Game Based Learning for Computer Science Education

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ABSTRACT
Today, learners increasingly demand for innovative and motivating learning scenarios that strongly respond to their habits of using media. One of the many possible solutions to this demand is the use of computer games to support the acquisition of knowledge. This paper reports on chances and challenges of applying a game-based learning scenario for the acquisition of IT knowledge as realized by the German BMBF project SpITKom. After briefly describing the learning potential of Multiplayer Browser Games as well as the educational objectives and target group of the SpITKom project, we will present the main results of a study that was carried out in the first phase of the project to guide the game design. In the course of the study, data were collected regarding (a) the computer game preferences of the target group and (b) the target group's competencies in playing computer games. We will then introduce recommendations that were deduced from the study's findings and that outline the concept and the prototype of the game.

Categories and Subject Descriptors
K.3.2 [**Computers and Education**]: Computer and Information Science Education – *information systems education.*

General Terms
Design, Experimentation, Standardization, Verification.

Keywords
IT knowledge, game based learning, game design, learners difficult to reach

1. INTRODUCTION
Making education accessible to everyone is a problem: Besides age, the earning capacity as well as the social background influences the use of information and communications technology (ICT) (cf. [4]; [28]). As Unterfrauner [27] states, the smaller the income the smaller the penetration rate of PCs and the smaller the possibility for youths to have access to the Internet (no access point). Also, according to the JIM Study [13], the level of education influences the way, the computer is used. It is stated that the higher the educational background, the more likely youths are prepared to use the computer as a means for information people with a lower educational background rather use the computer to communicate and to play games. Thus, people with a lower educational background less likely develop competence in using the computer as a tool for information and/or work (e.g. word-processing programs) or in applying technology and media to certain subjects, i. e "digital literacy" [8]. Nowadays, most jobs however require at least basic skills and knowledge in the professional use of common computer applications. They are virtually indispensable for vocational integration, preservation and continuation, and already for creating an adequate application e-skills are mandatory. Thus, social circumstances seem to reinforce prevailing educational disadvantages. And for many this barrier is difficult to overcome. People with a low educational background very often have negative learning experiences. They have little or no confidence in their skills and abilities and only limited motivation to learn [1]. Traditional education has little chance to bring them back into education. Game based learning approaches however seem to meet the target group's needs (cf. [6]; [13]; [26]; [15]).

2. GAME BASED LEARNING
Within the past decade, studies have analyzed and demonstrated that commercial as well as educational games (a) support constructivist learning and teaching, i.e. constructive, situated and social learning ([7], [18], [3]) and (b) almost perfectly match the determinants of intrinsic motivation ([17], [20]).
According to Meier and Seufert [14], game-based learning approaches particularly make sense if the content to be learned is dry and only somewhat interesting, if the considered target group

is rather difficult to motivate for learning, if the target group already has an affinity for (computer) games (e.g. younger target groups), and/or if the target group does not have the necessary competencies to deal with a CBT/WBT (e.g. the competence to act or learn self-directed).

Playing games, whether they are explicitly designed to foster the acquisition of knowledge or not, may support the development of certain strategies and skills such as problem-solving, decision-making, understanding complex systems, planning or data handling (cf. [10], [18]). Computer games may also support the acquisition of knowledge according to a predefined set of subject-related facts [18] that can be matched against a fixed syllabus. The German research project SpITKom for example supports the acquisition of IT knowledge to master the European Computer Driving Licence (ECDL).

When it comes to the development of Multiplayer Browser Games, research from Social Cognition Studies is of paramount importance. Steinkuehler's ([24], [25]) work on Massively Multiplayer Online Games, for example, emphasizes the potential of social mechanisms for learning such as collaborative problem solving practices as well as reciprocal apprenticeship "through which individuals enculturate one another into routine and valued practices and perspectives" [25, p. 12]. According to a study carried out by Klimmt et al. [11], gamers like Multiplayer Browser Games because of their particular social aspects of the game play and because of their specific characteristics regarding time and flexibility („easy-in, easy-out").

3. THE SPITKOM PROJECT

SpITKom (**Sp**ielerische Vermittlung von **IT-Kom**petenz)[1] took the decision to realize a Browser Game against the background of the currently very successful Multiplayer Browser Games (e.g. Ikariam[2]). Its main focus is to support the acquisition of IT knowledge, thus preparing and enabling educationally disadvantaged learners to find an apprenticeship. Further on, SpITKom aims at supporting the acquisition of practical knowledge related to the building industry. Therewith, SpITKom targets at bringing forward the participants' professional and social competence. Also, by directing the game to the building industry, it is intended to support the development of a professional identity.

3.1 Educational Objectives

SpITKom focuses on the acquisition of **IT-knowledge** as one of the key competencies and requirements of today's labour market. It has chosen to integrate the ECDL as a commonly accepted standard that reflects and certifies up-to-date skills and knowledge in the use of a computer and common applications. In its standard version 5.0, the ECDL syllabus comprises 478 learning outcomes, organized in seven modules including topics such as „Using the computer and managing files", „Word processing " and „Web Browsing and Communication" (see: www.ecdl.org).

Besides IT-related skills and knowledge, SpITKom aims at the acquisition of **knowledge related to the building industry**. As opposed to the ECDL, this content is not based on a fixed curriculum or a certain syllabus of instruction but is geared to the different scenarios (garage, detached house, park, etc.) as realized in the game. Every scenario is described by means of phases and their respective workflow. Building a garage for example comprises the phases: setting-out the building-site and stripping the topsoil, trenching for the strip foundation, casting the strip foundation, etc. For every phase additional information is available.

3.2 Target Group

SpITKom is directed at learners difficult to reach who are participating in state funded professional qualification programs offered by the Education Centres for the Building Industry (BZB). The target group consists of predominantly male participants aged 17 to 25. According to the target group analysis that was carried out in the beginning of the project, only a few of the participants have a school leaving certificate. Their level of literacy is very low. Also they have strong personal and social deficits that hamper or even inhibit finding an apprenticeship. Their command of the German language is poor. Also, their capacity to memorise or to concentrate on something is rather low. They have little stamina, a poor frustration and conflict tolerance and only little or no ability to work in a team or to communicate. They are not used to learn at all and they are not willing to actively participate in learning activities [22]. Despite these similarities, the target group is not homogeneous. They have very different attitudes towards work, different working techniques, talents, expectations and cultural distinctions.

Instead of a computer, this target group is rather in possession of television and gaming consoles [13]. Thus, they have developed little or no competence in using the computer as a tool for information and/or work. By now, most jobs require at least basic media competencies though. This also applies to the building industry which increasingly relies on the use of computers for day to day communication or logistic matters for example.

4. PARAMETERS FOR THE GAME DESIGN

In order to meet the target group's game play needs, a study was carried out in the beginning of the project (i.e. autumn 2009) that assessed the target group's computer game preferences and their computer game literacy (cf. [1], [22]).

4.1 Methods

The study's methods of data collection included questionnaires (n=43), qualitative interviews (n=18) and observations of the target group playing the Serious Games *McVideogame* and *Techforce* (n=9). The transcripts of the qualitative interviews were coded and analyzed with qualitative content analysis. The data of the videotaped game sessions were assessed as case studies and interpreted with a combination of segmentation and sequential analysis.

4.2 Samples

The samples consisted of predominantly male participants of several state funded professional qualification programs in the field of building industry aged 17 to 25. Besides lacking basic abilities in reading, writing and calculating, a lot of these young people had negative experiences with formal education.

[1] The project is funded by the German Federal Ministry of Education and Research (BMBF) and the European Social Fund (ESF). Up-to-date information on the project can be retrieved from: http://www.spitkom.de

[2] http://www.ikariam.com

4.3 Results

The majority of the target group prefers to play action games (e.g. Sports and Racing Games and First-Person-Shooter) in its spare time. Multiplayer Browser Games are not played on a regular basis. However, the results of the study suggest that Multiplayer Browser Games (which usually contain construction and management features) could appeal to the target group. From the analysis, several potential reasons that support this suggestion have been identified.

Firstly, parts of the target group get into construction- and management-oriented actions within other genres. 68 % of survey respondents agreed that in computer games it is fun to build something up and to manage it (see Figure 1).

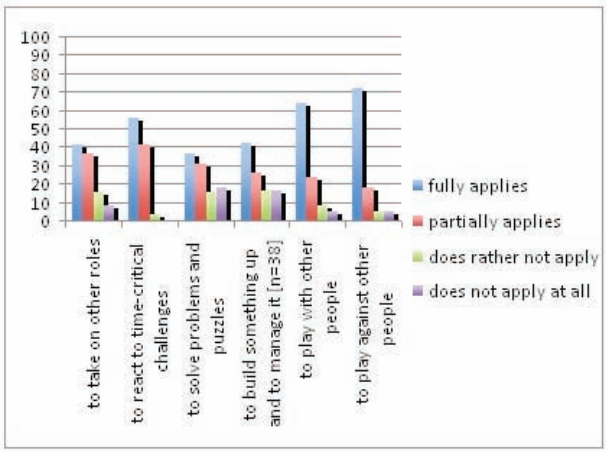

Figure 1. What do you like especially in computer games? (in %) (n=39)

The following quotations from the qualitative interviews offer a closer look at target group's fascination for building up and managing in computer games:

"I like Age of Empires because you have to build up everything. First, you have several citizens, you build up a city, soldiers, then you are going all through the ages, from the middle ages to nano, to space ships and stuff like that. It is always going further, up to pirate ships, then you are going to the age of military, World War I, World War II, and then modern world war. It is always going further up, it always takes years, then you have to collect more, and then you are coming into another age, and that is also a kind of strategy, you have to expand, you have to watch out with whom you are allying yourself, see who could become a danger to you." (I14)

"If you have a favorite team, and if you are then thinking that [in FIFA Manager 2008] you are the manager, what do I say, you are the president of that team (...), that is, I have the players in my hand, I have the arena in my hand, everything belongs to me, so to say, I am allowed to lead, I am allowed to say yes or no, I am this person, that as well, that's why, I found it really cool." (I17)

Secondly, the observation of participants playing the Online Anti Advergame *McVideogame* shows that, in general, the target group is interested in and able to handle a management simulation in a school context.

However, the observation also reveals that many players have difficulties dealing with a complex game system which is not offering a high degree of guidance and instruction. Many players were overwhelmed by too many variables and options as well as they were confused as their inputs were not followed by immediate feedback. Thus, it can be assumed that the target group's mastery of construction and management games presupposes a well-structured game environment, high level of stimuli and immediate feedback to game play actions. The following statement of an interviewee contains an assessment of the interface of the management simulation *Hospital Tycoon* (based on a screenshot which was presented to him during the interview). It illustrates the target group's desire for well-structured games offering pretty clear guidance und instruction:

"[In Hospital Tycoon] the clicking here and there could be simplified. There should be not that many bars and buttons. (…) First of all, I would need reference points in order to know what my task is, what I have to accomplish. (…) I need a definition of task to know what to do. [In Hospital Tycoon] I would not right away know where to begin (…). There are too many categories (…). It should be structured better! (…)." (I7)

4.4 Recommendations

Although the majority of study's participants does not play Multiplayer Browser Games in its spare time, the construction and management features of Multiplayer Browser Games could attract the target group. Furthermore, "the social relationships involved in game play" [11] could contribute to the attraction of the target group, which is very keen on playing with or against other people (see Figure 1).

In order to meet the target group's game play needs, it is recommended to offer a well-structured game environment (including a lucid interface and clear instructions), a high level of stimuli and immediate feedback to game play actions. As a consequence, it is recommended to look at Social Games such as *FarmVille*[3] or *Social City*[4] as a reference for accessible, easy to use game environments that offer high level of stimuli as well as ongoing feedback. Further recommendations derived from the student's gaming habits and preferences comprise (cf. [1], [22]):

- The player should be able to choose and/or design an avatar (though the avatar can not be controlled within the genre). In the course of the game the avatar should change its appearance according to the score.
- The story should enable a career advancement; e.g. from apprentice to master.
- The text embedded should be as short and clear as possible.
- The in-game ranking should not reproduce the usual classroom ranking. Therefore, in-game success should not only be influenced by performance of IT knowledge, but also by stamina and, above all, collaboration.
- The interface should be clearly arranged and simple (e.g. a manageable number of functionalities the player has to use while playing the game).
- Elements other than game play elements (e. g. IT questions, IT knowledge) have to be tied in with the game logic, (i.e., it must always lead to an in-game advantage). Additional information,

[3] http://www.farmville.com

[4] http://www.facebook.com/SocialCity

which does not offer any in-game value, will be neglected by the target group.

- Latency should be avoided (e.g. immediate feedback should be given to anything the player does).

5. CONCEPTUAL FRAMEWORK SPITKOM

SpITKom aims at utilizing the pedagogical potential computer games provide (cf. [7], [18]) by offering a learning scenario based on a Browser Game. It aims at initiating intrinsic motivation because, as compared to extrinsic motivation, intrinsic motivation increases the efficiency of learning [21]. Moreover, SpITKom builds on the learning potential of collaboration and reciprocal apprenticeship [25]. The main user interfaces for the learner are the learning game (see Figure 2) and the IT-Café (see Figure 3).

Figure 2. SpITKom Browser Game (Draft Version)

The game guides the learner through building- and construction-projects. Its main intention is to bring the target group (learners difficult to reach) "in touch" with the integrated IT-knowledge. A more elaborate engagement, i.e. the actual learning, takes place within the IT-Café.

In the course of the game, test items related to IT knowledge (ECDL) are displayed to the user. The answers influence the game play (score, money). By matching the ECDL learning outcomes against the learner's concrete abilities it analyses the learner's needs and offers questions and *Units of Learning* in the sense of a concrete, contextualized unit of education or training (cf. [5]) that can each be traced back to a single learning outcome. The questions are rated 1 (easy) to 3 (difficult). Depending on the learner's performance (right/wrong), the system's core backend component - the CCT (Competence Checker and Trainer) which is realized through the IT-Café (see Figure 3) - chooses the follow-up question in an adaptive manner in order to rate the learner's knowledge. Also, answers of learners are collected and stored in the learner's profile. The learner can enter the IT-Café to perform some explicit learning tasks (access learning contents, perform comprehensive tests, review own profile). Additionally, the learner can communicate with co-learners and teachers.

Figure 3. IT-Café (Draft Version)

6. BASIC TECHNICAL ARCHITECTURE

The SpITKom system is partially based on the Open ICOPER Content Space (OICS), which was developed in the context of the ICOPER project[5]. The OICS is based on the OpenACS[6] platform that is available under an open source licence, as it is the case for all modules needed for running the OICS. The OICS platform offers services that integrate concepts and data for the management of sharable educational resources.

In the context of SpITKom, the webservice infrastructure of the ICOPER components were integrated into a completely new user interface (i.e. game and IT-Café) [23]. In the following, the relevant OICS resource types and their respective data models as realized in the SpITKom project, are depicted:

In the OICS, *learning outcome definitions* capture the key characteristics of a learning outcome, independently of its use in any particular context or target group, using the LOD schema [16]. Within the context of SpITKom, the items of the ECDL syllabus are represented as LODs. They are stored in the learning outcome repository.

The OICS enables to pull *learning content* from repositories through the OAI-PMH protocol [12] or to push content from authoring environments through a publication service with metadata described in a profile of the LOM standard [9]. Within the context of SpITKom, the ECDL learning contents are realized as SCORM units stored in the OICS content repository [2].

The OICS associates *assessments* with learning outcomes, which allows generating personal achievements. They are stored in the QTI format. In the course of SpITKom, the individual ECDL tests are played using the open source QTIEngine[7].

In the OICS, *personal achievement profiles* allow learners to organize their achieved learning outcomes. Evidence records related to them are stored in the PALO data format [16]. In the course of SpITKom, assessment results delivered from the QTI-engine are stored into the profile repository, using the PALO format.

[5] http://www.icoper.org

[6] http://openacs.org/

[7] http://www.qtitools.org/landingPages/QTIEngine/

7. CONCLUSION AND OUTLOOK

It has proved rather difficult to motivate learners difficult to reach to get involved with learning activities. The SpITKom project is set to tackle this challenge though by providing a learning offer that is geared to the target group's preferred activities. The recommendations that were deduced from the target group analysis and that were implemented with the prototype have led to a Brower Game which is set to meet the target group's needs. It therefore has all the chances to be successful, i.e. to help learners difficult to reach to get involved with learning. First results of a recent prototype evaluation show that (a) the game design meets the target group's expectations regarding the graphical user interface (GUI) and that it is (b) accepted as an intuitive and low-threshold learning offer. Its game play was evaluated as easy to understand and that requires no genre specific prior knowledge. Moreover, game testing demonstrated that the game indeed motivated players to engage themselves in information technology (at least, in the course of the game), which cannot be taken for granted when it comes to the SpITKom target group. It can be assumed that the game's linkage between players' IT knowledge and their success in the game (via parameters such as *Duration of Building Time*, *Score* and *Money*) plays a major role in the initiation of that engagement.

An overall study with particular focus on the learning in SpITKom however, will be carried out in the first half of the year 2012. Until then, the game and the IT-Café will be finalized (05/2011) and the target group will have played and learned with the SpITKom-game for nearly half a year (07/2011 – 12/2011). This will allow the final study to draw conclusions with regard to (a) the implementation of the game into the instruction of a state funded professional qualification program, (b) the effects of the game-based-learning-approach on the target group's engagement with information technology, (c) the (possible) appearance and structure of collaborative learning processes within the Multiplayer Browser Game, (d) the effects of outcome-oriented delivery of content and services on the individual learning processes, and (e) the learning outcome with a special focus on IT-knowledge, building industry knowledge and professional identity. It will be of particular interest to evaluate the general capacity and motivation of learners (i.e. learners difficult to reach) to take over responsibility for their learning and respectively the corresponding learning outcome.

It is planned to set up a mobile version of the SpITKom game in order to scrutinize additional effects on motivation and learning outcome for learners difficult to reach. The mobile version will complement the existing Browser Game and will make use of the integrated infrastructure (IT-Café) thus providing the basis for a game-based learning approach for mobile devices.

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9. REFERENCES

1. Adam, L./Czauderna, A./Vogt, S./Witting, T./Kaminski, W.: Spielerische Vermittlung von IT-Kompetenz für benachteiligte Jugendliche zwischen Schule und Ausbildung. Ergebnisse der Vorstudie. Unpublished Report by Institute of Media Studies and Media Education, Cologne University of Applied Sciences, Cologne, 2010.
2. ADL SCORM (2004). Advanced Distributed Learning Sharable Content Object Reference Model, 2nd ed., Overview, 22 July, Alexandria, VA.
3. Berger, F./Marbach, A.: Erkundungen im Spannungsfeld von Pädagogik, Spielspass und technischer Machbarkeit. Gedanken zur Konzeption und Entwicklung spielbasierter digitaler Lernumgebungen. In: MedienPädagogik. Zeitschrift für Theorie und Praxis der Medienbildung, 15, 2008.
4. Boes, A./Preißler, J.: Vorlage zum Berichtsgegenstand Digitale Spaltung bei der Arbeitskonferenz des Verbundprojekts „Berichterstattung zur sozio-ökonomischen Entwicklung der Bundesrepublik Deutschland: Arbeit und Lebensweisen" vom 27. bis 28.02.2002, Bonn, 2002.
5. Derntl, Michael; Neumann, Susanne; Oberhuemer, Petra (2009): Report on the Standardized Description of Instructional Models. ICOPER 2009.
6. Egenfeldt-Nielsen, Simon (2007): Educational Potential of Computer Games. New York: continuum books 2007.
7. Gee, J. P.: What Video games have to teach us about learning and literacy. Revised and Updated Edition. Palgrave Macmillan, Basingstoke, 2007.
8. Hague, Cassie; Williamson, Ben (2009): Digital participation, digital literacy, and school subjects. A review of the policies, literature and evidence. A report for Futurelab. Retrieved January 2, 2010, from: http://archive.futurelab.org.uk/resources/publications-reports-articles/literature-reviews/
9. IEEE LTSC (2002). Final Draft Standard for Learning Object Metadata. Retrieved 01/15/10 at http://ltsc.ieee.org/wg12/files/LOM_1484_12_1_v1_Final_Draft.pdf.
10. Kirriemuir, John; Mcfarlane, Angela (2004): Literature review in games and learning: A report for NESTA Futurelab. Retrieved September 1, 2009, from: http://archive.futurelab.org.uk/resources/publications-reports-articles/literature-reviews/
11. Klimmt, C./Schmid, H./Orthmann, J.: Exploring the Enjoyment of Playing Browser Games. In: CyberPsychology & Behavior, 2, 2009; S. 231-234.
12. Lagoze, C. and Van de Sompel, H. (2001) The Open Archives Initiative: Building a Low-Barrier Interoperability Framework. Proc. 1st ACM/IEEE-CS Joint Conf. Digi- tal Libraries, ACM Press, pp. 54–62.
13. Medienpädagogischer Forschungsverbund Südwest / JIM-Studie 2009. Retrieved: 28.12.2010 from: www.mpfs.de.
14. Meier, C.; Seufert, S.: Game–based learning: Erfahrungen mit und Perspektiven für digitale Lernspiele in der betrieblichen Bildung. In A. Hohenstein & K. Wilbers (eds.): Handbuch E–Learning für Wissenschaft und Praxis (Erg. Lfg. 5,5.1/1–12), Köln: Deutscher Wirtschaftsdienst.
15. Mitchell, A., & Savill-Smith, C. (2004): The use of computer and video games for learning. A review of the literature. London: Learning and Skills Development Agency.
16. Najjar, J., Derntl, M., Klobucar, T., Simon, B., Totschnig, M., Grant, S., & Pawlowski, J. (to appear 2010). A data model for describing and exchanging Personal Achieved Learning Outcomes (PALO). International Journal of IT Standards and Standardization Research.
17. Petko, D.: Unterrichten mit Computerspielen. Didaktische Potenziale und Ansätze für den gezielten Einsatz in Schule

und Ausbildung. In: MedienPädagogik. Zeitschrift für Theorie und Praxis der Medienbildung, 15, 2008.
18. Prensky, Marc (2007): Digital Game-Based Learning: Practical Ideas for the Application of Digital Game-Based Learning. St. Paul, Minneapolis: Paragon House 2007.
19. Ritterfeld, U./Cody, M. J./Vorderer, P. (Hrsg.): Serious Games: Mechanisms and Effects. Routledge, New York/London, 2009.
20. Schiefele, U.: Motivation und Lernen mit Texten. Hogrefe, Göttingen, 1996.
21. Schiefele, U./Schreyer, I.: Intrinsische Lernmotivation und Lernen: Ein Überblick zu Ergebnissen der Forschung. Zeitschrift für Pädagogische Psychologie, 1, 1994; S. 1-13.
22. Schmitz, B.; Czauderna, A.: Spielbasierte Kompetenzentwicklung für Bildungsbenachteiligte Jugendliche. In: Holger Diener, Dennis Maciuszek, Steffen Malo, Alke Martens, Bodo Urban (eds.): Tagungsband der Abschlusskonferenz des Verbundprojektes Alphabit in Zusammenarbeit mit dem 4. Workshop Game-based Learning, Seiten 59-75. Fraunhofer Verlag 2010.
23. Schmitz, B.; Klemke, R.; Totschnig, M.; Czauderna, A. (2011): Outcome-oriented learning games – transferring a higher education architecture to basic qualification. Submitted to: CD4TEL 2011 – Computational Design for Technology Enhanced Learning. Technical Session at ICCSA 2011, Santander, Spain, June 20-23, 2011.
24. Steinkuehler, C. A. (2004): Learning in massively multiplayer online games. In: Y. B. Kafai, W. A. Sandoval, N. Enyedy, A. S. Nixon, F. Herrera (Eds.): Proceedings of the Sixth International Conference of the Learning Sciences (pp. 521–528). Mahwah, NJ: Erlbaum.
25. Steinkuehler, C. A. (2008): Massively multiplayer online games as an educational technology: An outline for research. Educational Technology, 48(1) (pp. 10-21).
26. Ulicsak, Mary (2010): Games in Education: Serious Games. A report for Futurelab. Retrieved January 4, 2010, from: http://archive.futurelab.org.uk/resources/publications-reports-articles/literature-reviews/
27. Unterfauner, Elisabeth; Marschalek, Ilse; Fabian, Claudia Magdalena (2010): MOBILE LEARNING WITH MARGINALIZED YOUNG PEOPLE. In: Proceedings of the IADIS Interantional Conference Mobile Learning 2010 in Porto, Portugal, pp. 28-36.
28. Zwiefka, N.: Digitale Bildungskluft: Informelle Bildung und soziale Ungleichheit im Internet. In: Rössler, P. (Hrsg): INTERNET Research. Band 28. Verlag Reinhard Fischer, München, 2007.