to the cosmic time line etc.. For example, what is the typical distance between stars? Many students seem to think that most stars are located quite close to each other. In a scaled model of the Universe in which a typical star is the size of a golf ball, many students envision the nearest stars (golf balls) to be just a few tens of meters away, i.e. well within sight range. This reveals a length-scale misjudgement by many orders of magnitude - in reality, the closest such neighbouring golf ball would be more than a thousand kilometres away! Many similar misconceptions on astronomical length scales among students have been documented by Miller & Brewer (2010, International Journal of Science Education, 32:12, 1549). One interesting way of getting students to develop a more realistic intuition about the spatial and temporal scales of the Universe could be through the use of outdoor science trails. From the standpoint of constructivism, it seems reasonable that the physical experience (e.g. fatigue experienced after walking through a scaled model of the Universe) may help the students to build a more accurate internal map of the various scales of the cosmos. A very nice example is given by the TimeTrek (Lehto et al. 2013, International Journal of Astrobiology, 12, 1) at Tuorla Observatory in Finland, where a 13.7 km nature trail with information signs will lead students through the history of the Universe and the Earth. However, having a fixed physical trail comes with many practical disadvantages, as this makes it cumbersome to maintain and update. In the case of TimeTrek, huge boulders had to be moved to various places along the track, and about 80 brass plates were manufactured during the design phase. Here, we instead intend to develop a set of virtual trails that students can follow using the geotracking capabilities of their smartphones. As the students walk along these trails, they will not only receive information on objects, locations or important events in the history of the Universe when reaching certain coordinates, but also be faced with quizzes and puzzles related to the course content and their chosen track. Hence, our project is more similar to the

eTrek project currently being developed at Tuorla observatory (Lehto et al. 2019, International Symposium on Education in Astronomy and Astrobiology, Utrecht, the Netherlands, Edited by Deustua, S.; Eastwood, K.; ten Kate, I.L.; EPJ Web of Conferences, Volume 200, id.01020), than their original nature trail. In our developed virtual walking trails for three of our most basic astronomy courses – *Introduction to astronomy (Orienteringskurs i astronomi), The structure of the Universe (Universums byggnad)* and *Searching for extraterrestrial intelligence (Sökandet efter intelligent liv i rymden).* These also represent the three astronomy courses Uppsala University with the largest number of students (more than 50 students each). All of these courses are suitable for outdoor activities, as they are always offered in the period from March-October (period 1, period 4 and during the summer).

Relation to earlier work

Recent years has seen a growing trend in student-centered learning where the focus is shifted towards the students own commitment to acquiring knowledge. In this project, one similarly requires students to get involved in a learning experience that goes beyond traditional lecturing. The students are encouraged to visualize concepts which are hard to grasp without novel ways of putting them into context. Literature has shown that combining spatial localization with learning has positive effects on the students learning (see e.g. Miller et al. 2013, Science, Vol 342, p. 1111-1114; and the ERASMUS+ project – Non-formal learning: Scavenger hunts, see link; http://www.increase-erasmusplus.eu/wp-content/uploads/2017/01/scavenger_hunt_report_final.pdf or webpage; http://www.increase-erasmusplus.eu/). As already mentioned in the earlier section, walking trails of this kind have also been developed on a University level in Lehto et al. (2013, 2019).

The walking trails

We developed three different walking trails, one for each of the basic astronomy courses; *Introduction to astronomy* (5 ECTS), *The structure of the Universe* (5 ECTS) and *Searching for extraterrestrial intelligence* (5 ECTS). We constructed one trail about the past history of the Universe (where the path served as a time axis, similar to the Finnish TimeTrek) for *Introduction to astronomy*, one about length scales within the Milky Way (for the course - *Searching for extraterrestrial intelligence*) and one about the future of the Universe (for the course - *The structure of the Universe*). Two of these tracks run from the centre of Uppsala downstream along Fyrisån towards Ultuna, and from the centre of Uppsala to the royal mounds of old Uppsala. The third track – the one about the future of the Universe – feature alternative paths depending on the ultimate fate of the Universe (which remains undetermined, due to the incomplete understanding of dark energy which dominates the energy budget in contemporary cosmology). In this trail, the students may choose freely among the different paths and may even choose to complete more than one of these.

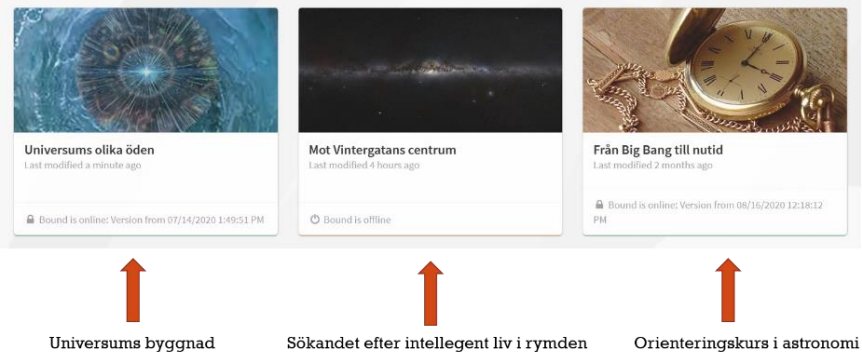

Figure 1: The three trails developed for the three different courses.

As an example of a scenario that a student would be encountered with we can consider a trail starting in the centre of Uppsala. The student now sets out on a walk with a geographical destination marked on a map. Once under way, a number of questions has to be answered which relates the distance and time spent thus far on the walk with actual astronomical length and time scales. The student continues in a similar fashion until a distance/time deemed sufficient has been covered - the tracks that we constructed reach up to about 4 km in total length. The questions to answer are also contain an set of simple calculations which mostly focusses on a conceptual understanding rather than having to perform tedious, time- consuming calculations. Given elementary knowledge of e.g. the mass-density gradient of the Milky Way, the students can calculate how the distance to neighbouring stars changes as they move closer to the center of the Milky Way, and by doing so, gain intuition of the length scales of our galaxy.

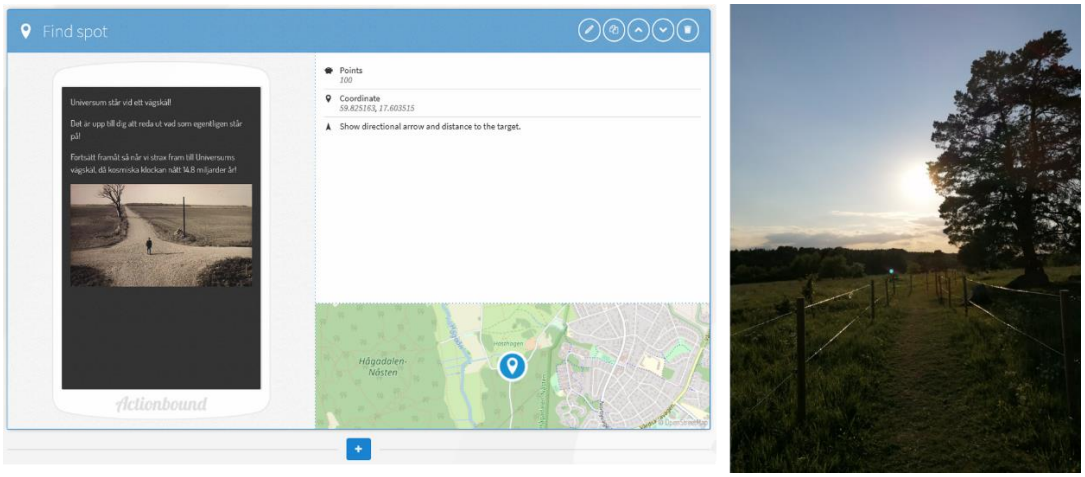

Figure 2: To the left; A screenshot of the way instructions/quizzes/information are passed to the student as they are walking the trail. Such windows will appear in the telephone application as the student locates the given GPS coordinates. To the right; a picture from a location along the walking trail.

Apart from being engaging, and stimulating team work among students (walking together in small groups may make some tasks along the way simpler), we expect students to

develop a more solid understanding about cosmic length and time scales than if just encountering these as numbers in a textbook.

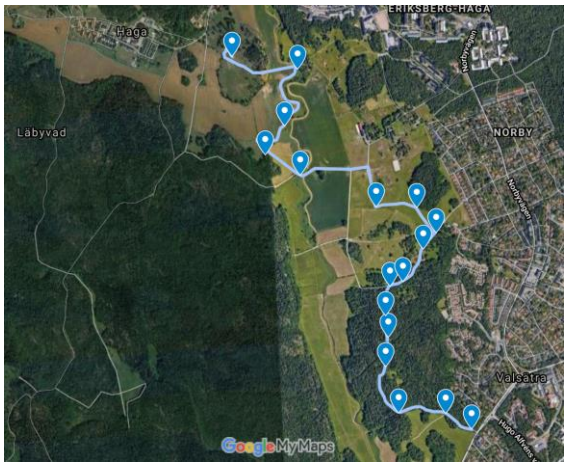

Figure 3: One of the possible walking trails developed for the course *The structure of the Universe*. The trail is 4 km long and runs through Hågadalen, western Uppsala.

Of course, since long walks may be difficult to undertake for students that have physical disabilities, we did not make any of these exercises compulsory – instead we will offer them as voluntary exercises for bonus points added to the final examination. If the need arises for alternative ways of completing the trails it is entirely possible to adjust them such that people of specific needs also may partake, for e.g. by bicycle or other forms of transport that enables high mobility.

Results

The walking trails where successfully implemented in the planned courses; *Introduction to astronomy*, *Searching for extraterrestrial intelligence* and *The structure of the Universe*. The participation from the students varied in the different courses where *Introduction to astronomy* and *Searching for extraterrestrial intelligence* drew the most students. The current Covid-19 pandemic seemed to impact the extent to which students felt compelled to come to Uppsala in cases where the students lived in another city. Furthermore, the course *The structure of the Universe* offered another alternative bonus exercise which could be completed at home – which is suspected to have lowered participation in this course. In the first implementation of these walking trails a total of 75 students participated.

We assessed the implementation of the walking trails by questionnaires administered directly in the applications. The results returned an average grade from the students of 4.5/5, while the median grade where 4, 5 and 5.

In addition to grading from students, free-text answers were provided to ensure that any problems with the tracks were made clear and suggestions for improvements could be put forth.

The effects on the students competence is evidently very hard to assess with any statistical certainty since the trails have only been implemented during one semester thus far. Using the trails in the future will continually improve the statistics such that we can begin evaluating what students as a whole feel about the exercise and whether a better understanding seems to have been established in larger student groups.

Discussion, Conclusion & Outlook

We deem that the implementation of the walking trails are successful since they fulfil the purpose that we stated at the outset. It became clear that the construction of such trails is indeed a quite complex matter that requires a lot of time and detailed thinking. Since we are dealing with highly complex matters when setting up the imagined environment in which the students will walk through virtually, it required a large amount of modelling to construct an accurate representation that is simple enough to understand at the introductory level of the included courses. One can therefore easily imagine developing more intricate and enveloping scenarios for the students to walk through, given the time to do so. These trails also open up the possibility of administrating practical exercises that the students may undertake at suitable locations along the trails. For example, certain locations along the tracks offer very nice vantage points from which students can practice many of the basic concepts related to astronomical observations, such as; measuring angular size and distance, luminosity distance estimates, sky-coordinate exercises etc.. If offered some handheld tools that are easily carried along while walking, students could use simple methods used historically to understand how observations have developed during the ages and how modern methods and technology have come from these simple first steps.

It is also important, and relevant for any pedagogical development project, to find a way of evaluating the impact of the implemented ideas. Therefore, if accurate assessment is sought for, we should think about ways of standardizing test that the impact of projects like these have on the students learning.

References

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