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Students' concepts about meteorite impacts on earth – geographical assessment and pedagogical consequences

Martin Müller

Summary

Meteorite impacts have been an ongoing phenomenon throughout Earth's history. In order to sample students' concepts and ideas, the topic has to be assessed from a geoscientific perspective.

Not only in the past but also today asteroids and comets pose a high risk for our planet. Small meteorites occur most often and only cause local damage but can nevertheless bea danger for cities. Larger meteorites are considered a risk for coastal areas due to highly likely tsunami generation. Objects with more than 2km diameter require special supervision for they can cause a global "impact winter" and lead to a mass extinction, including humankind. Interviews with representatives of the MunichRe Group, the WBGU (scientific council of the German government) and the DKKV have also shown that meteorite impacts are dealt with as a high-risk potential and one of the most dangerous natural hazards.

Further connections to geography on multiple scales and dimensions (e.g. existing craters like the Nördlinger Ries; effects of an impact on the evolution of life) lead to the examination of students' knowledge and imaginations about meteorite impacts. The model of "Didaktische Rekonstruktion" (model of educational reconstruction) was used in order to help interpreting the collected data (quantitative results from 2x25 questionnaires and qualitative results from interviews conducted at the Willibald Gymnasium in Eichstätt). It combines the scientific approach, the study of students' ideas and the practice to an iterative process. The emphasis is on sampling students' (11th grade, age 16-18) ideas about meteorite impacts. Results show that

- *There is high interest both in the subject in general and also in special aspects (geological processes, risk and consequences of an impact on today's ecosystems and civilization)*
- *Students gather their knowledge about meteorite impacts mainly NOT from school lessons but from TV documentaries and cinema movies*
- *Students are aware of the threat of meteorite impacts to humanity but are unable to connect this to their individual perspective*

Students' preconceptions furthermore include wrong interpretations of impact statistics and size relations and are highly different from student to student. Moreover, data shows a lack of awareness of the geological timescale. The central aspect for future studies should therefore be the educational implementation of the topic "impacts" in geographical curricula.

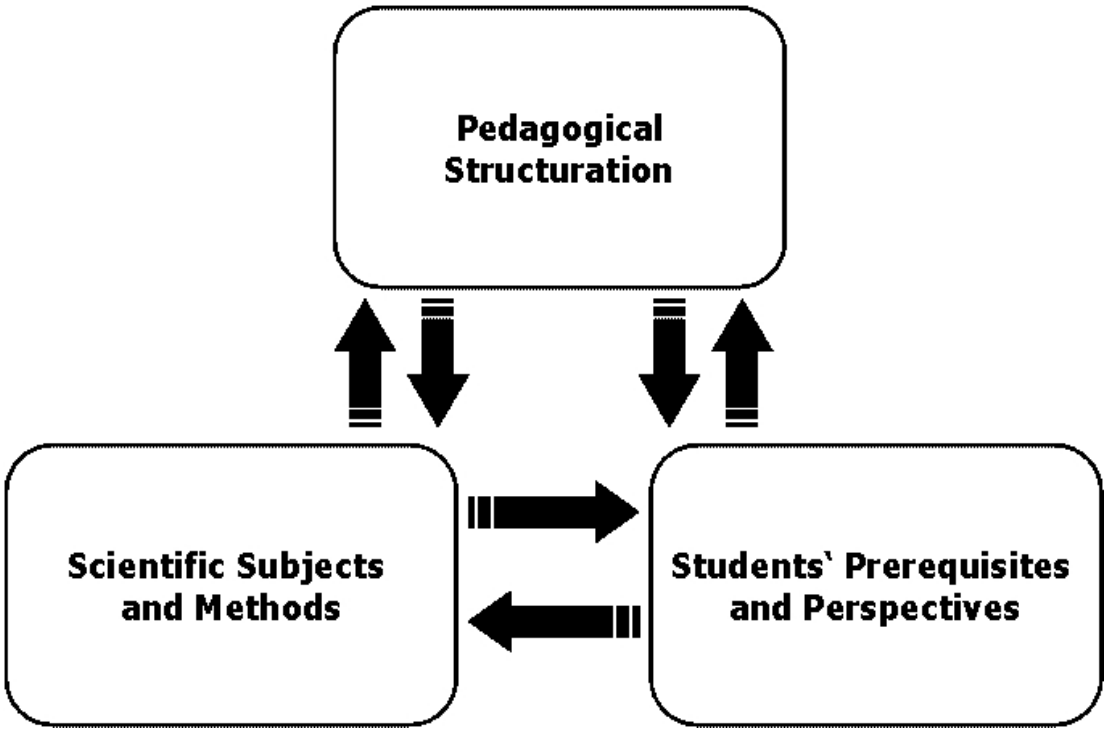

Figure 1: Connections of different levels of pedagogical work; the pedagogical structuration should fundamentally depend on scientific structures as well as on students' prerequisites.

Theoretical background – the model of educational reconstruction

This paper is concerned with presenting a theoretical framework for combining scientific contents, students' preconcepts and practical teaching to one coherent process. The "model of educational reconstruction" (MER) is applied on the topic of meteorite impacts on earth, which plays a more and more significant role in geoscientific research.

Some theoretical approaches of general educational studies refer to contents and structure of a scientific discipline under inclusion of the scientific methods and ways of thinking. Students' ideas, interests and pre-knowledge remain, however, unconsidered. Newer approaches try to compensate for this deficit by an investigation of these prerequisites. Each scientific lesson can, however, lapse into an "experience apprenticeship" at a neglect of science. Thus, the general antagonism between the structures and contents of science and the prerequisites of the students remains.

GROPENGIESSER/KATTMANN/KOMOREK (1997)[1] have proposed a model which shall combine the three levels of educational work with each other in an iterative matrix (see figure 1).

1 GROPENGIESSER, H., KATTMANN, U. and KOMOREK, M. (1997) Das Modell der Didaktischen Rekonstruktion – Ein Rahmen für naturwissenschaftsdidaktische Forschung and Entwicklung. In: Zeitschrift für Didaktik der Naturwissenschaften. Y. 3, Nr.. 3, p. 3-18.); p. 11

As curricular contents are not only part of science but often also interrelated to society and individual circumstances, GROPENGIESSER/KATTMANN/KOMOREK (1997) define the educational framework as more complicated than the scientific one. This complexity is necessary to help students develop appropriate concepts of the world they live in.
MER consists of three interdependent phases (see figure 1), which will each be shortly presented in the following paragraphs.

1. Content analysis
One component of MER - the "content analysis" introduced by MAYRING[2] - focuses on the analysis of scientific contents and methods, which should be critically assessed before used in a teaching context.
Scientific research results should not simply be taken as confessed but be reflected – this results in the following questions, which should be part of the content analysis:

- which scientific statements are available on this topic and where can limits of these statements be observed?
- which genesis, function and meaning do scientific concepts have and in which context are they respectively?

The content analysis includes different scientific ideas on a certain topic, mainly derived from monographs and science textbooks and should be aligned with the following four-step-approach:

- choice of the sources: monographs and textbooks have primarily to be chosen
- summary: the essential statements of an author should be included
- explication: the development of a theory has to be interpreted in its unique stamp
- structuring: the results achieved in the explication should be logically structured

The standard methodical procedure has already been used in multiple studies in physics education, chemistry education and biology education[3].
However, the topic of meteorite impacts is not covered completely by any textbook[4], which leads to a widened methodological approach in this study to analyse the scientific content: three interviews with experts were conducted in order to grasp a variety of views on the impact topic: Dr. Gerhard BERZ of the MunichRe insurance group, Dr. Max TILZER of the WBGU (member of the scientific council of the German government) and Dr. Gerd TETZLAFF, Vice-president of the DKKV (German catastropy management) were asked about the importance of meteorite impacts in their daily business. Together with the review

2 MAYRING, P. (1990) Einführung in die qualitative Sozialforschung. München.

3 see for example HILGE, C. (1999) Schülervorstellungen and fachliche Vorstellungen zu Mikroorganismen and mikrobiellen Prozessen – ein Beitrag zur Didaktischen Rekonstruktion. Oldenburg.

4 this situation has changed, however, with the publication of BOBROWSKY, P. and RICKMAN, H. (eds.) (2007) Comet/Asteroid Impacts and Human Society: An Interdisciplinary Approach. Berlin, Heidelberg, New York.

of scientific articles and internet resources this procedure can provide valuable data for the content analysis, too.

2. Sampling of preconcepts

GROPENGIESSER/KATTMANN/KOMOREK (1997) summarise cognitive constructs of different complexity levels under the term of preconcepts. They assume students' concepts are coherent structures and built up logically. Thus they should not be treated as being missing or even false ideas, but as „notwendiger Ausgangspunkt des Lernens"[5]. Questions typical of the sampling of students' preconcepts are:

- which preconcepts have students on a particular topic?
- are the ideas derived from an every-day-life or subject context?
- which different meanings are assigned to central scientific terms? [6]

Generally speaking it is *„weniger wichtig, in welchen Quantitäten bestimmte einzelne Vorstellungen in einer Schülerpopulation vorkommen"*[7]. However, MER is open to different methodical procedures, although a concentration on qualitative research can be observed in the previously published works.

This study enlarges the empirical basis as questionnaires are used to collect a wider spectrum of preconcepts. The general dispute (esp. in German literature) about the adequacy of methodology should not distract from the fact that other studies already proved the combination of quantitative and qualitative data to be highly valuable for sampling students' concepts[8].

3. Educational Structuration

Basis for the educational structuration is the systematic connection of ideas from science and of students' preconcepts. Typical questions for this process are[9]:

- which correspondences and teaching possibilities origin from the comparison of concepts of scientists and students?
- which student prospects have to be taken into account in view of practical teaching?
- which meta-cognitive thinking tools can be useful for an adequate learning process?

Central part of MER is thus the comparison of concepts which prevents a one-sided normative procedure. The comparison is carried out to find peculiarities, things in common, differences and limitations. The educational structuration forms the synthesis from content analysis and student ideas, however, represents also the basis for additional

5 „necessary starting point for studying"; GROPENGIESSER/KATTMANN/KOMOREK (1997) p. 11

6 GROPENGIESSER/KATTMANN/KOMOREK (1997) p. 11

7 "less important in which quantities certain single ideas occur in a pupil population" GROPENGIESSER/KATTMANN/KOMOREK (1997) p.11

8 LIBARKIN, J.C. et al. (2005) Qualitative Analysis of College Students' Ideas about the Earth: Interviews and Open-Ended Questionnaires. In: Journal of Geoscience Education. v. 53, n. 1 , Februar 2005, p. 17-26.

9 LIBARKIN, J.C. et al. (2005) Qualitative Analysis of College Students' Ideas about the Earth: Interviews and Open-Ended Questionnaires. In: Journal of Geoscience Education. v. 53, n. 1 , Februar 2005, p. 17-26.

lessons-related examinations or acceptance studies.
In this study, the educational structuration was processed down to a practical level as a four-lesson-module on meteorite impacts was developed and tested. This module is available for further re-testing and improvement in ongoing studies.

4. Importance of MER
The model of MER takes several aspects of the educational and pedagogical tradition into account, including parts of KLAFKI's pedagogical analysis and the opinion of the "Berlin school" (HEIMANN, OTTO, SCHULZ) that all variables determining a school lesson are interdependent.
Moreover, GROPENGIESSER/KATTMANN/KOMOREK (1997) argument, that MER represents an essential progress in consistently integrating the epistemological position of (moderate) constructivism[10]. Furthermore the following points can be seen as special performances of the model[11]:

- use of the content analysis as a pedagogical task
- student ideas are necessary points of contact of studying
- comparability of the ideas of scientists and students
- synergetic effects when understanding "strange" ideas
- self corrective procedure

These points and the attempt to integrate different levels of educational work in one model aiming at the practical school lesson are important innovations. Therefore the model was selected for this work and deserves further applications in geography education research.

Geoscientific background – meteorite impacts on earth

The development of the scientific idea of meteorite impacts can be coarsely divided into three phases: from the 1960s on, the idea of impacts and impact craters, e.g. the Nördliner Ries in Germany, became commonly known in the scientific community, basically through the pioneering work of Edward CHAO und Eugene SHOEMAKER[12].
In the following decades a paradigm change took place as the earth was recognized as an open system to space, which is regularly influenced by meteorite impacts. This change of ideas reached an early culmination with the work of Luis and Walter ALVAREZ, who proposed a cosmic cause for the K/T extinction event 65 million years ago[13].
The (until now) last phase of the impact discussion was triggered by the impact of comet Shoemaker-Levy 9 on Jupiter in July 1994, which did not only multiply the acceptance of

10 see DIESBERGEN, C. (2000) Radikal-konstruktivistische Pädagogik als problematische Konstruktion. Eine Studie zum radikalen Konstruktivismus und seiner Anwendung in der Pädagogik. Bern, Berlin, Brüssel, Frankfurt/M., New York, Wien. for an in-depth critique of radical constructivism

11 GROPENGIESSER/KATTMANN/KOMOREK (1997) p. 14/15

12 BAYERISCHES GEOLOGISCHES LANDESAMT (1996) Geologische Karte von Bayern - Erläuterungen. München

13 ALVAREZ, L. et al. (1980) Extraterrestrial cause für the Cretaceous-Tertiary Extinction. In: Science 208, S. 1095 and ALVAREZ, W. et al. (1982) Iridium Anomaly Approximately Synchronous with Terminal Eocene Extinctions. In: Science 216, S. 886

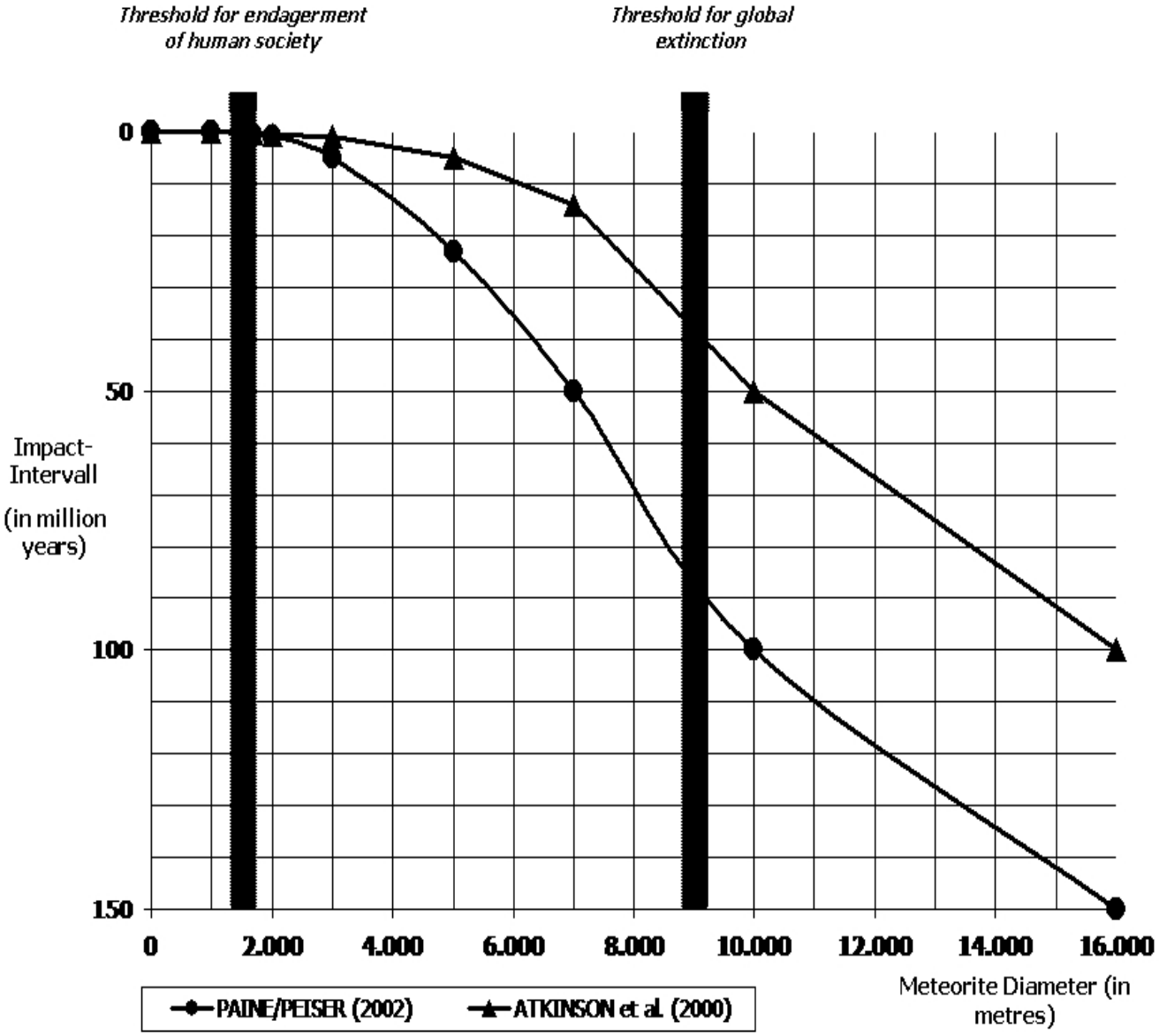

Figure 2: Connection between impact energy and impact probability; different sources can vary in results; an impact the size of the Nördlinger Ries (Germany, diameter ca. 1 km) could occur every 230.000 years; also note the the varying figures for the barrier of global mass extinction

impacts within the scientific community but also lead to the 1998 cinema movies "Deep Impact" and "Armageddon", which – despite their scientific nonsense – prove to be highly influential on preconcepts about meteorite impacts.

1998 marked also the beginning of the systematic search of geologists for impact structures and of astronomers for NEOs[14]. Since then the number of known NEAs has steeply increased and is approaching the number of 5000[15]

In order to qualify the results and

14 NEO = near-earth-object

15 NASA (2007) Near Earth Object Program. http://neo.jpl.nasa.gov/

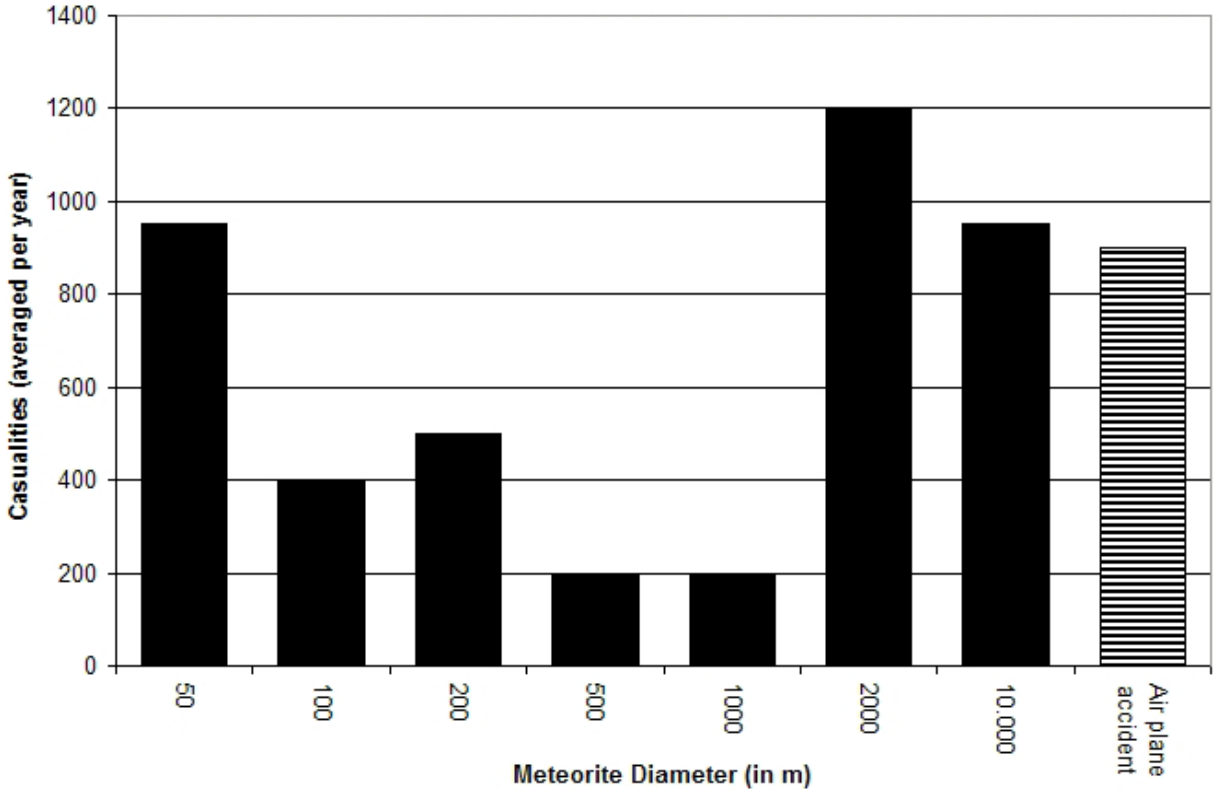

Figure 3: Statistical casualty numbers for different meteorites (Chapman, 2004); for comparison see the number of casualties of airplane crashes per year (averaged); big impactors dominate above all the statistics, as their occurrence could lead to a mass extinction, including humankind; smaller impacts are also a high risk due to their high probability.

risk of different impactors, the Torino scale was introduced. Five groups of objects can be differentiated according to their impact risk and be connected to their effects during impact - using the kinetic energy released during impact. Until now only few asteroids had to be classified in category 2[16] However, the energy released during impact can reach far beyond volcanic eruptions or earthquakes and thus lead to much more destruction) or even lead to mass extinctions (see figure 2).
These statistics are underpinned by all three expert interviews conducted in connection with the content analysis of MER. The reinsurance company MunichRe calculates with meteorite impacts on a 1000 year planning basis – similar to catastrophes like an earthquake beneath Tokyo or a hurricane in New York[17]. The scientific council of the German government (WBGU) characterized the threat of NEOs as "Damocles"-risk: probability very low but almost indefinite vulnerability and damage of all earth systems possible[18].

16 check http://neo.jpl.nasa.gov/ for current impact risks

17 interview with Dr. Gerhard BERZ

18 interview Dr. Max TILZER and WBGU (1999) Wissenschaftlicher Beirat der Bundesregierung. Globale Umweltveränderungen. Welt im Wandel: Strategien zur Bewältigung globaler Umweltrisiken. Jahresgutachten

Thus the topic of meteorite impacts deserves also attention in an educational context for its exemplary status of high-risk natural hazards and the possible global effects of a future impact.

Design of the study and methods

Geography education defines itself as empirical social science[19] and has thus to critically integrate these methods into its own work. The most used instruments in social sciences are interviews and questionnaires and are also used in this study. Generally it has to be noticed that scientific questionnaires and interviews pose a new situation for students and should therefore be preceded by a short introduction.

Overall design

The overall design of the study included a questionnaire at the very beginning to sample students' prerequisites and to construct an objective selection procedure for the interview partners. The interviews were conducted shortly before a four-lesson module designed to cover most parts of the impact topic on SEC II level. A second questionnaire was used to re-test students' concepts after the module and help improving the used materials.

The whole study covered a time of three weeks in July 2004 at the Willibald-Gymnasium in Eichstätt (class 11, age 17-18; N=25)

Questionnaires and interviews

Questionnaires were used to sample students' interest in meteorite impacts, their sources of information and partly also their preconcepts. For quantitative results, questionnaires prove to be highly efficient tools as they provide lots of data within a short timeframe. Questions regarding the interest in the topic are methodically aligned with the studies from HEMMER (2000) to allow a direct comparison of data. Questions dealing with preconcepts were not standardized to allow for a greater freedom of ideas to be expressed.

The interview partners were not chosen randomly[20] but selected with the help of an index built up by students' answers given in Q1. The index included scores from quantitative data regarding their interest and ideas.

Research question

Starting out from the model of MER the main empirical study sampled students' prerequisites (interest, preconcepts, risk assumption) on the topic of meteorite impacts.

Implications from the COLDEX-Programme

The study was part of the COLDEX-Programme funded by the European Union (IST-2001-32327). Main aim

1998. Berlin, Heidelberg, New York.

19 e.g. HEMMER, M. (2000) Westen ja bitte – Osten nein danke! Empirische Untersuchungen zum geographischen Interesse von Schülerinnen and Schülern an den USA and der GUS. München.

20 as this can lead to a corruption of the results (see BORTZ, J. and DÖRING, N. (2002) Forschungsmethoden and Evaluation. Heidelberg.)

of this programme was to measure the efficiency of the implemented new media and to protocol the social component during the lessons. In this case, the emphasis was on the CRATER simulation which provides a simulation of different meteorite impacts. The simulation can be used via www.geosim.org and was also tested for its acceptance in Q2. The results show that the conceptual change has been successful after the four-hour teaching unit. The PC simulation CRATER was an important part of the lesson from student perspective – but it should be subjected to further improvements.

Sources of information
Studies about students' prerequisites narrow their view if they do not include questions about the sources of these preconcepts. In this study, Q1 and the interviews both included questions about the possible sources of information about meteorite impacts.

Interest in the topic
MER defines preconcepts as being much more complex structures than information or knowledge. However, the sampling of preconcepts leads necessarily to the questions about the origin of these complex ideas. Apart from studying the sources of information also other prerequisites like interest can improve the understanding of the formation of different preconcepts. Thus Q1 included questions on students' interest in special aspects of the impact topic, which can also be analysed quantitatively.

Risk assessment
Not only do preconcepts consist of cognitive elements but also of affective aspects regarding a certain topic. In the case of meteorite impacts, students' assessments of the individual and global risk were collected in Q1 and the interviews.

Students' preconcepts
Central aspect of MER is to sample students' preconcepts about a certain topic. Therefore Q1 consisted of a set of multiple-choice and open questions to gather both standardized and individual data on the existing ideas. On the one hand, this procedure helped to gain information about the individual structure of ideas. On the other hand, some results can be generalized and used as representative data.
Starting from this data set, the interviews helped to deepen the insight in the structure of certain preconcepts and showed the need for clarification of uncertain results from Q1, like the question regarding the "deep time" topic[21].

21 See TREND, R. (1998) An investigation into understanding of geological time among 10- and 11-year-old children. In: International Journal of Science Education 20, p. 973-988.
TREND, R. (2000) Conceptions of geological time among primary teacher trainees, with reference to their engagement with geoscience, history, and science. In: International Journal of Science Education 22, p. 539-555.

Sources	Total Number
TV Documentary Films	12
Science Books	2
School	3
Cinema Movies	8
Popular Science Magazines	2
Daily/Weekly Newspapers	0
Other Sources	4

Table 1: Sources for students' preconcepts (N=25); the results show that most of the students gain their knowledge from TV documentary films or cinema movies; these results match the findings from the interviews, where the movies "Deep Impact" and "Armageddon" are named the prime source; one student expressed his concern about the quality of these sources: "...one cannot be sure if you can believe them" (Interview 1); "other sources" include the Rieskratermuseum in Nördlingen or the Juramuseum in Eichstätt, both close to the visited school.

Results and significance of the findings for geoscience education

Sources of information

As shown in detail in table 1, students gather their information about meteorite impacts mainly not from school lessons but from TV or cinema movies. As the scientific quality of these sources is highly questionable, one has to be prepared for preconcepts not fitting with current scientific concepts.

Interest in the topic

The collected data shows a high average interest in the topic of meteorite impacts, which is in agreement with studies from HEMMER/HEMMER[22] on interest in geographical topics – their findings show a high interest in natural catastrophes in general.

Preconcepts and risk assessment

A purely quantitative evaluation does not lead to a comprehensive picture of students' preconcepts about meteorite impacts, as the open-ended questions interviews provided a more detailed dataset:

The question about the process of a meteorite with a diameter of 50 meters of close to a small town (Q1) was answered in detail by all students. The ideas are in this respect uniform as all of them envisage the destruction of the town. But already the statements about the crater size differ from "three kilometers" to "hundreds of kilometers". Only one student gave a realistic value of hundreds of meters. This does not only hint at the variations of ideas held by the students but also at the

22 HEMMER, I. and HEMMER, M. (1996) Welche Themen interessieren Jungen and Mädchen am Geographieunterricht? – Ergebnisse einer empirischen Untersuchung. In: Praxis Geographie Nr. 12, p. 41-43.

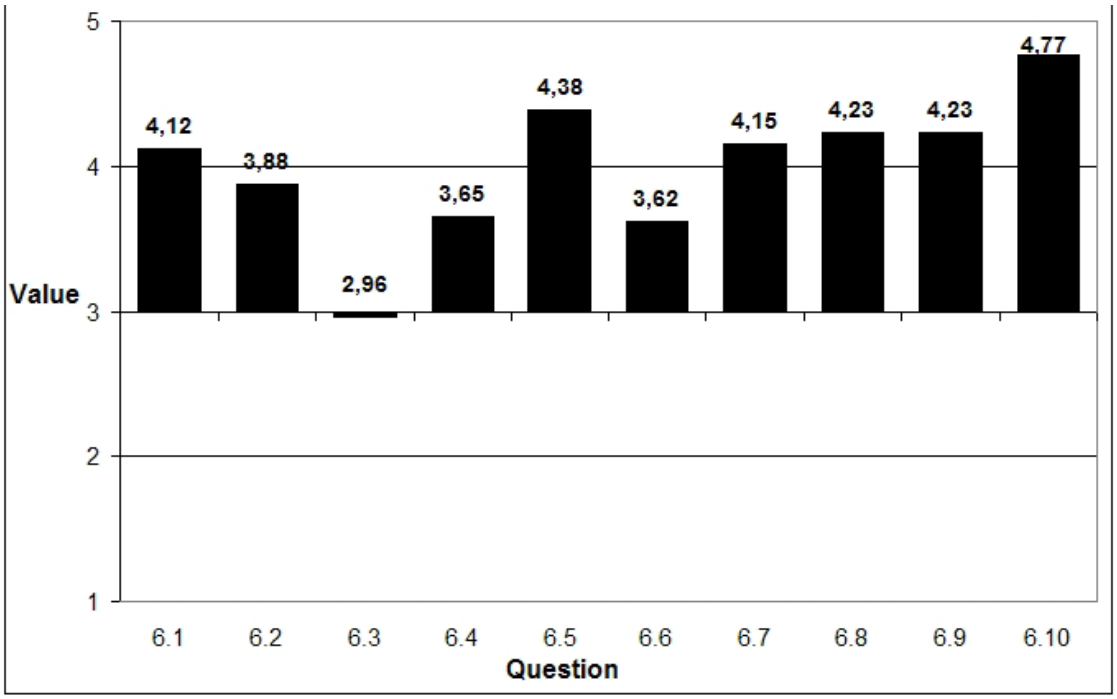

Figure 4: Values for interest in special aspects of impact topic; value 1 is low interest, value 5 high interest; note the high above average values for Q6.5 (impact propability today) and Q6.10 (field trip to a crater); the low value for Q6.3 (impact physics) can be explained be mentioning the word "physics", which will be changed in future studies

difference of students' and scientific concepts.

A similar question about the process and consequences of an impactor with the size of five kilometers, however, gives more even results. Most of the students estimate the result to be the extinction of mankind – this is also the current scientific view. It is noteworthy that many (13 of N=25) students described the effects of global darkness due to dust. However, there were also other concepts present, some of them expressed during the interviews:

"*[...] the whole continent would be badly affected, also the ice age was triggered by a meteorite, climate change"*[23]

"[...] that the earth would be completely destroyed [...]"[24]

"Due to the force of impact, perhaps also ocean currents or climate could be changed so that today's fertile areas would be deserts or oceans"[25]

Furthermore it can be shown that students realize the danger of im-

23 [...] würde auf jeden Fall der ganze Kontinent in Mitleidenschaft gezogen werden, auch die Eiszeit wurde meines Wissens von einem Meteoriten ausgelöst, Klimaveränderungen

24 [...] dass die Erde vollständig zerstört sein wird [...]

25 Durch die Wucht des Aufpralls würde [sic!] vielleicht auch Meeresströme oder Klimaverhältnisse so verändert, das heute fruchtbare Gebiete zu Wüsten oder Ozeanen würden

pacts for mankind as a whole, however, do not transfer this assessment to their individual situation. This is less a false preconcept than an inability to grasp statistics on a geological timescale.
Summarizing it is to stress that these results could only be sampled by combining qualitative and quantitative methods and grasp an overall picture of interest, sources of previous knowledge and preconcepts.

Conclusion

This study uses new approaches on three central fields of geography education: a paradigm change is carried out and taken to a concrete level with the topic of meteorite impacts showing the earth as an open system.
Secondly, MER performs an integration of different educational methods and modes of operation to a coherent process which can also be applied in practical teaching.
Finally the cooperation with the department of computer science of the University of Eichstätt made it possible to publish a website (www.geosim.org) on the topic of meteorite impacts, which is also designed for the use in school lessons (CRATER standalone simulation also available).
The results of interviews, questionnaires and expert interviews show the topicality both of meteorite impacts and MER and should lead to further activities

- in embedding the topic of meteorite impacts in the context of natural disasters both in science and education
- in expanding and refining MER in the context of geoscientific education research, using both qualitative and quantitative data
- in improving the four-lesson-module and the CRATER simulation

"Meteorite impacts are a good example of how endangered life is. Earth is a vulnerable planet. One can also connect this topic to man-made global change. The more you know about it, the better you can defend yourself."
Dr. Gerhard BERZ (interview 2005)

References

ALVAREZ, L. et al. (1980): Extraterrestrial cause for the Cretaceous-Tertiary Extinction. In: Science 208, p. 1095-1108

ALVAREZ, W. et al. (1982): Iridium Anomaly Approximately Synchronous with Terminal Eocene Extinctions. In: Science 216, p. 886.

ATKINSON, H., TICKNELL, C., WILLIAMS, D. (Eds.) (2000): Report of the Task Force on Potentially Hazardous Near Earth Objects. UK Government, London.

Bayerisches Geologisches Landesamt (1996): Geologische Karte von Bayern- Erläuterungen. München.

BECKER, L. et al. (2004): BEDOUT: A Possible End-Permian Impact Crater Offshore Northwestern Australia. In: Science, Vol. 304, Juni 2004, Issue 5676, p. 1469-1476.

BINZEL, R. P. (2000): The Torino Impact Hazard Scale. In: Planetary & Space Science 48, p. 297-303.

BLOOM, B.S. et al. (1972): Taxonomie von Lernzielen im kognitiven Bereich. Weinheim.

BOBROWSKY, P. and RICKMAN, H. (eds.) (2007): Comet/Asteroid Impacts and Human Society: An Interdisciplinary Approach. Berlin, Heidelberg, New York.

BORTZ, J. und DÖRING, N. (2002): Forschungsmethoden und Evaluation. Heidelberg.

CHAPMAN, C.R. (2004): The hazard of near-Earth asteroid impacts on earth. In: Earth and Planetary Science Letters 222. p. 1-15.

DIESBERGEN, C. (2000): Radikal-konstruktivistische Pädagogik als problematische Konstruktion. Eine Studie zum radikalen Konstruktivismus und seiner Anwendung in der Pädagogik. Bern, Berlin, Brüssel, Frankfurt/M., New York, Wien.

EHRLICH, P.R. et al. (1984): The Cold and the Dark. The World after Nuclear War. London.

ENGELHARD, K. (1997): Erziehungswissenschaftliche Grundlagen des Unterrichtsfaches. In: HAUBRICH, H. et al. (1997) Didaktik der Geographie konkret. München.

ERIKSON, E. (1986): Evolutionary and Developmental Considerations. In: Grinspoon

FRANKE, M.R. (2001): Der Impakt eines Asteroiden in Mitteleuropa. Eine Analyse der Auswirkungen des Impakts eines Near-Earth-Objects auf Nuklearkraftwerke und Anlagen der Großchemie sowie die Folgen für Mensch und Umwelt. Berlin.

GRINSPOON, L. (Ed.) (1986): The Long Darkness. Psychological and Moral Perspectives on Nuclear Winter. New Haven, London.

GROPENGIESSER, H. (1997): Didaktische Rekonstruktion des Sehens. Oldenburg.

GROPENGIESSER, H., KATTMANN, U. und KOMOREK, M. (1997): Das Modell der Didaktischen Rekonstruktion – Ein Rahmen für naturwissenschaftsdidaktische Forschung und Entwicklung. In: Zeitschrift für Didaktik der Naturwissenschaften. Y. 3, Nr. 3, p. 3-18.

HÄUSSLER, P., BÜNDER, W., DUIT, R., GRÄBER, W., MAYER, J. (Eds.) (1998): Naturwissenschafts-didaktische Forschung. Perspektiven für die Unterrichtspraxis. Kiel.

HÄUSSLER, P. und LAUTERBACH, R. (1976): Ziele naturwissenschaftlichen Unterrichts - Zur Begründung inhaltlicher Entscheidungen. Weinheim.

HAUBRICH, H. et al. (1997): Didaktik der Geographie konkret. München.

HEMMER, I. und HEMMER, M. (1996): Welche Themen interessieren Jungen und Mädchen am Geographieunterricht? – Ergebnisse einer empirischen Untersuchung. In: Praxis Geographie Nr. 12, p. 41-43.

HEMMER, M. (2000): Westen ja bitte – Osten nein danke! Empirische Untersuchungen zum geographischen Interesse von Schülerinnen und Schülern an den USA und der GUS. München.

HILGE, C. (1999): Schülervorstellungen und fachliche Vorstellungen

zu Mikroorganismen und mikrobiellen Prozessen – ein Beitrag zur Didaktischen Rekonstruktion. Oldenburg.

HOLT-JENSEN, A. (1980): Geography. Its History and Concepts. London.

KAVASCH, J. (1987): Meteoritenkrater Ries, ein geologischer Führer. Donauwörth.

KLAFKI, W. (1985): Neue Studien zur Bildungstheorie und Didaktik. Weinheim, Basel.

KRATWOHL, D.R. (1964): Taxonomy of Educational Objectives. New York.

LANGE, D. (1996): Impakte extraterrestrischer Körper, Vulkanausbrüche und Erdbeben: Energiebilanzen und Häufigkeitsverteilungen im Vergleich. Diss. Kiel.

LIBARKIN, J.C. et al. (2005): Qualitative Analysis of College Students' Ideas about the Earth: Interviews and Open-Ended Questionnaires. In: Journal of Geoscience Education. v.53, n.1 , Februar 2005, p. 17-26.

MAYRING, P. (1990): Einführung in die qualitative Sozialforschung. München.

MÖLLER, C. (1975): Techniken der Klassifizierung und Hierarchisierung von Lernzielen. in: FREY, K. (Eds.) Curriculumhandbuch Band 2. München.

NELSON, S.A. (2002): Meteorites, Impacts, and Mass Extinctions.
(Source: http://www.tulane.edu/~sanelson/geol204/impacts.htm).

NEOMAP (2004): Space Mission Priorities for Near-Earth Object Risk Assessment and Reduction. Berlin.

PAINE, M, PEISER, B. (2002): The frequency and consequence of cosmic impacts since the demise of the dinosaurs. Hamilton Island.

PAINE, M. (2004): Tsunami from Asteroid/Comet Impact.
(Source: http://www1.tpgi.com.au/users/tps-seti/spacegd7.html).

PLÖGER, W. (1999): Allgemeine Didaktik und Fachdidaktik. München.

ROTH, G. (2000): Das Gehirn und seine Wirklichkeit. Kognitive Neurobiologie und ihre philosophischen Konsequenzen. Frankfurt am Main.

SAGAN, C. und DRUYAN, A. (1997) : Comet. Revised Edition. London.

SHOEMAKER, E. M. (1988): Guidebook to the geology of Meteor Crater, Arizona. Tempe, Arizona.

THRIFT, N. (2003): Space: the fundamental stuff of geography. In: HOLLOWAY (2003), p. 95-109.

TREND, R. (1998): An investigation into understanding of geological time among 10- and 11-year-old children. In: International Journal of Science Education 20, p. 973-988.

TREND, R. (2000): Conceptions of geological time among primary teacher trainees, with reference to their engagement with geoscience, history, and science. In: International Journal of Science Education 22, p. 539-555.

TURCO, R.P. et al. (1983): Global Consequences of Multiple Nuclear Explosions. In: Science 222, p. 1283-1292.

UHLIG, H. (1970): Organisationsplan und System der Geographie. In:

Geoforum 1, p.19-52.
WBGU (1999): Wissenschaftlicher Beirat der Bundesregierung. Globale Umweltveränderungen. Welt im Wandel: Strategien zur Bewältigung globaler Umweltrisiken. Jahresgutachten 1998. Berlin, Heidelberg, New York.

WWW-Sources:
http://impact.arc.nasa.gov/index.cfm
http://neo.jpl.nasa.gov/stats/
http://www.geosim.org
http://www1.tpgi.com.au/users/tps-seti/spacegd7.html
http://www.tulane.edu/~sanelson/geol204/impacts.htm

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