VISUALIZATION OF KNOWLEDGE MATURITY FOR PRODUCT-SERVICE DEVELOPMENT

Christian Johansson[a] and Åsa Ericson[b]

Division of Functional Development, Luleå University of Technology, SE-971 87 Luleå, Sweden.
Email: [a]Christian.Johansson@ltu.se, [b]Asa.Ericson@ltu.se

An extension towards a service perspective in manufacturing firms challenge the established knowledge base of products, making it necessary to assess the team's competences in light of a broader view of knowledge. In this paper, the knowledge maturity scales are presented as a method for teams' to visualize such wider view. Thus, the team can assess which areas that are and are not covered, as well as estimate the state of the current knowledge. The scales have emerged in an industry-academic research project, but needs to be further improved to fit into a service perspective for manufacturing firms. The purpose in this paper is to present the scales, the reasoning that was used to design them and to discuss the necessary improvements of them.

Keywords: Knowledge management, Knowledge maturity, Stage-Gate process, Decision making, Product-Service System, PSS.

1. INTRODUCTION

Recently in manufacturing firms, the intentions to provide service offers can be seen. For example, leasing of products has become more interesting for both manufacturers and customers in a business-to-business environment. Today, these companies tend to incorporate a vision of service provision into their strategies, communicating more softer and intangible values than previously. Such values are also seen from a customer point of view, and is expressed by a will to provide e.g. "total care products" [1]. This new business model has over time been recognized as a specific value offer [2] or servitization [3]. The core is that services will become the base for manufacturers' offers and in some cases these will totally replace the purchase of goods, in particular this is true for those firms that aim to brand their company as sustainable focused. At the heart of the new business model is the belief that service provision can change consumption patterns [4], yet such views have to affect the design and the development of the goods to have a profound impact on sustainability issues. Here we argue that the aspects — an extension to incorporate a new business model and the integration of service perspective in early product development — challenge the established paradigm of manufacturing companies.

It is recognized that product development at a large extent has to manage other aspects than what we can call "mere facts". Bucciarelli [5] concludes that design and development work are social activities, i.e. people communicate, collaborate, share and build on each other's ideas etcetera. Previous research has found that the stage-gate process [6] works as a *boundary negotiating artefact* [7]. The development team can relate their work to the criteria for the gate decisions; thereby they can assess and negotiate what is needed to fulfill the expected deliverables in the gate reviews.

The stages handle a wide array of knowledge and information. However, only a limited amount constitutes the decision base in the gates. While supporting progress, the stage-gate model also filters information and prohibits the build-up of a wider knowledge base. In a traditional product development process this is still fairly straightforward, with activities being focused on raising the understanding of the goods and its use. Here, the service development takes place when the product has been developed.

Research into Design — Supporting Sustainable Product Development. *Edited by* Amaresh Chakrabarti
Copyright © 2011 Indian Institute of Science, Bangalore, India :: *Published by* Research Publishing
ISBN: 978-981-08-7721-7

Services are considered as "add-ons" that are offered on an "after market" [8]. With this perspective, integrating service aspects with the development of the goods becomes troublesome. Instead of merely gathering information about customers' preferences on the device (i.e., what features they would like to see improved), activities have to focus on peoples' goals and wanted outcomes (i.e., what they like to achieve with the device). A service perspective means that activities should be seen from the user's perspective, and services are integrated activities [9]. The service perspective also adds complexity, because these aspects are intangible and difficult to measure.

In general, if such non-measurable aspects are handled in a development process, there is usually an effort to represent them with numbers and figures. However, interpreting an experience into an assessed number insists on knowing the rationale for such transformation. In this context, the quality of the knowledge base is interesting, that is, what level of maturity does the knowledge base have. Therefore, this paper presents knowledge maturity scales and discusses rationale for expanding the criteria to include a service perspective in early development of goods.

Beside a pragmatic view of the term knowledge, the paper includes other delimitations. Decision making is handled from the perspective of engineering design, in particular a process view. The theoretical foundation presented here composes of distinct knowledge domains, but are interpreted and viewed from the engineering design perspective. Further, even though inspired from previous empirical studies the paper does not include accounting of such data. Data from aerospace industry is reported on in Johansson [10]. This has implications for generalizations and the transparency of our research method, in particular the choice of relevant theory presented in this paper.

2. RESEARCH METHOD

The knowledge maturity scales presented in this paper are based on empirical data from a research project in cooperation with an aerospace manufacturer; see Johansson [10] for details. Through a series of workshops with up to eight participants, with the aim to develop a knowledge support for an accelerated development process of stage-gate format, industrial experts were closely involved in the research effort. The participants of the workshops assisted in the development of the knowledge maturity scales and allowed for the researcher to elicit their expertise of the work contexts, determining what is an utopian decision-making situation and conversely what is the worst case scenario. This approach offers a validation of sorts, albeit a more rigorous test is needed to further validate the knowledge maturity scales.

The aerospace context is a bit different from many other industrial contexts since product development is performed in extended enterprises with many companies, meaning that product development is closely regulated in contracts between the partnering companies. This means that the study cannot be generalized beyond this context, because many other sectors utilize a market push strategy.

This study place the knowledge maturity scales in the frame of a shift to a service perspective for manufacturing firms, presenting findings from literature, and then discussing and analyzing them from this specific perspective. First the concept of knowledge is outlined as an effort to highlight the pragmatic view on knowledge that is the basis for the knowledge maturity scales. Second, we present the concept of knowledge maturity, followed by the third part where the knowledge maturity scales are presented and discussed.

3. THE CONCEPT OF KNOWLEDGE

From a scientific point of view, knowledge is archetypically defined as 'justified true belief'. This definition, especially the meaning of "true", has been a subject of controversial discussions for a long time leading to a more facetted view of knowledge. Nowadays, knowledge is recognized as encompassing dynamic dimensions as well, i.e. knowledge is also socially constructed and evolves and changes over time. Knowledge is commonly divided into two main categories, namely, tacit and explicit knowledge. Tacit knowledge is not easily expressed; it is highly related to human's experiences

and actions. The idea of tacit knowledge stems from the term local knowledge [11], which describes that some facets of knowledge are related to what is locally known and inherent in practices and routines, thus not straightforwardly expressed. Explicit knowledge can be articulated and (relatively) easily formalized, for example into rules of thumb.

There is also a distinction between knowledge and information. Information can be separated from context and humans, hence can also be formalized and disseminated within the organization. Knowledge is context dependent and part of a human's mind and body [12]. This view makes it possible for discussions of explicit knowledge as being nothing else than information to occur. In respect of knowledge as part of mind and body, a distinction of theoretical and practical knowledge can be done (erudition and skill are other terms that can be found in literature). People can possess theoretical knowledge as well as practical, so a human can convey knowledge by intellect and/or by skills.

For a firm knowledge assets are important, thus knowledge has no direct value for the company if it cannot be transformed into actions and performance. A definition of knowledge from a company perspective could be that: knowledge is actionable information [13]. And, for information to progress knowledge actions, it has to fulfill some basics, namely being relevant, purposeful, in time and verified.

A company's knowledge base can be described as facts, rules and procedures gathered and organized into schemas [13]. Yet, it is understood that a firm's knowledge base is built up of more that what is produced in daily work activities [14]. For example, what is interpreted by individuals, given a new context, anchored in the beliefs and commitments of individuals are also part of the firm's knowledge base [12]. Nonaka *et al.* [12] present four categories of knowledge resources that create value for a firm (these resources are intertwined and cannot be seen as snapshots):

- Experiential — tacit knowledge shared in common experiences; e.g. know-how, emotions, conceptions.
- Conceptual — explicit knowledge manifested in images, symbols and language, e.g. product concepts, design. These are explicit to the firm, but difficult to come to terms with what is perceived by external actors.
- Routine — tacit knowledge embedded in practice, e.g. culture. These are reinforced and shared in particular ways of thinking and doing in everyday business.
- Systemic — explicit knowledge that are systematized and packaged in, e.g., manuals and databases.

A criticism of contemporary knowledge management is that it focuses mainly on the systemic knowledge resources from a monitor and control perspective [15]. In a decision making situation, a crucial challenge is how to assess the knowledge sources and knowledge assets with respect to their fitness for purpose. In these situations, there is a degree of ambiguity and uncertainty that needs to be handled. What is the readiness of the information? Is it reflecting assumptions or verified facts? Is there missing information? Is it current or out of date? Is there need of improvements? How does the tacit knowledge complement the formal documentation? Therefore, an approach of knowledge management as empowerment of actions is suggested.

For the knowledge maturity concept presented in this paper a pragmatic view of the term knowledge is applied. A company perspective is used to capture the term knowledge, this means that all sorts of aspects that can be transformed into activities and performance relate to knowledge. So, we will content with acknowledging that knowledge is not straightforwardly defined and include both tacit and explicit aspects, but still knowledge is used in some senses in companies. Though, the "maturity" part needs to be discussed in the context of knowledge.

4. KNOWLEDGE MATURITY

Commonly, the word 'maturity' is described in dictionaries as an end state, as for example "*the state of being fully grown or developed*" [16, p. 791]. However, this is not sufficient for understanding maturity in this context. Grebici *et al.* [17] define 'information maturity' as "*a compromise between the target uncertainty and the expected uncertainty*" [17, p. 282], thus explaining that immature information (uncertain, incomplete, imprecise etc.) is exchanged in collaborative design teams. Their

proposed information maturity framework aims to decrease risk of design errors, to support exchange of information at the right level and in the right time and to highlight coordination problems. Nonaka [12] outline the potential to formalize information, which is in line with the information maturity framework intentions to support distributed work.

Bohn [18] defines maturity of knowledge as "*understanding the effects of the input variables on the output*" [18, p. 63]. In such a definition 'understanding' indicates that knowledge cannot be separated from context and humans [12]. 'Understanding' is a highly subjective and personal human activity, thus depending on the individual's attitude, skills and personality. Also, people "*know more than we can tell*" [19, p. 4], indicates that people cannot provide the right knowledge in the right time in all cases and that knowledge creation is an intertwined process in our doings.

The concept of knowledge maturity presented in this paper relate to these views, i.e. there are both tacit and explicit aspects that should reach a state of completeness. However, the level of completeness is assessed on satisficing rationality [20]. Satisficing rationality means that decision makers have limited access to information, have limited capacity to process the information, cannot know all alternatives and cannot judge their consequences. Hence, the concept of knowledge maturity is assessed in terms of 'good enough' or 'close enough' [20]. This builds on supporting a dialogue among the actors.

Conceptual models [21] can be used to initiate a dialogue about what understanding that underpins our doings, i.e. what meaning people give to certain information to take for them purposeful actions. A conceptual model is not a blueprint of reality, rather it is a tool to support the reasoning and communication of dilemmas in order to aid visualization of satisficing decision making. Technology Readiness Level (TRL) [22] as well as Capability Maturity Model [23] for processes are good candidates of the conceptual model category. Below the TRL concept is described in more detail.

4.1. Technology Readiness Level

The framework for TRL was developed by NASA [22] to guide the technical development work within space missions. Aerospace is an industry that is governed by a rigorous regulatory framework, stating the role of testing and certification. You simply cannot bolt parts on a plane that might not hold. The costs for failure of any component or system will be too high in this setting. TRL is an approach to judge the completeness in the technology by making the evaluation and validation processes from research to 'flight proven' visible. Thus, also making it reasonable to assess the as-is state in relation to the targeted to-be state.

TRL features a 9-level criterion scale, using the analogy of a thermometer, see Figure 1. The scales represent states from TRL 1: observed basic principles to TRL 9: successful mission operations, i.e. flight proven.

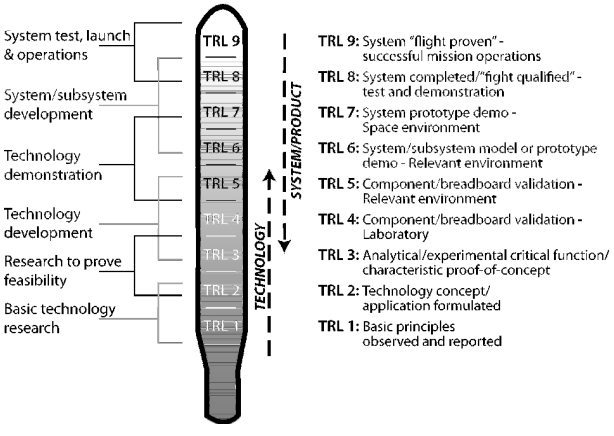

Figure 1. Technology Readiness Level, adapted from [22].

TRL is a commonly established method within the aerospace industry. Apart from measuring the technological maturity, one of the benefits of using TRL are recognized to be the negotiation about the TRL value and that TRL provides a common language among the actors [24]. Though, the negotiation is also supported by the focus on technology, e.g. evaluation methods and measures exist and aspects can be made tangible by using the technology as the object for the discussions. As described above, knowledge is a more complex aspect in decision making since it is more or less intangible.

5. THE KNOWLEDGE MATURITY SCALES

The knowledge maturity scales are developed as a complement to the TRL method. In each development project, progress in the knowledge base is also expected. Commonly, such knowledge creation (i.e. learning) takes place in a collaborative environment. Lessons learned systems are used to store and disseminate some issues of knowledge creation, but does not support the direct interpersonal communication in teams. In this direct communication between actors the reasoning builds up understanding to give meaning to future activities. However, main parts of that reasoning are embedded in "things we just do", e.g. based on organizational culture, routine tasks and praxis. These "things we just do" depend on different contexts, for example, some can be found on a organizational level, some on a division level, some on a professional guild level and some on a personal level. The knowledge maturity scales represent an effort to inspire to a dialogue to make the reasoning visible and to support decision making.

First, a generic knowledge maturity scale was developed, see Table 3.1.. It is important to keep in mind that 'generic' in the scales refer specifically to the case company (in Johansson [10]) and is not the same as general for all companies.

The definitions of criteria for levels 2 and 4 have been intentionally omitted. These levels function as intermediary levels where the criteria of the higher level are not fully met. When the actors position their knowledge maturity in such an intermediary level, they are nudged to discuss ways to reach the next level. By doing so, they find 'pointers' for what is needed. This performance is similar with the discussions in TRL, i.e. a comparison between the as-is state in relation to the targeted to-be state.

Secondly, the scale was adapted to fit into three dimensions of knowledge maturity, namely input, method and experience, see Table 4.1..

The input dimension relates to the information from sources outside the development team. External information is a necessity and has a profound impact on the product under development. The challenge

Table 1. Generic knowledge maturity scale.

5	Excellent	The content and rationale is tested and proven. It reflects a known confidence regarding, for instance, risks. The procedure to produce the content and rationale reflects an approach where verified methods are used and where workers continually reflect and improve. Lessons learned are recorded.
4	Good	
3	Acceptable	The content and rationale is more standardized and defined (i.e. documented and formalized). There is a greater extent of detailing and definition (compared to previous level). The procedure to produce the content and rationale is more stable (compared to previous levels) with an element of standardization and repeatability.
2	Dubious	
1	Inferior	Content and rationale is characterized by instability (e.g. poor/no understanding of knowledge base). The procedure to produce the content and rationale is dependant on individuals and formalized methods are non-existent.

Note: *Source* [10].

Table 2. Generic scales for input, method, experience.

		Input	Method	Experience
5	Excellent	Input is detailed and verified.	Tested, standardized and verified methods that are under continuous review and development.	Long verified experience and expertise within area of concern.
4	Good			
3	Acceptable	Input is available in detailed form, but is not verified.	Standardized and tested methods have been used.	Proven experience and competence within area of concern.
2	Dubious			
1	Inferior	Risk of incorrect input data.	Untried methods have been used (ad-hoc).	The person doing the work is inexperienced (first time).

Note: *Source* [10].

is to assess the quality of information. The method dimension relates to a wider view including tools and procedures as well. There are often specific ways of working, i.e. standards. The challenge is to assess the actors' confidence of the methods, tools and procedures. The experience dimension relates to human aspects, those who do the work have a great influence on it. The challenge is to assess the consequences of people's competences. These three dimensions are interrelated and the value from the discussions based on the scale is the negotiation about a strategy for the specific context.

Also in this scale, Table 4.1., the level 2 and 4 have been intentionally omitted to support the efforts to find relevant criteria for the specific task.

6. KNOWLEDGE MATURITY FOR PRODUCT-SERVICE DEVELOPMENT

The move in industry towards provision of services is commonly described as a specific value offer [2] or servitization [3]. It might be misleading to talk about provisions of services, since it seems like these 'services' more relates to 'value' than ordinary services. In manufacturing companies the focus has traditionally been on products, where services, e.g. maintenance, spare parts and training, are offered to keep the goods up and running. The change into a focus on value offerings and providing systemic solutions challenge the established development procedures, subsequently, act both as a window to start rethinking routines and as an opportunity to take a step closer to partners in the value chain. From a development perspective, it is important that engineers and designers are involved in early phases. This, we argue, is a way to realize the the extension towards a service perspective, but also challenging due to the different thinking, reasoning and doing compared to what has been learnt and practiced so far.

For example, the idea of what a product actually is changes. This kind of reflection is not necessary in manufacturing companies today, since everyone knows that the goods is the product and that services should support it. For a service business model, despite attempts to do so, it is not straightforward to find the answer in the name. Also, since the idea is to provide the users/customers with what they perceive as value, the core of the product is a matter of negotiation. Commonly, as exemplified with the TRL, physical artifacts can be assessed and evaluated vis-à-vis product specification, for a service model agreeing on a product to specify is in itself an issue. The development team has to be supported in their efforts to communicate cross knowledge domains and settle for the 'product' (the degree of combination and/or integration of goods and services) that is 'good enough' for all parties.

From the teams' point of view, the aspects that are included in product-service development are based on both tacit and on explicit knowledge. For general terms, like value, all parties have an opinion what it is, but in development teams the understanding of the terms used are rarely discussed.

Commonly, it is assumed that the interpretation is shared, yet over time discussions and even conflicts can emerge. Tacit knowledge and experiences usually need more dialogues and reflections than explicit knowledge. Typically, product development embarks from specifications that state the requirements on the product, while from a service perspective; the 'product' (degree of combination or integration of products and services) has to be settled by the team that should do the design. Understanding information from users/customers includes to interpret, and thereby to do subjective judgments to translate it. And, this goes both ways since the user/customer have to express their requirements related to what they perceive as value. Here we suggest adapting the knowledge maturity scales to support this kind of dialogues. The generic scale for input, methods and experience (Table 4.1.) could be improved to fit a service perspective by, for example add a set of questions to nudge the team in a direction.

Additionally, to be truly effective as a decision support instrument, the knowledge maturity scales needs to be complemented by a visualization tool to provide stakeholders with a timely awareness of what aspects of the service offer that needs to be further scrutinized to reach a confident level to open a gate. The focus of a visualization to support knowledge maturity assessments should be on providing the right information at the right time to the stakeholders, meaning that they should in an effortless manner be able to pinpoint areas of weakness and/or disagreement between the stakeholders. Further, this kind of decision support should make use of a peer review process to allow the stakeholders to perform a perspective sharing dialogue, which give pointers for project progress.

7. CONCLUDING REMARK

This paper embarked in the effort to present and discuss the rationale for knowledge maturity scales for the purpose to set up criteria for improved scales, which can support decision making for an extended business model including a service perspective.

Having inherent ambiguity, the new business model brings great opportunities, but also poses risks of not being able to assess the readiness of the teams' knowledge base. In typical product development 'unknowns' relates to a goods, meaning that we do not know the answer but we know what to ask about.

In product-service development, the knowledge base is built up of much more tacit knowledge, due to the integration of service and value, meaning that asking the right questions is difficult for the team. The knowledge maturity scales allow discussions to find the as-is level of competence, still guidance is needed to take on a service perspective that avoid "business-as-usual" mentality.

Therefore, we conclude that the knowledge maturity scales, especially the generic scales for input, method, experience, should be improved by a set of questions at level 2 and 4. That guidance could support stakeholder with the comfort and confidence to take a go/no-go decision for product-service development.

For further research the effort is to make the knowledge scales more adaptable to product-service development by designing a set of questions and visualize the team's answers to those questions. Such a tool put forward a conceptual model of the team's knowledge domains and competences at an abstract and holistic level. In this generic picture, pointers to areas where additional competences are needed should be highlighted, i.e. pointing out low maturity areas. The generic appearance supports discussions in a cross-disciplinary team and avoids them to go into details early on. By this, there is a possibility to decrease time-consuming discussions that build on no shared design view in the team, and increase the effectiveness in decision making.

ACKNOWLEDGMENTS

The authors would like to express their gratitude to the case company for good and inspiring collaboration in the previous study that enabled the development of the knowledge maturity scales.

REFERENCES

1. Alonso-Rasgado T., Thompson G. and Elfström B.-O., "The design of functional (total care) products", *Journal of Engineering Design*, 15, 515–540, 2004.
2. Tukker A., Van Den Berg C. and Tischner U., "Product-services: A specific value proposition", in "New Business for Old Europe: Product-Service Development, Competitiveness and Sustainability", A. Tukker and U. Tischner, Editors, Greenleaf Publishing 2006.
3. Bains T.S., Lightfoot H.W., Evans S., Neely A., Greenrough R., Peppard J., Roy R., Shehab E., Braganza A., Tiwari A., Alcock J.R., Angus J.P., Bastl M., Cousens A., Irwing P., Johnson M., Kingston J., Lockett H., Martinez V., Michele P., Tranfield D., Walton I.M. and Wilson H., "State-of-the-Art in Product-Service Systems", ImechE, Vol 221, Part B: J. Engineering Manufacture, pp. 1543–1552, 2007.
4. Manzini E. and Vezzoli C., "Product-Service Systems and Sustainability: Opportunities for Sustainable Solutions", Report UNEP, 2001.
5. Bucciarelli L.L., "Designing Engineers, MIT Press, 1994.
6. Cooper R.G., "Winning at New Products: Accelerating the Process from Idea to Launch", 3rd ed., Perseus Books, 2001.
7. Lee C.P., "Boundary Negotiating Artifacts: Unbinding the Routine of Boundary Objects and Embracing Chaos in Collaborative Work", Computer Supported Cooperative Work, 16, 307–339, 2007.
8. Normann R., "Reframing Business: when the map changes the landscape, Wiley, 2001.
9. Edwardsson B., Johnson M.D., Gustafsson A. and Strandvik T., "The Effects of Satisfaction and Loyalty on Profits and Growth: Products versus Services", Total Quality Managment, 11, 2000.
10. Johansson C., "Knowledge Maturity as Decision Support in Stage-Gate Product Development: A Case From the Aerospace Industry", Doctoral Thesis, Department of Applied Physics and Mechanical Engineering, Luleå University of Technology, 2009.
11. Normark M. and Randall D., "Local Expertise at an Emergency Call Centre", Ninth European Conference on Computer-Supported Cooperative Work, 2005.
12. Nonaka I., Toyama R. and Konno N., "SECI, Ba and Leadership: a Unified Model of Dynamic Knowledge Creation", Long Range Planning, 2000.
13. Turban E. and Aronson J.E., "Decision Support Systems and Intelligent Systems, Prentice-Hall, Inc., 2001.
14. Brusoni S., Prencipe A. and Pavitt K., "Knowledge Specialization, Organizational Coupling, and the Boundaries of the Firm: Why Do Firms Know More Than They Make?", *Administrative Science Quarterly*, 46, 597-621, 2001.
15. Ackerman M., Pipek V. and Wulf V. eds., "Sharing Expertise: Beyond Knowledge Management", MIT Press, 2003.
16. Oxford_University_Press, "Maturity", in "Oxford Advanced Learner's Dictionary. Oxford University Press, 2000.
17. Grebici K., Goh Y.M., Zhao S., Blanco E. and Mcmahon C., "Information Maturity Approach for the Handling of Uncertainty within a Collaborative Design Team", 11th International Conference on Computer Supported Cooperative Work in Design, 2007.
18. Bohn R.E., "Measuring and managing technological knowledge", Sloan Management Review, 61–73, 1994.
19. Polanyi M., "The Study of Man, University of Chicago Press, 1967.
20. Simon H.A., "Rational Decision Making in Business Organizations", *The American Economic Review*, 69, 493–513, 1979.
21. Checkland P., "Systems Thinking, Systems Practice: Includes a 30-Year Retrospective, John Wiley & Sons, 1999.
22. Mankins J.C., "Technology Readiness Levels", White Paper NASA Advanced Concepts Office, Washington, DC, USA, 1995.
23. Paulk M.C., Curtis B., Chrissis M.B. and Weber C.V., "Capability Maturity Model SM for Software, Version 1.1", Software Engineering Institute, Carnegie Mellon University, Pittsburgh, PA, 1993.
24. Graettinger C., Garcia S., Siviy J. and Schenk R.J., "Using the Technology Readiness Levels Scale to Support Technology Management in the DoD's ATD/STO Environments", Technical Report Carnegie Mellon University: Software Engineering Institute, Pittsburgh, PA, USA, 2002.