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**MEANS OF EDUCATION ABOUT THE IMPACT HAZARD – EVALUATION AND SUGGESTIONS
*TALKING ‘PLANETARY DEFENSE’ IN SCHOOLS, MEDIA AND MUSEUMS***

Martin Müller⁽¹⁾, Gisela Pösges⁽²⁾

⁽¹⁾ [no affiliation] *Hauptstrasse 13 B, D-85238 Petershausen, +49-174-4697551,*

⁽²⁾ *RiesKraterMuseum Nördlingen, Eugene-Shoemaker-Platz 1, D-86720 Nördlingen,
+49-9081-84710 and ZERIN (Center for Ries Crater and Impact Research
Nördlingen), Vordere Gerbergasse 3, D-86720 Nördlingen, +49-9081-84750,*

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Meteorite impacts and planetary defense are a key topic within certain areas of national and international scientific discussions and activities. Members of NASA, ESA, Roskosmos, Romanian Space Agency, B612 foundation and other organizations are represented in the “planetary defense community”.

Common goals are: understanding the threat posed by asteroids and comets, developing defense mechanisms, and communication and education about the impact hazard. Especially education about planetary defense is a complex undertaking as a wide range of didactical materials and tools are offered. This presentation is therefore concerned with three central aspects of the topic:

- High-level evaluation of different means of education about the impact hazard
- Focus on education by implementation in school curricula and in museums
- Suggestions for next steps for the planetary defense community with regards to educational outreach

The high-level evaluation includes sample coverage of media, internet sources, school curricula and museums as means of education about the impact hazard.

Analysis shows the difference between potential and actual outreach and diverging estimation of educational impact (see table 1).

	Websites/ Webinars	TV documentaries	School Curricula	Dedicated Museums
Potential Outreach				
Actual Outreach				
Quality/ Content*				
Accessibility				
Costs				
Educational Impact				

Table 1: The evaluation covers key dimensions according to potential and actual outreach, quality of delivered information, accessibility, costs and educational impact (excluded are channels with presumably low quality content, e.g. feature films)*

TV documentaries

Numerous programs deal with the impact threat and planetary defense. In the past too often the quality of the content lacked basic scientific knowledge and also negatively influenced students' concepts about the impact hazard (wrong concepts). The situation has improved, however, with the involvement of planetary defense community members taking active roles in the production of TV documentaries. One example is the History Channel series "The Universe" with several episodes dealing with the impact hazard (<http://www.history.com/shows/the-universe>).

The documentaries are translated / dubbed in multiple languages and very often repeated continuously in free TV. With this the outreach of high quality TV documentaries is truly significant.

Costs for TV documentaries are generally high, however, often covered by the production company and not by the planetary defense community.

Accessibility of the documentaries is restricted to households with TVs – some programs are, however, available online already.

Conclusion 1: *Quality of content presented in TV documentary has increased significantly*

Action Required 1: *Members of planetary defense community should continue/increase efforts to be part of high-quality TV documentary productions about the impact hazard*

Websites/Webinars

Several websites are available on the impact threat. NASA and ESA provide insights into their NEO programs: NASA Near Earth Object Program (<http://neo.jpl.nasa.gov/>) and ESA Space Situational Awareness Program NEO Segment ([http://www.esa.int/Our_Activities/Operations/Space_Situational_Awareness/Near-Earth_Objects - NEO Segment](http://www.esa.int/Our_Activities/Operations/Space_Situational_Awareness/Near-Earth_Objects_-_NEO_Segment)). NASA also produced a sophisticated series of webinars: Asteroid Grand Challenge Virtual Seminar Series (recorded sessions with speaker sound/video and slides) available at <http://sservi.nasa.gov/agc-seminar-series/>.

All these sources show a high quality and in-depth information base as they are produced by the experts of the planetary defense community. The potential outreach is very high – all people with internet access should be able to connect to these websites/webinars. However, checking the actual click rates of some of the websites reveals a gap between potential and actual outreach (see table 2) – especially for the official contributions. Unofficial websites like Wikipedia or Youtube videos can reach far higher click-rates.

Site	Clicks	Notes
NEO Program Website	<i>not available</i>	http://neo.jpl.nasa.gov/
ESA SSA Program Website	~ 3000 to 12.000 hits in this area of the ESA site	http://www.esa.int/Our_Activities/Operations/Space_Situational_Awareness/Near-Earth_Objects - NEO Segment
Wikipedia article on planetary defense	~ 21.000 clicks in 90 days	http://en.wikipedia.org/wiki/Asteroid_impact_avoidance
The Chelyabinsk Meteor video on Youtube	8700 clicks overall	Youtube recording of 1.5 hour presentation: https://www.youtube.com/watch?v=Y-e6xyUZLLs
Meteorite Impact Simulation on Youtube	~ 2.600.000 clicks overall	Discovery Channel - Large Asteroid Impact https://www.youtube.com/watch?v=bU1QPtOZQZU
NASA Asteroid Grand Challenge Virtual Seminars	~ 150 participants per session	http://sservi.nasa.gov/agc-seminar-series/

Table 2: Clicks on a sample of websites featuring the impact hazard and planetary defense; note: all click numbers were retrieved in March 2015

Costs for websites are comparably low; webinar recordings take some effort for proper preparation and execution. Accessibility is only restricted to internet access.

Several actions can be derived out of these findings:

Conclusion 2: Website outreach is often overestimated due to difference between possible target group and actual clicks

Action Required 2a: Communicate links to websites/webinars within planetary defense community (proper community management required, e.g. setup and maintenance of distribution lists) and – if possible – to other target groups (e.g. teachers)

Action Required 2b: Use existing websites with significant outreach (e.g. Wikipedia) to publish high quality information about impact threat

School Curricula

Focusing on education in schools, the implementation of the topic in school curricula (current status and way forward) is presented.

A study on students' concepts and interest in the impact topic shows important results for the planetary defense community:

Results from curricula analysis and expert interviews:

- An impact today would have both climatological, geological and biological consequences as well as economic, political and social effects
- Public education should address impacts as part of the topic of natural hazards and cover both the natural sciences and human society aspect – covered best by Geography
- One key aspect of the educational implementation should be the development of a deep-time framework

Results from the analysis of student's concepts and interests:

- There is high interest in the subject on different age levels
- Students gather their knowledge about meteorite impacts both from public education and TV documentaries/cinema movies
- Students' concepts highly differ between ages and gender
- Most often pre-concepts include non-scientific interpretations of impact statistics and size relations
- The data from questionnaires clearly shows a lack of awareness of the geological timescale ('deep time')

Covering the impact hazard in public education curricula is thus viewed as a solution to provide both coverage of a wide audience and high quality information about the topic at the same time. The favored way of dealing with the impact hazard would therefore be to address the topic in public education. There a thorough approach – factoring in scientific and educational requirements – could be established.

Costs of this approach are minimal, however, the effort of including the impact threat in curricula country per country could be significant.

Conclusion 3: *One preferable option is to cover the impact topic in school curricula*

Action Required 3: *Increase efforts to include impact threat/planetary defense in school curricula (preferably Geography)*

Specialized Museums – Rieskratermuseum Nördlingen

The Ries Crater Museum is located in the medieval town of Nördlingen. Since opening in 1990 the museum has welcomed over one million visitors mainly school classes. Up to 40.000 people visit the museum each year. The Ries Crater Museum is a special geological museum focused on a natural catastrophe which took place 15 million years ago – the impact of an asteroid which formed the impact crater Nördlinger Ries.

The Museum is housed in a renovated 16th century stable is divided into six exhibition rooms with different topics.

Room A illustrates the geographical position of the crater and displays a huge black-and white- image as well as an impressive topographical model of the Ries Crater.

In addition to its impressive collection of meteorites Room B provides an overview of the different shapes of impact craters in our solar system.

Room C describes the geological situation prior to the impact and explains the impact process with the help of a video of a NASA experiment to produce artificial impact craters for a better understanding the natural process.

Room D is the “heart” of the museum. Here an impressive and easy-to-understand film describes the Ries impact while the visitor has the opportunity to sit on the artificial “crater rim” and take a closer look at important impact rocks Suevite, Bunte Breccie and even the wonderful green Moldavites.

Room E is devoted to the period after the impact and displays fascinating fossils from the Ries Lake that was formed. Room F offers an overview of the different geoscience theories of the Ries Crater over the course of time and also addresses the role of collision catastrophes in the creation and development of life on Earth.

The highlight of the Museum is an original sample from the moon collected by the Apollo 16 mission in April 1972 (John Young and Charles Duke). This lunar rock is similar to the most important Ries Crater rock Suevite. The permanent loan from NASA is a donation to the Museum to express NASA’s appreciation for the very successful field training of the Apollo 14 and 17 astronauts in August 1970.

In addition to the permanent exhibition the museum presents a special annual exhibition addressing relevant geological, planetological or paleontological topics. For example, 2012 was the 10th anniversary of the famous meteorite fall of Neuschwanstein (2012), in 2013 the meteorite fall of Chelyabinsk in Siberia (2013) was important news. The 2014 exhibit highlights the very successful NASA lunar mission of Lunar Reconnaissance Orbiter.

The Museum maintains excellent relationships with organisations related to Museums topics, including NASA, ESA, DLR (German Aerospace Agency) and geological and planetological institutes and museums. The Museum offers guided tours as well as field trips in the Ries Crater.

Over the past 25 years the Museum has hosted AMICO (Asteroids, Meteorites, Impacts and their Consequences), LMI (Large Meteorite Impacts) Paneth (Colloquium about meteorites and impact cratering processes) and numerous other conferences.

The Museum is a contact point of impact researchers worldwide. Every year the Museum and the association “Friends of the Ries Crater Museum” organized a series of lectures in the Museum itself or in the nearby ZERIN (Center for Ries Crater and Impact Research Nördlingen). ZERIN offers the opportunity for seminars and summer courses for universities and other institutions to learn about impact cratering. ZERIN also possess a drill core archive and a representative rock collection from the Ries and other craters worldwide.

The Ries Crater is a unique site where heaven really did meet earth. Here theoretical information (learned in the museum) is enriched by practical experiences (visiting quarries and outcrops with the typical impact rock formation).

Although the museum currently has no special room dealing with planetary defense, this topic could easily be added (e.g. as special exhibition).

Costs for museums are on the high end, however, can be handled via focusing on specialized museums.

Accessibility to museums is restricted due to necessary travel arrangements and locale of the museums.

Conclusion 4: Specialized museums like the Rieskratermuseum have significant number of visitors and play a vital role in public outreach

Action Required 4a: Planetary defense community should reach out to specialized museums to add chapter on planetary defense

Action Required 4b: Planetary defense community should also consider reaching out to other science museums for adding a chapter on the impact threat & planetary defense (“add-on”)

Summary and Recommendations

Main results are the significant difference of potential and actual outreach of web-based information materials, the improving quality of TV- based information over the last years and the major influence museums can have on a local level.

Additionally, the Ries Crater Museum Nördlingen in Germany is highlighted as best-practice example for local education about the impact hazard.

The above mentioned actions which are required to increase public outreach need organizational changes for the planetary defense community – starting from consolidated and maintained distribution lists (IAA/ESA/NASA/etc) through formulating key common goals with regards to educational outreach - with agreed timelines, clear ownership and aim to support overarching strategic decisions. This approach ensures the sustainable education of a wider audience about planetary defense.