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Enhancing IT Architect capabilities: Experiences within a university subject

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Abstract

The role of IT Architect is important in the development and successful implementation of Information Technology systems across the world. The people performing the role are critical to the success of the systems. This paper reports on the results of an experiment aimed at developing two key IT architect capabilities within the context of a post graduate Systems Architecture subject. One capability is related to problem solving and while surprisingly student problem solving confidence was impacted other aspects of problem solving important for IT Architects were unchanged. The other capability being researched, future time orientation was also unchanged through intervention. Therefore alternative approaches for improving these capabilities are preferable as factors such as external pressures on the students within the semester outweighed any short term capability improvement.

Keywords

IT Architect, Capabilities, Software Engineering Education, Problem Solving

INTRODUCTION

As Carriere et al. (1999) state, "architecture is increasingly being viewed as a key artefact in realizing an organization's technical and business goals." Architecture is defined by the IEEE as "The fundamental organization of a system embodied in its components, their relationships to each other and to the environment and the principles guiding the design and evolution" (ANSI/IEEE 2000) The people who develop these architectures are often called *Information Technology (IT) Architects.* Therefore, the capabilities of the people creating the architecture influence the likely success in achieving organisational goals. This importance has also been recognised by the emergence of IT Architects as a profession with formal independent certification guidelines (Open Group 2005). In addition, as architecture development is part of the social process called information systems development, all the people involved and their capabilities are critical (Hirschheim, Klein & Lyytinen 1995). Therefore, because these systems are human artefacts, understanding what makes some Information Technology (IT) architects more effective than others is critical as it enables organisations to select and develop these architects and thereby improve the resultant systems.

To date there has been little research investigating the critical capabilities for IT Architects or, once such capabilities have been determined, whether they can be improved. Recent work (Frampton, Carroll & Thom 2005; Frampton et al. 2006) has identified a number of capabilities that are important for IT Architects. Having identified these capabilities, the question now is whether they can be improved through education programs? In particular, knowledge of whether such improvement was possible within a standard university subject would be valuable both for IT Architect development and also for overall Information Systems education. However, there has been only minimal work on developing IT Architect related professional capabilities within a university framework with the exceptions being some reflections of the teaching of software architecture (Swonger et al. 1992) several years ago, and experiences teaching enterprise architecture by Wegmann (2004).

This paper reports the findings from the third phase of a project aimed at identifying critical capabilities for IT Architects and determining if two of these capabilities can be improved within a university subject. The first capability is an aspect of problem solving which is focused on the generation of alternative solutions and evaluating outcomes before acting. The second capability being investigated relates to a person's time perspective, specifically their approach to the future. The research question in this phase is:

> "*Are two student capabilities related to the role of IT Architects improved by systems architecture education?*

This paper has six sections. The second section reviews the research related to this area; the third section describes the experiment design, while the fourth section reports the results, which are discussed in the fifth and conclusions are drawn in the final section.

BACKGROUND OF EXISTING RESEARCH

There is a long list of research about the capabilities or competencies of IS professionals, including systems analysts (Downey 2006; Hunter 1994; Misic 1996; Misic & Graf 2004; Schenk, Vitalari & Davis 1998) and other key roles (Clark, Walz & Wynekoop 2003; Trauth, Farwell & Lee 1993) within Information Systems. However, there has been only very limited research to identify the key capabilities required for IT Architects. Outside the academic arena there have been some descriptions of the required characteristics. Examples of such industry descriptions are Bredemeyer (2006), Hofmesiter et al. (2000) Maier & Rechtin (2000) and several publications from Carnegie Mellon's Software Engineering Institute (SEI) of which some examples are Bass et al. (2003) and Northrop (2004). Both Bredemeyer and the SEI also provide courses for IT Architects.

We are investigating the education of capabilities[1], where a capability is defined by Scott (1999) as the:

> *"Combination of attributes, qualities, skills and knowledge that enables a person to perform to a high standard in a given context and role".*

This definition and usage of 'capability' is different from usage of the term within the fields of organisational design and management; in those contexts capability is a characteristic of the organisation rather than an individual (Reich & Benbasat 2000; Ulrich & Lake 1990).

Initial work (Frampton, Carroll & Thom 2005) has shown that while the IT architect role overlaps those of systems analysts and designers, architects perceive other requirements are also important, in particular visualisation of solutions and future oriented thinking. It identified three areas of preferable characteristics for IT architects: (a) suitable background and experience, (b) four personality characteristics, and (c) eight capabilities. These were identified by experienced IT Architects as important to their practice.

Subsequent work (Frampton et al. 2006) developed a survey targeting four of the capabilities identified as critical for IT Architects in the initial study. This survey was piloted, refined, and then administered to several IBM Australia/New Zealand groups, including certified and uncertified IT architects. Certification was chosen as a distinguishing characteristic because IBM's certification program has operated for over 10 years and has been recently acknowledged by the Open Group (Open Group 2005) as an appropriate indication of IT Architect effectiveness Therefore, the survey results provided a comparison between groups of IT architects with different levels of capability. We found that while all IT architects appeared to be very skilled problem solvers, the more highly skilled IT architects approached problems in a different manner. Also, the higher skilled IT architects had a significantly longer term view of their actions. These two differentiating factors were *"Approach Avoidance Style (AAS)"* within the Problem Solving Inventory (PSI) (Heppner, Witty & Dixon 2004) and the *"Future (ZTPI-F)"* factor within Zimbardo's Time Perspective Inventory (ZTPI) (Zimbardo & Boyd 1999).

RESEARCH METHOD

This research was performed in order to determine if two IT Architect capabilities could be improved within a university subject. The research was undertaken in five stages:

(1) Develop teaching material aimed at developing two capabilities previously identified by Frampton et al. (2006) as critical for IT Architects. This material is to be used in a post graduate level subject in Systems Architecture. Assistance from RMIT teaching and learning specialists and other experts was gained in designing the materials and targeting them to the two capabilities.

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[1] Competency is also used to describe aspects of people performance and the Australian Council of Educational Research (ACER) review (Curtis & McKenzie 2002) stated that "*Competency* is used to refer to an observable behaviour performed to a specified level and therefore provides a basis for the assessment of performance." The reason why this research focuses on capability is that as per these definitions competency is what performance is observed, capability is what enables the performance to occur. The latter is the focus of the research as no actual in-practice observation is being undertaken.

(2) Survey students at the start of teaching the subject to determine their current self assessed level for the two capabilities, using a modified version of a survey used in a prior phase of the research (Frampton et al. 2006),

(3) Apply the specially developed teaching materials to students in tutorials within the subject,

(4) Survey the students at the end of the subject, using the same survey as at the start of the subject, and

(5) Analyse the results to determine if the two targeted capabilities had been changed by the teaching.

This research required ethics approval and this approval guided several aspects of the overall design. In particular, ethical considerations restricted the possible alternatives for the teaching approaches and also the scope and measurement possible for the research. For example, due to the requirements of the ethics process to ensure equity for all students, all students must have access to teaching of both targeted capabilities, which meant that no control group was possible. Also, no connection between the research focus and any assignments results, overall grade, or extra credit of any kind was permitted as this could have affected students' voluntary participation. It was necessary to avoid any power or dependency relationships between the students and researchers. Thus none of the researchers was involved in subject delivery or assessment. One alternative research design that was rejected was to conduct the research across two years with only *ZTPI-F* material being taught one year and only the *AAS* material being taught the other, and then comparing survey results between years. While this would have allowed for a control population, the design was discarded as the differences in students, lecture material, tutors etc. would have been too significant from semester to semester or year to year.

More detailed definition of the targeted capabilities was required in order to design appropriate teaching materials. For this design the *"Approach Avoidance Style (AAS)"* is described as "active searching for a variety of alternative solutions and reviewing of previous problem-solving efforts" (Güçray 2003). A successful subject focusing on problem solving using the PSI as indicator had previously been reported (Thomas 1998). While the target student cohort was different, the subject was at college level, and was therefore an indicator that the focus on *AAS* approach would be appropriate and impacting it could be possible. In addition, the *"Future (ZTPI-F)"* is described as "present behavior is dominated by a striving for future goals and rewards. … these items suggest an orientation away from focusing on immediate benefits and toward calculating future gains and costs" (Zimbardo & Boyd 1999). No reports of teaching to improve or enhance this capability were found but the description included sufficient information to enable effective teaching design.

Survey design

The survey used in this research was a reduced version of the survey used in prior work (Frampton et al. 2006). There were three changes for this research. The first was the removal of two of the scales, being the Cognitive Styles Index (Allinson & Hayes 1996) and the Vividness of Visual Imagery Questionnaire (VVIQ) (Marks 1973) because no statistically significant differences had been found between the different IT Architect populations with those scales. The second change was increased granularity in the age ranges being reported by the participants because the students had a different demographic profile from the participants in the prior research. The third change was minor wording changes in the introduction to reflect the modified survey and other minor wording changes in the introduction to the PSI due to potential cultural issues with members of the major student cohort. Therefore the survey comprised four sections:

1. Introduction to the survey
2. Problem Solving Inventory (PSI)[2] (Heppner & Petersen 1982)
3. Zimbardo's Time Perspective Inventory (ZTPI) (Zimbardo & Boyd 1999)
4. Conclusion of the survey including age range and student name to enable matching of the pre and post subject responses and tutorial allocation.

Student interaction design

For the students there were five major points of interaction with the experiment. First they were briefed on overall experiment, when they also received copies of the plain language statement and the informed consent forms. Then those deciding to participate completed the pre-subject survey[3]. As part of the overall subject enrolment the students then selected one of two possible tutorial streams. One stream focussed on *AAS*, while the other focussed on *ZTPI-F*. Both streams also exchanged material at the end of the stream to ensure each group

[2] The PSI is a trademark of CPP inc., formerly Consulting Psychologists Press.
[3] Both times the students completed the survey there was also an incentive to participate; with each participant having a chance to win one of two A$75 book vouchers.

learnt about both capabilities. The students then undertook the subject. One week before the end of the subject the students who still consented to participate completed the same survey as at the start of the subject.

Teaching design

The objective for the teaching was to improve the two selected capabilities as measured by standard survey instruments. The selected capabilities were taught through problem-based learning tutorials (Biggs 2003). The use of tutorials was dictated by the research material being supplementary to the existing subject content and objectives and as such displacement of lecture material was not appropriate.

The subject is a master's level, software engineering Systems Architecture subject, conducted in semester 1 of 2006, by RMIT University Computer Science & Information Technology. The subject was taught over thirteen weeks, with twelve weeks of lectures and tutorials, and one week of mid-semester break. Both the lecture and tutorial were two hours long. The lectures were taught by an external expert and the two tutorial groups were taught by different tutors on the same day and time in different rooms. The tutorials were in the evening immediately after the lecture. Both tutors had previously completed the subject, had tutored prior versions of the subject and one of the tutors also has a university qualification in teaching.

The experiment was undertaken within an existing Systems Architecture subject as the targeted capabilities are aligned with the existing teaching objectives and the material developed for the tutorials supported the other material in the subject. Regardless of whether the students participated in the research or not they chose and attended the tutorial streams.

There were two major groups of students in the subject. These two groups were:

1. Undergraduates. These are software engineering bachelor's degree students, in their fourth year of study. The first two years are standard subjects within the university, while the third year is an external industry internship, with the fourth year being a combination of major industry-based capstone project, and masters level elective subjects (RMIT University 2006a).
2. Postgraduates. These are students enrolled in one of a number of coursework masters degrees (RMIT University 2006b), these are in two groups, being international full time students, often also working part-time; and local part-time students, working full-time and studying part-time.

Two streams of tutorials were developed, one focussed on *AAS* focus, the other on *ZTPI-F*. Each stream has three tutorials, delivered in weeks four, five, and eight of the twelve week subject. The first two and half of these tutorials covers material specific to the focus area. In the second half of the third tutorial the students explained and gave examples of the concepts covered in their stream to the students from the other stream. Both tutorial streams included specific material on personal reflection to encourage deeper student learning.

The development of the *AAS* focussed material was heavily informed by Newell and Simon's problem solving approach (1972) and also by D'Zurilla & Goldfreid's (1971) definition of problem solving, "a behavioral process, whether overt or cognitive in nature, which (a) makes available a variety of potentially effective response alternatives for dealing with the problematic situation and (b) increases the probability of selecting the most effective response from among those various alternatives." The first tutorial presented two alternative models for problem solving with the exercises based on the Melbourne 2006 Commonwealth Games which were being run at the same time as the subject. This tutorial also introduced a very different approach to problem solving, Theory of Inventive Problem Solving (TRIZ) (Altshuller, Altov & Shulyak 1996), and the associated exercises contrasted the TRIZ approach with Newell and Simon's approach. The second tutorial focused on the development of alternative solutions for problems. Two alternative generation approaches were taught: De Bono's Six Hat Thinking (2000) and brainstorming. The exercises focussed on issues reported in the newspapers relating to the 2006 Commonwealth Games. The final tutorial had two sections. The first section explored approaches for evaluating possible solutions for problems and focussed on evaluation criteria and alternative evaluation mechanisms (Newell & Simon 1972). In the second section of this tutorial the tutorial groups merged and each group explained what had been taught regarding *AAS* and *ZTPI-F* and then additional Commonwealth Games exercises were performed by all students in mixed groups from both streams to underline the learning.

The *ZTPI-F* tutorial material focussed on strategic thinking approaches, scenarios and on deepening the students understanding of delays between ideas or proposals first being presented and their actual implementation. The first tutorial aimed to increase students' awareness of long-term timeframes using material from The Long Now Foundation (2005). Their project to build a clock for a 10,000 years lifespan was the major example for the exercises. For the second tutorial, alternative models of strategic thinking methods for developing and evaluating strategies were used. In particular alternative models of thinking such as those discussed in Leonard & Straus (1997) were explained and then explored with exercises also relating to the original planning in the 1990s for the 2006 Commonwealth Games. The first section of the third tutorial focused on scenarios during which the students learnt about scenarios primarily using material from Schwartz (1996) and then explored the concept using examples again related to the Commonwealth Games. The second half of the tutorial was the same as for the *AAS* tutorial stream. To reinforce the long term focus, *ZTPI-F* tutorials included quizzes about the dates of common inventions and the elapsed time before they became successful or popular.

SURVEY ADMINISTRATION & RESULTS

Pre-subject survey administration & processing

Participants completed the survey and then any missing values were corrected and outliers removed. All students were treated as a single group for this processing with no distinctions or corrections performed for any groups such as specific tutorial or whether the students were post graduate or under graduate. This was because students chose their own tutorial and also assignment groups included both post and under graduate members.

Initial pre-subject analysis

The data were examined to confirm that they were normally distributed. There were thirty-three participants that could be allocated to specific tutorials and two participants for whom it was not possible to determine tutorial enrolment[4], making a total of thirty-five participants.

The participants' responses for all the factors reported by the PSI and ZTPI were then compared to norms using t-tests for those instruments. For continuity, the norms[5] used were the same as in prior research (Frampton et al. 2006) and the results are reported in Table 1 Student pre-subject norm analysis below.

	Factor	t value	Significance
Problem Solving Inventory	*Problem Solving Confidence (PSC)*	-.788	0.436
	Approach Avoidance Style (AAS)	**-2.399**	**0.023**
	Personal Control (PC)	-1.407	0.169
Zimbardo's Time Perspective Inventory	***Past Negative (ZTPI-PN)***	**-2.302**	**0.028**
	Present-Hedonistic (ZTPI-PH)	-1.554	0.130
	Future (ZTPI-F)	**3.315**	**0.002**
	Past-Positive (ZTPI-PP)	**-2.825**	**0.008**
	Present-Fatalistic (ZTPI-PF)	**-2.076**	**0.046**

Table 1 Student pre-subject norm analysis

The only statistically significant difference for the students from the norms for the PSI was for the *AAS*. The students were already significantly better than the general population norms for this factor. That is, they reported that they already generated more alternatives for any given problem and evaluated those alternatives prior to taking any problem solving actions. For the ZTPI factors there were four factors that were statistically significantly different for the participants from the norms. Those factors and some observations were:

- *PN* – The students are less negative about the past than the norm population, that is, they had less negative memories of the past.
- *F* – The students are already more oriented towards future than the prior norm participants,
- *PP* – The students are less positive about the past than the norm participants, that is, they are less likely to interpret past events in a positive manner when asked about them, and
- *PF* – The students are less present fatalistic than the norm participants, that is, they think they have more control over events.

Both tutorials were compared with each other to determine if there was any significant difference between them on any of the factors. There were no significant differences between them on any factors.

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[4] Registration for tutorials is not enforced or attendance recorded and adding such a process for this experiment was deemed not appropriate when discussed with the ethics committee.

[5] These norms were for prior survey respondents and the groups were Canadian adults for the *PSI* and US college students for the *ZTPI*.

Post-subject survey administration & processing

The tutorials for the targeted capabilities were held during weeks four, five, and eight of the subject. Following this, in week eleven, the students who had participated in the initial survey were asked to complete the survey again. Both the two scales used in the survey, PSI & ZTPI, had previously proven good test/re-test reliability therefore this was reasonable.

All missing values and outliers were processed in the same manner as the pre-subject survey responses and again the responses were normally distributed. There were twenty seven students allocated across both tutorials and there was also one participant that it was impossible to determine which tutorial they were enrolled in, making the total number of participants twenty-eight. The reason for the reduction in numbers of participants from thirty-five to twenty-eight is unknown; however one student who had responded to the initial survey had withdrawn from the subject, while others had reduced their attendance at tutorials and lectures.

Again, norms analysis was performed and using t-tests and with the same values as prior research (Frampton et al. 2006) and the results are in Table 2 Student post-subject PSI norm analysis below.

	Factor	t value	Significance
Problem Solving Inventory	*Problem Solving Confidence (PSC)*	0.971	0.340
	Approach Avoidance Style (AAS)	-0.541	0.593
	Personal Control (PC)	-0.735	0.469
Zimbardo's Time Perspective Inventory	*Past Negative (ZTPI-PN)*	-1.613	0.120
	Present-Hedonistic (ZTPI-PH)	**-3.354**	**0.002**
	Future (ZTPI-F)	1.835	0.078
	Past-Positive (ZTPI-PP)	**-3.143**	**0.004**
	Present-Fatalistic (ZTPI-PF)	-1.325	0.197

Table 2 Student post-subject PSI norm analysis

These results show that there were no statistically significant differences between the norms for the PSI factor results and for the students at the end of the subject. This is different from the pre-subject responses where the value for *AAS* was statistically significantly different from the norm population. One reason is that there were less respondents and that this smaller group has different overall characteristics from the complete pre-subject group. Please refer to the next major section for discussion as to other possible reasons.

For the ZTPI responses, these results show that the students at the completion of the subject were statistically significantly different from the prior norm groups for the factors *PH* and *PP*. That is, the post subject students were more focused on present pleasures and were also more positive about the past than the norm groups. This result would match expectations that as the end of the semester approaches students are only focussed on that event and this being a measurable difference supports the validity of the survey being used in this research. The result for the PP factors is similar to that pre-subject. For the other factors there are differences:

- Before the teaching the students were less *Past Negative (ZTPI-PN)* than the norm population, now they are similar to that population,
- The post subject responses are no longer significantly different from the norm for the *Future (ZTPI-F)* factor, that is, they do not now have a longer term view, and
- The participants are no longer less *Present Fatalistic (ZTPI-PF)* than the norm population, that is, they no longer feel more in control.

Pre-subject and post subject comparison

The pre-subject and post-subject responses were compared using paired t-tests on all factors to determine if any were statistically significantly different. There were two such differences and the results are in Table 3 below and discussed in the next major section.

	Factor	t value	Significance (2-tailed)
Problem	***Problem Solving Confidence (PSC)***	**-2.434**	**0.022**

	Factor	t value	Significance (2-tailed)
Solving Inventory	*Approach Avoidance Style (AAS)*	-1.954	0.062
	Personal Control (PC)	-0.487	0.630
	Overall (PSI Total)	**-2.178**	**0.039**
Zimbardo's Time Perspective Inventory	*Past Negative (ZTPI-PN)*	-1.019	0.319
	Present-Hedonistic (ZTPI-PH)	1.441	0.161
	Future (ZTPI-F)	0.380	0.707
	Past-Positive (ZTPI-PP)	0.513	0.612
	Present-Fatalistic (ZTPI-PF)	-1.002	0.325

Table 3 Comparison of pre-subject and post subject results

This result shows that at the completion of the subject the participant's perception of their Problem Solving Confidence had reduced and also their overall problem solving expectation was less at the end of the subject.

Post hoc power analysis was also performed to ensure that there was a sufficient response from both surveys for the effects to be actually significant. This analysis was performed using the tool Gpower (Erdfelder, Faul & Buchner 1996). Following Cohen (1992), for all calculations an effect size (d) of 0.8 was used (as the subsequent analysis was paired samples t-Tests on means) and an alpha of 0.05 were used. The numbers in each population were similarly distributed and as such do not violate the requirements for the power calculation. The calculated power for before subject versus after subject was 0.9299 (being 1-beta). These values show that the likelihood of falsely reporting significant differences between the two cohorts was less than 10% and consequently any differences reported as significant can be treated as such (Cohen 1988; Kitchenham & Pfleeger 2002).

DISCUSSION

In informal discussions the students' comments were very positive about the material, teaching, and overall intention and approach of the tutorials for the capabilities. In particular they expressed the view that the material was useful and helped them understand both problem solving and also thinking about the future.

However there were changes in the pre and post subject comparison to norms, and while there was no significant difference in the targeted capabilities, one other problem solving factor that was not the direct focus of the research, *Problem Solving Confidence,* was significantly different between the start and end of the semester. Possible reasons for these counter-intuitive or unexpected findings are discussed in four categories.

Environmental

External time pressure on the participants was the key factor from student discussion and conversations effecting the observed changes compared with norms and lack of impact of the capability tutorials. For undergraduates the major external pressure was other subjects and assignments, including a major capstone project, while for post graduates the effort of working while studying often leads to expedient decision making and short term behaviors. This would lead to a stronger focus on short term actions, choosing the single most expedient solution and not evaluating the possible results, all things that are explicitly contradictory to *AAS* and *ZTPI-F*. Another possible environmental aspect is that *AAS* and *ZTPI-F* related attitudes and behaviour could be influenced by other events outside the university or by other causes that are not obvious in this research.

Individual

At the commencement of the subject the participants were already significantly different from the norms for the factors being studied. Therefore it may not have been possible to further improve this capability in this cohort of participants. The students that Thomas (1998) had worked with were different from those in this research in that Thomas' students were lower than the respective norms for the PSI. One other possible reason for the findings in this research is the findings by Ericsson (2002) that becoming an expert requires at least ten years of deliberate practice. A single university subject can not provide this.

Measurability

Another aspect of the findings in the research may be that effects may not be seen until there is a longer delay after the material has been delivered. Alternatively, that for any measurable differences in the targeted capabilities to be evident there is a requirement for significantly more reinforcement. Also it is possible that any differences are only evident after the techniques that were taught have been used or applied in practice a certain number of times. Also, what this research is measuring may not be actually teachable but is a manifestation of some innate personality trait.

Educational

There are several possible educational reasons for the findings of this research. The change in *PSC* shows that it is possible to influence some of the students problem solving behaviours, in fact, the reduction in PSC strongly suggests that the students are now less confident as they have an increased understanding of the complexity of problem solving through the tutorial material. This conclusion was also supported by comments made by the students in the written feedback about the subject.

It is possible that there was insufficient time spent learning and reinforcing the concepts underpinning the AAS and ZTPI-F. Also the specific structure, content, and delivery of the material were not appropriate or focussed enough to impact the factors being studied. Finally, the capability may have already been determined by prior education, culture or by life experiences and could not be easily impacted through any later educational intervention.

CONCLUSIONS AND FUTURE WORK

A first approach to enhancing two critical capabilities for IT Architects for students studying Systems Architecture was not successful in producing a measurable positive difference in those capabilities. While inclusion of specific teaching within a strongly related subject would appear to be an appropriate manner in which to develop the capabilities this research has shown this may not be the case or if it is any evidence of change in the capabilities may not be measurable within the same confines. This result is useful for academia and industry in designing alternative approaches for developing these capabilities and opens up a new research area into designing, developing and evaluating appropriate educational approaches, and also increases our knowledge relating to the acquisition of key IT Architect capabilities.

Limitations

No information as to the cultural background and influences of any of the participants was collected or analysed. Other researchers (Hofstede 2001; Trompenaars & Hampden-Turner 2000) have shown that attitude to time, amongst other things, varies by culture and as such that could affect the results from this research. Also, there was no gender analysis of the participants as the proportion of females was too small for a meaningful sample, again this could influence the result. Also, the available data on norms for all factors was of variable relevance. For example, norms for Zimbardo's Time Perspective Inventory are based on American college students, which could be significantly different from participants in this research.

Future work

This research suggests several areas for related research. These include analysing prior experience and educational background to determine if the participants already had acquired the key capabilities, extending the research for different ethnic and organisational cultures, including additional investigation of the underlying personality characteristics associated with the capabilities, and changing the educational aspects of the research and determining any differences. These changes could include:

- More extensive material, including different and more IT specific examples,
- Including a process for tutor feedback and continuous improvement,
- Including the material throughout a complete degree program, rather than in a single subject,
- Delivering the material in a different manner, such as off-site or within lectures,
- Including a specific assignment or assessment component for the capabilities, and
- Teaching without the external time pressure.

Overall this research has shown that for enhancing some particular capabilities critical for IT Architects the obvious approach of including focussed material within a single 'standard' university subject may not be an appropriate approach and that external pressures inhibit the immediate application of learning for many students. However, it has shown that it possible to modify student's perceptions of problem solving through such an approach which is an important educational result.

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