Fostering innovation:
What we can learn from experts and expertise

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Abstract
Innovation has become the hot topic of today's working life, yet it is still unclear how education would best support this skill. What should we be developing? Much can be learnt comparing adaptive experts' problem solving behavior to that of non-experts. Based on a literature review and in-depth interviews of product development experts, whose job is to solve new and often poorly defined problems, we have identified a number of key abilities that innovative experts possess.

By establishing critical differences between experts and non-experts, we have already narrowed down the question of how we should be developing the innovators of tomorrow. The next question is how to develop these identified abilities. The literature gives reason to believe that the key is in the amount and quality of experience in solving problems, as is indicated by the conducted interviews as well. We conclude by a brief analysis of what elements are needed in problem solving exercises in order to help students to become experts in their chosen field.

Keywords: expertise, experience, problem solving, innovation, creativity

1. INTRODUCTION

Developed countries are shifting from industrial economies to knowledge economies [4, 14], which are based on information and innovation. Sawyer [35] argues that these knowledge economies can only thrive if we prepare all students, not a chosen few, to participate in creative systems. Deep understanding instead of mastery of lower-order facts should be required from all students [5, 8]. In fact, we should be developing experts out of our students [6].

The connection between expertise and creativity has received little academic attention [42], possibly because much creativity research has focused on relatively simple and general problem solving exercises used in laboratory conditions. However, while general knowledge can suffice for creative behavior, true innovations are unlikely to occur without domain-specific expertise [42]. Some kind of general creativity is not enough, one needs to have good knowledge of the target area in order to see potential and break the existing limits of knowledge (cf. [15]). Expertise frees up mental resources from mundane tasks via automation and experts have a talent of seeing immediately what is relevant (e.g. [23]), an extremely important skill in the complex, information-rich real world. In addition, in some fields expertise clearly requires some degree of creativity. One example is product development, where professionals are routinely required to come up with new ideas. By studying how these experts differ from non-experts and what the differences are based on, we can gain valuable insights into fostering innovation.

2. HOW EXPERTS DIFFER FROM NON-EXPERTS

2.1 Literature review of expertise research

Expertise has been studied in a very wide range of activities, including sports, games, art and numerous professions. It is defined as consistently superior performance in representative tasks of the field of expertise [18, 19], and it is usually associated with some minimum amount of experience (e.g. the ten-year-rule of Simon & Chase [39]) in operationalizations of the term. There is a consensus in the literature that expertise is based more on experience, especially on deliberate practice, than on any innate abilities or intelligence measures [16, 17, 21]. Another characteristic of expertise is domain-specifity – expertise in physics does not lead to expertise in chemistry. Nevertheless, some general skills and aspects of expertise can be identified. These differences arise form the fact that experts have a larger knowledge base, which is better organized, and which they are able to utilize more efficiently than non-experts [6, 13, 20, 29 (pp.173-183)].

One of the benefits experts posses is having a better overall picture and being able to discriminate between relevant and irrelevant information. For example, while students classify physics problems based on their surface features, expert physicists classify them based on their deep structure [27]. Expert chess players, on the other hand, spend more of their time looking at important pieces than what novices do [12]. Both of these examples illustrate that experts are better at judging what information is needed in order to solve the problem.

Not only do experts know better than novices what is relevant, they also know it faster. Volleyball experts recognize faster whether there is a ball visible in pictures taken from games [1] and chess experts are faster noticing whether there is a check in the displayed image of a chess game [34]. There are also numerous examples of the phenomenon in professions where acting fast can be critical, such as firefighting and critical care nursing [24, 23].

Knowledge of promisingness is one key manifestation of expertise. For example, chess experts do not really consider more options than less skilled players, they simply think of better possible moves [26, 11]. According to Bereiter and Scardamalia [6], knowledge of promisingness is especially required for creative expertise. While creative accomplishments require risk, only successful risks bare fruit in the form of innovations. Thus it is important to know when taking a risk is worth it. Bereiter and Scardamalia [6] describe knowledge of promisingness as impressionistic knowledge based on matching to the goal, matching to one's own capabilities and recognizing pointers to further possibilities. Such knowledge as what is promising or relevant is often tacit or intuitive - the experts have a feeling what they should do, but cannot necessarily tell why [23].

A final component of expertise worth mention is that of metaskills, related to for example learning and the usage of knowledge. Monitoring, adjusting and analyzing one's thinking, learning and knowledge is a basis for problem solving and expertise [20, 6]. Experts know the limits of their knowledge, how to learn and how to set goals and proportionate them to the resources available [6]. Learning skills can be developed, for example expertlike learners are more learning goal -directed and have higher level goals (knowledge building goals) than non-expertlike learners (who are limited to task accomplishment goals) [6]. (see Table 1, below, for a summary of the characteristics of expertise)

2.2 Expert Interviews

2.2.1 Methods

<u>Subjects</u>

During Fall 2007, 11 in-depth interviews of experienced product developers were conducted. The participants to the study were selected based on nominations from product development managers for especially capable product developers within their department. They represented 4 large industrial and product development companies in Finland. The subjects had from 6 to 36 years of experience in product development and, with one exception, were all Finnish. Their current positions varied from chief developers and project managers to product development managers, but all of them had several years of hands-on experience in development projects.

Interviews

The interviews utilized a simplified variant of the critical incident based technique critical decision method [25]. The subjects produced a step by step account of one example project that had gone particularly well and of one that had had more challenges than usual. The interviews lasted from 1.5 to 3.5 hours. The focus was on the initial phases of the project, where concepts are created and developed, rather than on the detail design and ramp-up for production. The interviews were transcribed and a number of reoccurring themes were identified and classified from the responses using an affinity diagram approach.

2.2.2 Results

The interviews revealed that product development experts have typically a very wide interest and knowledge related to their field, which they reported to enable them to create better ideas. This is in accordance with Simonton [40]: "creative people tend to have wide interests and to entertain themselves with hobbies that often bear some remote connection with their professional activities". The experts pick up ideas from diverse sources: hobbies, previous projects, neighboring fields, vacation trips... They see potential and analogies in even seemingly unrelated concepts and then develop the idea further. For example, one interviewee reported getting a concept for a technical manual from a city map.

The experts have knowledge from bordering fields as well, which enhances working as a group. They know if someone should be consulted before changing something. They also have metacognition related to their groups: they know what belongs to whose job and they know whom they should ask for help if needed (see also [28]).

The product developers highlighted the need to see the big picture. One interviewee described product development as a series of hundreds of small decisions and that the catch is to do them efficiently: focus on the important aspects and not waste time on trivial ones. As in the literature (e.g. [6]), the importance of goals and directing one's efforts came up repeatedly.

Being able to tell the relevant and irrelevant apart is crucial, but it is not the only thing the experts seem to perceive immediately. The subjects reported "just knowing" whether something was promising, would be manufacturable, would be able to stand a certain pressure, et cetera. They relied on their intuition making these initial judgments and also reported plenty of rules-of-thumbs and cues.

Finally, it is worth noting that one thing that the experts clearly had problems with was verbalizing all of the related knowledge and information. Much was just put under the category of hunches, even though specific cues could often be discovered behind the feelings. The experts cannot guide someone else to do the job as well as they can and often have trouble explaining why they think something.

Table 1, below, summarizes the findings from the literature review and interviews.

Table 1. Important features of expertise and some of their consequences

Difference	**Result**
Better overall picture	Better recognition of problems, Better options created
Wide interests	Better options created, Better collaboration
Better and faster to know what is relevant	Better targeting of resources
Better knowledge of promisingness	Better targeting of resources, Better options created
Better metaknowledge	Better collaboration, Better targeting of resources
More goal-directed	Better targeting of resources
Good at combining information from different fields	Better options created
Much tacit knowledge	Challenges for sharing expertise and teaching

3. THE ROLE OF EXPERTISE AND CREATIVITY IN PROBLEM SOLVING

In everyday language problem solving is usually thought of as meaning solving exercise problems, but in fact problem solving lies at the heart of human activity. For example all decision making is problem solving, and according to Newell, Shaw and Simon [31], creative thinking, as well, is problem solving. Thus problem solving here encompasses a much wider meaning than solving exercises. In order to solve a problem, one must identify the problem, operationalize it, come up with alternative options or actions, and determine which would produce the desired goal state. Finally one has to evaluate whether the problem is solved or not.

Problems consist of an initial state, a goal state and a set of possible operators by which the problem state can be changed [32]. Problems can be either well-defined, where the initial and goal states as well as the possible operators are clear, or they can be ill-structured, where one or more of these are unknown [33, 37]. For example, most mathematics exercises are typical well-defined problems, whereas deciding whom to hire or creating a marketing strategy would be an ill-structured problem. Problems can also be classified as new or reoccurring - the solving of new problems requires generation of possible solutions, whereas reoccurring problems may be solved successfully by simple retrieval of the solution from memory. For example, product development consists of new problems and finding new solutions to old problems, and, furthermore, the problems are often ill-structured. Thus creativity and synthesis are required in solving these problems.

The first step of problem solving is to identify the problem. Already here expertise and creativity comes to play, as creative processes are initiated by problems, and in order to find the problem, motivation and the expertise-based will and skill to apply effort and learning to the right area are needed [41].

Once the problem has been identified, it needs to be operationalized. For example, in product development, as in other information-rich professions, there are often almost limitless amounts of knowledge available that somehow relates to the problem. To ensure purposeful, effective and efficient investment of the resources available, it is a very important skill to be able to tell the relevant apart from the irrelevant. The available time already limits the amount of factors that can be considered, and furthermore, humans have only limited information processing capacities (e.g. [10, 3, 38, 30]), we are not able to take a large number of variables into account at once. Experts understand what is relevant and can often quickly see the most important factors, as discussed in the previous chapter.

Creativity is most often associated to generating new and unexpected ideas. As creative experts such as product developers are able to systematically produce successful concepts, it is reasonable to assume that experts are able to come up with better ideas than beginners (see also [15]). Research also indicates that experts come to think of better alternatives in problem solving in the first place [12]. This results in both more effective and more efficient problem solving. Experts already often have more alternatives they can retrieve straight from memory, and as indicated by the interviews, they are successful in identifying analogies and getting inspired from diverse sources. In other words, experts see the potential in sometimes seemingly unrelated concepts, which might easily be overlooked by less skilled colleagues.

However, according to Schunn *et al* [36], the real difficulty of ill-defined problems often lies not in identifying alternative courses of action, but it recognizing more fruitful approaches. Coming up with bizarre ideas might be possible for novices, but can they produce truly new and useful ideas? Here experts' knowledge of promisingness (or intuition) is vital.

To summarize, expertise aids at least in four important phases of creative problem solving:

1. Identifying the problem
2. Operationalizing the problem (relevancy and promisingness judgments)
3. Generating good options
4. Developing the options in the most promising direction (or choosing the most promising option)

4. HOW TO FOSTER EXPERTISE

Once we have identified the critical differences between creative experts and non-experts (see Table 1, section 2.2.2) and how expertise can aid problem solving, the next step in creating an education enabling innovations is to find out how the experts' abilities can be developed. There is a general consensus that expertise is based on practice (e.g. [16, 17, 21]). Research has shown that years of experience are needed in order to become an expert [39]. Without applying theoretical knowledge to practice, there is a great risk that it remains inert [6], which is one of the problems the interviewees identified with newly graduated engineer colleagues. For example, much implicit processing and tuning knowledge representations is based on frequencies of events and connections encountered. Thus the more experience is provided, the stronger connections can be established. However, not everyone with extensive experience becomes an expert, so the quantity is clearly not the only relevant criterion – quality needs to be considered as well (see Table 2, below).

What then are the quality criteria we should be evaluating problem solving exercises against? First of all the variety of the experience the exercises provide needs to be considered. Do they cover the full range of relevant activities and knowledge students should be able to master? Furthermore, are the exercises similar to those encountered by real life experts – that is, are they applicable or relevant to the field of expertise the student is aiming for? Both of these questions are relevant for any type of expertise that is sought after.

However, perhaps the most important criterion when assessing creative development is validity (see Table 2, below). While variety and applicability measure whether the relevant skills and knowledge are being learnt, validity indicates whether the students are learning the right lessons: Does the experience give an accurate representation of the problem and its context? Even though the majority of real problems are ill-structured, characterized by ambiguity and uncertainty, often most of the problems students encounter during their studies are quite well-defined. While well-defined problems have their place in teaching and learning, especially in skill acquisition, they do not necessarily provide students with much experience on how to solve problems after graduation or allow for creativity. Furthermore, typical exercise problems are presented without context. However, in order to learn to recognize problems as they occur in the real world, context should be included to problems, as it allows students to develop a sense of what is promising and relevant in the situation.

Validity can be seen to include at least two other subcriteria in addition to the presence of context: received feedback and the impact of errors. Hogarth [22] classified learning structures into kind and wicked ones according to these two criteria. Even though he originally proposed the division in the context of learning valid intuition, it can be assumed to apply in a larger framework as well. In kind learning structures the environment provides relevant feedback[1], which allows accurate learning. On the other hand, if feedback is irrelevant, delayed and uncertain, the learning structure is wicked, and the students might draw the wrong conclusions from their actions. [22] The impact of errors is a careful balance: On one hand, too serious consequences inhibit experimentation, which is often connected to creativity. On the other hand, the precision of learning increases when the errors become more exacting, as this ensures that it is worth the extra effort to correct invalid actions. If consequences are too lenient, it can lead to false confidence, as the student might not even be aware of learning the wrong thing [22].

Table 2. Criteria for evaluating whether a problem solving experience is suitable for developing expertise

Quantity		How much experience of problem solving does the student gain?
Quality	variety	How big a range of different types of relevant problems is provided?
	applicability	Are the problems relevant for real life expert professionals?
	validity	Does the experience give an accurate representation of the problem and its context? Does it help students to learn the right lessons?
	context	Is the problem embedded in its context?
	feedback	Is feedback timely and relevant?
	consequences of errors	How serious are the costs of mistakes?

Table adopted from [7].

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1 Feedback here includes all of the responses the environment provides, such as seeing an experiment work, not only feedback given by other people, such as peers and teachers.

The above criteria give a clear background against which problem solving experiences can be evaluated. However, one must remember that the exercises themselves are only one part of the learning experience. The context of the learning can also be a significant factor in determining the effectiveness of the experience. For comparison, the expert interviewees often though that training should be improved by increasing the focus on methods, problem solving options, basic practical experience (e.g. how different metals bend) and ability to connect theory to practice, but also that students as well as new workers should be encouraged to make mistakes and be open towards options. A trustful and supporting social environment, open to new ideas, has often been named as an important enabler for creativity as well (see e.g. [41]). Belittling critique, as well as competition, can work against creativity by creating a closed atmosphere [41].

Another important factor to consider is motivation. For example, according to Zimmermann [43], motivation and learning have such a strong impact on each other that they can never be analyzed completely independently of each other. In addition to learning, intrinsic motivation also correlates with creativity [2]. According to modern motivation conceptions, intrinsic motivation cannot be caused by external forces, but it can be fostered in an encouraging, enthusiastic and creative environment [9].

A few concrete tips for creating a meaningful and motivating learning experience can be picked up from Hakkarainen, Lonka and Lipponen [20]: Knowledge acquisition should relate to problems, aiming to explain and understand phenomena. Students' preconceptions should be openly discussed and students should be encouraged to participate in and contribute to the collective knowledge acquiring of the class. Lastly, it is better to aim on a deep understanding of a few central concepts than cover shallowly a large amount of topics.

5. CONCLUSIONS

Creative experts, such as professional product developers, are able to consistently succeed in creating new. When attempting to educate the innovators of tomorrow, plenty of pointers to what we should be aiming to teach can be found from studying the differences between these experts and non-experts. Research has revealed that experts have superior skills in relevancy and promisingness judgments, which they can make fast and effortlessly. Experts also have a better overall picture of the problem and can utilize information from diverse sources – not from only past professional experiences, but hobbies, vacations, neighboring fields, et cetera. These allow experts to better recognize and find fruitful areas and ideas.

Experts also tend to be more goal-directed and have plenty of metaknowledge on how to learn, how to think and, for example in the product developers' case, how to function in a group. It enables experts to invest their resources more effectively and efficiently, and thus they become better at developing the initial creative ideas further. This is a very important aspect when innovations are desired, as innovations do not just magically appear, ready to be commercialized, but plenty of work goes to developing the ideas. To quote Thomas Edison, many innovative achievements are based on "1 percent inspiration, and 99 percent perspiration".

As expertise is based on experience, we clearly need to provide students with opportunities for solving problems in order to develop their skills in creating good ideas and developing them further to innovations. However, it is not irrelevant what kind of problems are being solved. The problems need to cover a wide range of relevant areas, be of the type that real experts encounter and provide students with the opportunity to learn the right things. In order to students develop their skills in relevancy judgments, context needs to be included. Feedback from the students' decisions and actions is also crucial. However, the problems themselves are not the only thing that has an impact on the learning outcomes: motivation and an encouraging, open environment should be supported as well to gain the best results.

While this article has focused more on individual aspects of expertise and problem solving, one must not forget that the problems are becoming so complex that no one individual can tackle them and have all the relevant knowledge and skills related to them. For example, product development is done in multidisciplinary teams. As a result, to create innovations people need to work together well despite very heterogeneous team compositions. The sum should be more than its parts, and many of the critical factors named by the product development experts were related to enhancing group work. This highlights the need for skills and tools for communication and collaboration. In addition to field-specific expertise, students should be equipped with the tools of creating a functioning and supportive social environment.

References

[1] Allard, F. & Starkes, J. L. (1980). Perception in sport. *Journal of Sport Psychology*, 2, 22-33.
[2] Amabile, T. M. (1996). *Creativity in context*. Boulder, CO: Westview.
[3] Baddeley, A. (1986) *Working memory*. Oxford: Clarendon Press.
[4] Bell, D. (1973). *The coming of the post-industrial society: A venture in social forecasting*. New York: BasicBooks.
[5] Bereiter, C. (2002). *Education and mind in the knowledge age*. Mahwah, NJ: Erlbaum.
[6] Bereiter, C. & Scardamalia, M. (1993). *Surpassing ourselves. An inquiry into the nature and implications of expertise.* Chicago: Open Court.
[7] Björklund, T. A., Korhonen, J. M. & Reinikainen, M. T. (2007). Expert intuition – How to improve students' problem solving efficiency. ReflekTori 2007 Symposium of Engineering Education December 3-4 2007, *Teknillisen korkeakoulun Opetuksen ja opiskelun tuen julkaisuja* 1/2007, 58-67. Espoo: Teaching and Learning Development Unit, TKK. ISBN 978-951-22-9063-5, also available at http://www.dipoli.tkk.fi/ok/p/reflektori2007/refl07paptodo/nettiin/Reflektori2007.pdf
[8] Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How people learn: Brain, mind, experience, and school*. Washington, DC: National Academy Press.
[9] Byman, R. (2000). (Can motivation be taught?) Voiko motivaatiota opettaa? In Kansanen, P. & Uusikylä, K. (eds.). (Creativity, motivation, feelings. Directions of education research.) *Luovuutta, motivaatiota, tunteita. Opetuksen tutkimuksen suuntia.* (pp. 25-41) Jyväskylä: PS-kustannus.
[10] Cowan, N. (2001). The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *Behavioral and Brain Sciences 24*, 87–185.
[11] De Groot, A. D. (1978). *Thought and choice in chess*. Oxford, England: Mouton (2nd ed.). Originally published 1946.
[12] De Groot, A. D. & Gobet, F. (1996*). Perception and memory in chess: Heuristics of the professional eye*. Assen: Van Gorcum.
[13] Dreyfus, H. & Dreyfus, R. (1986). *Mind over Machine: The Power of human intuition and expertise in the era of computer*. Oxford: Basil Blackwell.
[14] Drucker, P. F. (1993). *Post-capitalist society*. New York: HarperBusiness.
[15] Ericsson, K. A. (1999). Creative expertise as superior reproducible performance: innovative and flexible aspects of expert performance, *Psychological Inquiry 10*, 4, 329–361
[16] Ericsson, K. A. (2006). The influence of experience and deliberate practice on the development of superior expert performance. In Ericsson, Charness, Feltovich & Hoffman (eds.). *The Cambridge Handbook of Expertise and Expert Performance* (pp.683-703) New York: Cambridge University Press.
[17] Ericsson, K. A. & Charness, N. (1994). Expert performance – Its structure and acquisition. *American Psychologist 49*, 8, 725-747.
[18] Ericsson, K. A. & Lehmann, A. C. (1996). Expert and exceptional performance: Evidence of maximal adaptation to task constraints. *Annu. Rev. Psychol*., 47, 273-305.
[19] Ericsson, K. A. & Smith, J. (1991). Prospects and limits in the empirical study of expertise. In Ericsson & Smith (eds.) *Toward a general theory of expertise: Prospects and Limits* (pp. 1-38), Cambridge: Cambridge University Press.
[20] Hakkarainen, K., Lonka, K. & Lipponen, L. (2004a). (Explorative learning. Mind, feelings and culture enabling learning.) *Tutkiva oppiminen. Järki, tunteet ja kulttuuri oppimisen sytyttäjinä*. Porvoo: WSOY.
[21] Hayes, J. R. (1985) Three problems in teaching general skills. In Chipman, Segal, & Glaser (eds.): *Thinking and learning skills: Vol. 2 Research and open questions* (391-405), Hillsdale, NY: Erlbaum.
[22] Hogarth, R. M. (2001). *Educating intuition*. Chicago: The University of Chicago Press.
[23] Klein, G. (1998) *Sources of power*. Cambridge, Massachusetts: MIT Press.
[24] Klein, G., Calderwood, R., Clinton-Cirocco, A. (1989). *Rapid decisionmaking on the fireground*. Proceedings, Human Factors and Ergonomics Society 30th Annual Meeting, Dayton, Ohio 1, 576-80.
[25] Klein, G. A., Calderwood, R. & MacGregor D. (1989). Critical decision method for eliciting knowledge, *IEEE Transactions on systems, man, and cybernetics 19,* 3, 462-472.
[26] Klein, G., Wolf, S., Militello, L. & Zsambok, C. (1995). Characteristics of skilled option generation in chess. *Organizational Behavior and Human Decision Processes 62,* 1, 63-69.
[27] Larkin, J. H., Mc Dermott, J., Simon, D. P. & Simon, H. A. (1980). Expert and novice performance in solving physics problems. *Science 208*, 1335-1342.
[28] Lave, J. & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.
[29] Lehtinen, E. & Kuusinen, J. (2001). (Educational psychology.) *Kasvatuspsykologia*. Juva: WSOY.

[30] Miller, G. A. (1956). The magical number seven, plus or minus two: some limits on our capacity for processing information. *Psychological Review 63*, 2, 81-97.
[31] Newell, A., Shaw, J.C. and Simon, H.A, (1962). The problem of creative thinking. In: Gruber, H.E., Terrell, G. and Wertheimer, M. (eds.): *Contemporary approaches to creative thinking*, New York: Atherton Press.
[32] Newell, A. & Simon, H. A. (1972). *Human Problem Solving*. Englewood Cliffs, NJ : Prentice Hall.
[33] Reitman, W. R. (1965). *Cognition and thought*. New York: Wiley.
[34] Saariluoma, P. (1985). Chess players' intake of task-relevant cues. *Memory & Cognition*, 13, 385-391.
[35] Sawyer, R. K. (2006). Educating for innovatio., *Thinking Skills and Creativity*, 1, 41-48.
[36] Schunn, C.D., McGregor, M. U. & Saner, L. D. (2005) Expertise in ill-defined problem- solving domains as effective strategy use. *Memory & Cognition 33*, 8, 1377-1387.
[37] Simon, H. A. (1973). The structure of ill structured problems. *Artificial Intelligence 4*, 181-201.
[38] Simon, H. A. (1996). *The sciences of the artificial*. Cambridge, MA: MIT Press. (3d ed.)
[39] Simon, H. A. & Chase, W. G. (1973). Skill in chess. *Am. Sci.,* 61, 394-403.
[40] Simonton, D. K. (1999) Creativity as blind variation and selective retention: Is the creative process darwinian? *Psychological Inquiry* 10, 4, 309–328
[41] Uusikylä, K. (2000). (Can creativity be taught?) Voiko luovuutta opettaa? In Kansanen, P. & Uusikylä, K. (eds.) (Creativity, motivation, feelings. Directions of education research.) *Luovuutta, motivaatiota, tunteita. Opetuksen tutkimuksen suuntia.* (pp. 42-55) Jyväskylä: PS-kustannus..
[42] Weisberg, R. W. (2006). Modes of expertise in creative thinking: evidence from case studies. In Ericsson, Charness, Feltovich & Hoffman (eds.): *The Cambridge Handbook of Expertise and Expert Performance* (pp.761-787). New York: Cambridge University Press.
[43] Zimmermann, B. J. (1990). Self-regulated learning and academic achievement: An overview, *Educational Psychologist 25*, 1, 3-17.