Blended education for systems architecting

Evaluation of the initial blended course version

Gerrit Muller
HSN-NISE
Kongsberg, Norway
Gerrit.muller@hbv.no

Joris van den Aker, Herman Postema
TNO-ESI
Eindhoven, the Netherlands
joris.vandenaker@tno.nl herman.postema@tno.nl

***Abstract*—Blended education, the combination of traditional face-to-face education with online possibilities, is seen as the way for the future in education. Challenge for course providers is to learn how to offer blended education and to make the transition toward blended education.**

In this paper, we evaluate a first version of a blended course. The organization took an existing course in architecting and transformed it into a blended version with the purpose to learn what blended education is an where the challenges are. We succeeded in running the blended course, and we obtained a clear list of improvements for future blended versions.

Keywords—blended education; blended learning; architecting; Sakai

I. Introduction

Customers for systems architecting training ask for a format that is more scalable in volume and geography. TNO-ESI offers educational programs in systems architecting for companies (in-house) training and open enrollment programs. These programs have an elapsed time of 8-12 month typical, and combine courses, casework in teams, and coaching. One of the limitations of the current set-up is the dependence on a scarce competence: systems architecting teachers and coaches.

Most companies that participate in the TNO-ESI educational programs have business in the System of Systems (SoS) world, or their systems are constituent systems of SoSs. An essential part of architecting is to understand the context of the system-of-interest, the supersystem, which often is an SoS.

At the same time, the educational world is evolving fast. Many major universities have Massive Open Online Courses (MOOC) offerings. Platforms to support on-line learning pop-up everywhere; examples are Coursera, Udacity, and open source platforms as Sakai.

The pioneers of on-line learning emphasize that simply replacing lectures by a collection of video streams is insufficient to achieve desired learning outcomes. Here the term blended appears, meaning that active forms of learning are necessary besides the one-way lecturing that video offers.

Digitalization of learning platforms and course material offers new opportunities to train and accelerate systems architecting competencies. One of the key challenges is to maximize added value by balancing efficiency and learning effectiveness.

II. Didactic model for architecting

In [1] we have described the need for experiential learning [2], where reflection plays a critical role [3]. Dewey [4] also emphasizes the role of experience and reflection learning.

The European Quality Framework (EQF) [5] defines learning outcome in terms of knowledge, skills, and competence to apply them properly. Atherton [6] shows Bloom's, and Anderson and Krathwohl's taxonomies for the cognitive domain. In these taxonomies, the challenge is to achieve learning at the higher levels, such as evaluating, creating, and Atherton's interpretation of understanding (not to be confused with the low-level understanding in Anderson and Krathwohl's taxonomy).

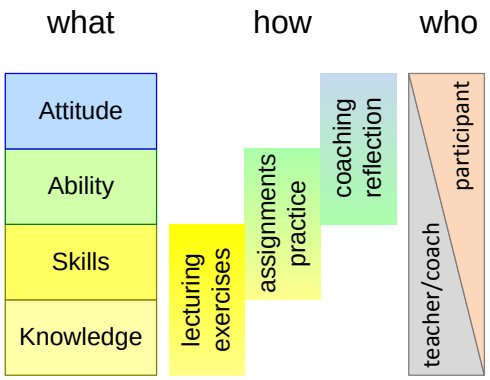
In [1] we explain our didactic model as shown in Fig 1. The left-hand side of Fig 1 shows four elements that together form competence. We use the word ability (to use knowledge and skills), so that we can use the term competence for the combination of these four elements. We add attitude explicitly to this model, since effectiveness in practice depends on attitude. Attitude seems to map on a combination of the cognitive and affective domains from Bloom [6]. The right-hand side of Fig 1 shows the typical learning forms.

Traditionally, universities offer lecturing and exercises to develop knowledge and skills. However, the educational challenge in industry starts at the transition from skills into ability in a dynamic, diverse, and industrial context. Ability requires experience. To develop the ability we need students to follow Kolb's learning cycle. The last step, acquiring attitude requires critical thinking among others about personal behavior and performance in the actual organizational context. We expect from architects that they can change and select perspectives, and the ability to re-frame problems in relation to the context.

At the ultimate right-hand side of Fig 1, we visualize the influence of external providers and the individual. Low in this stack, teachers may contribute a lot by lecturing and exercise feedback, while higher in this stack more action and

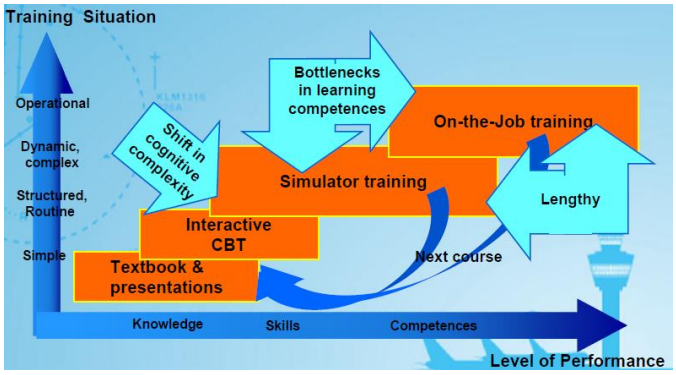
drive from the individual is essential. The role of the teacher or coach is reduced to inspiratory and catalyst.

Fig. 1. The four level competence model of the competence development program.



One of the challenges for architecting is to develop the higher order thinking skills [7] related to architecting. A field where people are trained in both routine and exceptional cognitive competences is air traffic control [8]. A related presentation [9] contains Fig 2. This figure shows how a shift in cognitive complexity causes bottlenecks in learning competences with lengthy learning trajectories as consequence.

Fig. 2. Current practice in Air traffic control training, taken from [9]



III. Context of the Architecting Course

In the late nineties, Philips had multiple initiatives to educate architects. Philips research had a 6-year long program, named the architecture school, for potential architects. The Center for technical training had several architecting courses, among them, the Systems architecting course (SARCH). These Philips efforts have evolved over time into the current architecting programs at TNO-ESI.

The teacher documented the experiences of teaching the SARCH course in [10] and [11]. In 2011, he published [12] to support this course. In 2004, an additional course in Architectural reasoning followed, based on [13], documented in [14] and [15]. TNO-ESI developed a conceptual modeling and analysis course; see [16] and [17]. Concurrently, these courses evolved into the SESA and SEMA courses in the master systems engineering at HSN in Kongsberg, Norway[1]. Recently, TNO-ESI developed a course that combines parts of the original systems architecting and architectural reasoning courses. The name of this combined course is 'Architecting for Business Value'.

TNO-ESI developed a competence development program that addresses more than simply training students in particular knowledge or skills. The program distinguishes four levels of competence following Fig 1. The program combines courses, casework, and coaching. The intent of the casework is to create an experiential learning environment. The coaching should help students in reflection. The courses cover soft skills and hard skills. Typically, the soft skills training is outsourced to providers specialized in personal skill development with a human science background. One of the hard skills courses in a course in systems architecting.

Large multinational companies purchase the training for their potential architects. These companies have an interest to offer the programs globally. This trend has an impact on the volume of the training, and on the location of the training. In some cases, there is also cost pressure. Especially for lower cost countries, there is a clear cost pressure. The availability of on-line courses and MOOCs creates an expectation of lower costs. One can wonder whether such expectation is realistic; can the higher levels of competency be trained in similar ways as lower level knowledge and skills?

Moreover, the diversity of the domains of the purchasing companies requires a degree of customizing of the courses. There are many dimensions where the domains differ, such as low versus high volume, consumer versus business, hardware versus software dominated, and product versus service orientation.

The current developments of online training raise many other expectations and possibilities [18], [19]. As consequence, the term blended learning rather than online learning has become popular. Blended learning blends various formats to provide the desired learning experience.

Guo recommends based on research [20] to limit video lecturing to 6 minutes. Other Internet sources [21] assert that the attention span dropped from 7 minutes to 5 minutes in 2013. [22] Recommends limiting the learning to "4 things at once",

IV. Objectives of the Blended Architecting Course

Based on the above trends, TNO-ESI decided to start an exploration of blended learning. The course 'Architecting for Business Value' is the starting point. The objectives of this exploration are:

- To create a format that is scalable, such that we can reach more participants, despite scarceness of teaching competence in architecting.

[1] All course material and descriptions are at www.gaudisite.nl

- To create a format that facilitates global delivery with less traveling of teachers and participants
- To serve a wide variation of domains
- To achieve at least the same learning outcome and experience as the conventional classroom version
- To explore potential benefits of blended learning over conventional classroom learning.
- Make it possible to integrate small online learning elements (such as video's, reflection exercises, and company specific reference cases) with daily practice of (junior) system architects and related stakeholders.

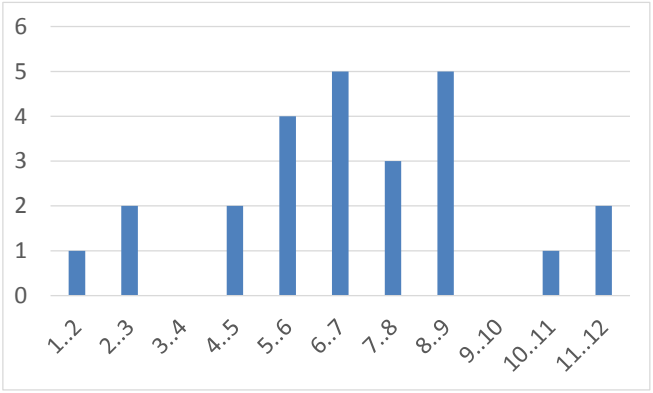
V. Course Content and Format

The original classroom version of this course is 5 days. In these 5 days, we offer the following program:

- Introduction in architecting in the business context, and the role and task of the architect (1 day)
- Architectural reasoning, in workshop form participants elaborate a case study in 3 days
- Platforms and re-use (1/2 day)
- Wrap-up (1/2 day)

The original SARCH course used a format with about 45 minutes of lecturing. Although the teacher invites interaction, most of this time is one-way communication providing theory and illustrations. The original architectural reasoning course used less time for lectures to focus more on working on a case. As first step toward blended learning, we have partitioned the theory in "nuggets" up to 12 minutes as preparation for video lecturing. We used the standard engineering principle in partitioning: strive for cohesion within the parts, and minimize coupling between nuggets.

Fig. 3. Frequency distribution of the length of the video lectures in minutes.



In total, we captured all theory in 25 video lectures with a total length of 2 hours and 48 minutes, and an average length of 6 minutes and 44 seconds. The distribution in Fig.3 shows that only 9 of the 25 videos have the recommended length (see Guo [20]) of 6 minutes or less. The original lecturing in the course was closer to 7 ½ hours plus 5 hours of interaction and discussion. The missing 5 hours of lecturing covers illustrations and cases. The captured video covers mostly the "pure" theory.

The first step that we envisioned is that students follow the theoretical parts online, so that the face-to-face sessions can focus on interaction and case work.

VI. First Edition and Evaluation

The first edition of the blended course consisted of three modules, following the flipped classroom approach [23]:

1. Online theory with online assignments. This module consisted of nine video lectures (see Appendix A). Participants got a period of 2 weeks to follow module 1
2. 3 day face-to-face workshop for interaction and casework
3. Online wrap-up. Participants got a period of 2 weeks to finish module 3.

This edition had 9 participants, 4 from research institutes, and 5 from various industrial companies. The online course used Sakai as platform.

A. Evaluation of online theory module

Participants spend on average 4.7 hours on module 1. Only 5 of the 9 participants made the assignments, from very short to quite extensive. Participants filled in the evaluation forms for Module 1 and Module 2 at the end of Module 2. As consequence, their answers on the modules may have influenced the other module.

Fig. 4. Evaluation results module 1, online theory

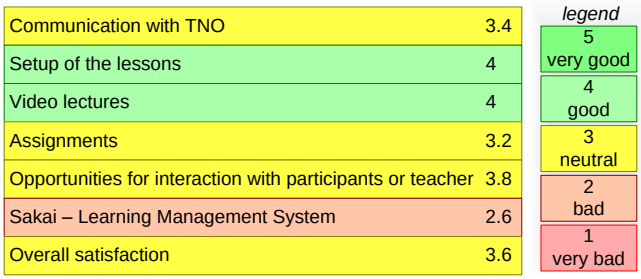


Fig 4 shows the survey results of module 1, where the numbers at the right hand side indicate the average of the answers. The survey used questions with a 5-point Likert scale. Although the answers range from very bad to very good, we see "good" or "very good" as acceptable evaluation, while "neutral" or worse means not good enough. On the average scale, this translates in 4 or higher as acceptable, while lower grades indicate insufficient results.

Fig. 5. Subset of specific feedback to module 1

Setup of the lessons
+ 5 positive comments
- Sometimes a little bit of jumping between topics.
- Videos are too short and too fragmented; there is too much overhead required to view all.
- A bit too much "school-like" (i.e. video - assignment). I prefer a set of videos and 1 or 2 large assignments.
Video lectures
+ Short but also filled with good concentration of info.
+ Somewhat brief.
+ High quality videos.
+ Clear videos, good content.
+ Clear explanation, good length.
+ Videos were short enough but gave a clear overview of different topics. It is a good introduction to make the face-to-face module more effective.
- Several comments on preferring slides
Assignments
- Expectations unclear
- Limited value due to lack of feedback
- Should be open assigmments without good/bad answers
Opportunities for interaction with participants or teacher
- Interaction opportunities were missing

The survey results show that we have some significant work to do to improve module 1. Fig 5 shows some of the specific feedback on module 1. An interesting concern is the comment that the videos are too short and fragmented. Most videos are too long according to the measured attention span of students. At the other hand, the feedback on the video lectures in general, and on their length specifically, is quite positive. Main point of attention is that several participants indicate that they like to get the slides and that the videos may show the slides more often. This triggers the question whether slide casts may be as effective as these carefully edited videos.

Participants ask for more interaction and for feedback for the assignments. They consider the expectations about the assignments to be unclear. Since the assignments are one of the ways to transform passive lecturing into active learning, this is a major point of attention.

B. *Evaluation of face-to-face module*

We used a standard course evaluation form for the face-to-face module. The analysis of these evaluation forms uses the Net Promoter Score (NPS). The NPS value is calculated by taking the number of promoters (people that strongly agree) minus the number of complainers (people that score “neither agree nor disagree” or worse). A positive NPS value means a good result; a negative value indicates that improvements are necessary.

Fig. 6. Evaluation results module 2, face-to-face, numbers in bold are the net promotor score.

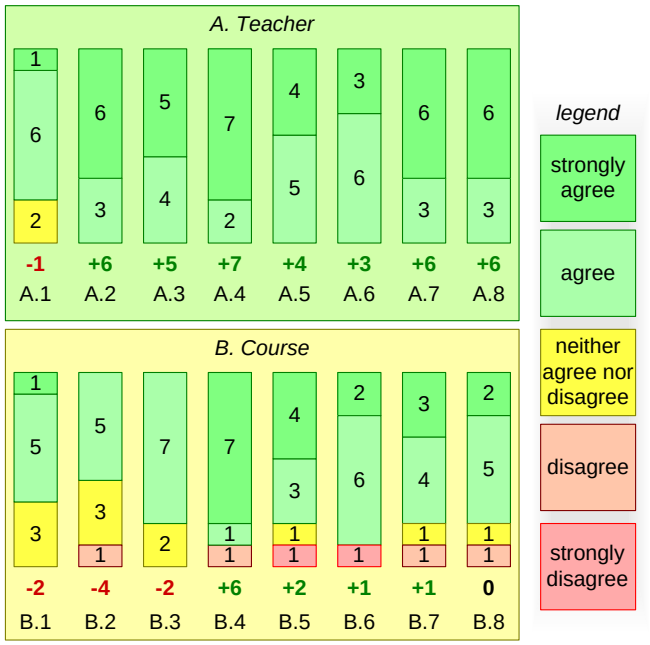


Fig 6 shows the evaluation results of module 2, the questions are listed in Appendix B. The number directly above the question is the NPS score for that question. Main criticism is the organization of the course material, followed by some concerns on structure and allotted time. However, in general course feedback is positive.

In this module, the case plays a crucial role. In the first edition, we chose for a drone to assist farmers in weeding their farmland. In retrospect, this case may have been too far off from the roots of the participants. They are not familiar with drone technology, nor with farming applications. The consequence is that participants lacked some motivation and at the end of the case felt that they had made too many assumptions to take the result seriously.

From teacher perspective, making many assumptions, and coming to conclusions despite the lack of solid background knowledge is a relevant learning point. Question is whether the wide variation in participants (academic and industrial, experienced and rather fresh, experts and generalists) disturbed the flow of the casework.

C. *Evaluation of Wrap-up module*

We decided during module 2 to make the online wrap-up optional. During module 2, we did a wrap-up for Module 2 in the last face-to-face session. The plan for the wrap-up in Module 3 was to require that participants write a reflection report on the case and the course. Since we made module 3 optional, we have too little feedback to discuss.

D. *Evaluation of the course platform*

TNO, based on input from partners, decided to use the open-source platform Sakai for the blended learning development. This platform has many features and is highly

configurable. For the blended course developers the configurability is a mixed blessing. At the one hand, it allows for various ways of working, at the other hand, the developers go through a steep learning curve.

From developers and teachers perspective, Sakai lacks some features and makes a number of assumptions that do not fit our needs. An essential missing feature is notification: the ability that the system sends an email to teachers when students have uploaded assignments or have posed questions on the forum. The lack of notification forces teachers to "poll" the system, and increases response time for feedback. Moreover, navigation is complex and time-consuming. Finally, the platform assumes that teachers will assess assignments, and grade them. For architecting, answers are open, and the main function of the teacher is providing feedback.

Fig. 7. Specific feedback from participants on the Sakai learning management platform as used for this course

Sakai – Learning Management System

- Too complex for a one-day module.
- Nice idea, but sometimes very confusing to find all materials or info.
- "Old school". The focus seems to be on how the makers of Sakai perceive their world, rather than on the user / consumer.
- Found Coursera much better (feels naturally) all videos and forms were part of the platform. Where were the lessons / questions. Distracting even blocking, between you and the learning.
- The UI for doing the assignments was bad.
- Not always intuitive use, but oke.
- Overwhelming.
- Bugs (I lost one assignment).
- Remove e-mail option. I was in doubt between email and messages.
- Not intuitive navigation.
- Double password (system, video) that cannot be customized.

Fig 7 shows specific feedback from participants on the leaning platform, as we configured it for this course. The configuration offered most features of the platform allwing us to experience their value. However, this superset approach complicated the use for the participants. It is clear from this feedback that significant attention is required to improve the learning platform and its configuration.

VII. Plans for Future

Short term, we can improve the course in its current form by addressing specific feedback. Major attention point is the interaction in module 1 to make module "alive":

- Facilitate an early connection between the participants and with the teacher
- Facilitate discussion and feedback on assignments
- Configure the learning platform for more intuitive interaction
- Especially the "active" nature of the online parts needs further exploration. Hence, we need to try the existing options for activating participants further

Medium term, we will expand the online material with slide casts of more theory, and case studies to illustrate the theory..

Longer term, we need to increase the benefits from the blended possibilities further, since participants do not receive the current blended course as well as the traditional face-to-face version. Even improving the weak points may not bring this version at par with the traditional course.

Long-term alternatives are to look into options that increase participant and learning platform interaction. An idea for such expansion is using serious gaming, as proposed in the Experience accelerator [24]. Another option is to look for connection with architecting tools, where participants can interact with actual case information. In the latter case, the boundary between work and learning may start to blur; learning can become an integral part of working, where blended learning elements facilitate the learning process.

Acknowledgment

The participants of the first edition gave us feedback, which enables this evaluation.

References

[1] G. Muller, "Reflective Practice to Connect Theory and Practice; Working and Studying Concurrently", proceedings of CSER 2015 in Hoboken, NJ

[2] D.A. Kolb, Experiential learning: Experience as the Source of Learning and Development, Englewood Cliffs, NJ: Prentice-Hall, 1984.

[3] D.A. Schön, The Reflective Practitioner: How Professionals Think in Action, Ashgate Publishing Limited, 1984

[4] Dewey, "Experience and Education", New York, NY: Kappa Delta Pi, 1938.

[5] European Commission, Education and Culture, Explaining the European Qualifications Framework for Lifelong Learning, Luxembourg: Office for Official Publications of the European Communities, https://ec.europa.eu/ploteus/sites/eac-eqf/files/brochexp_en.pdf, 2008

[6] J.S.,Atherton, Learning and Teaching; Bloom's taxonomy [On-line: UK] retrieved 4 February 2016 from http://www.learningandteaching.info/learning/bloomtax.htm, 2013

[7] F.J. King, L. Goodson, and F.Rohani, Higher order thinking skills, definition, teaching strategies, and assessment, Center for Advancement of Learning and Assessment, retrieved 4 February 2016 from http://www.cala.fsu.edu/files/higher_order_thinking_skills.pdf

[8] E. Oprins, Burggraaff, and H. van Weerdenburg, Design of a competence-based assessment system for air traffic control training, The International Journal of Aviation Psychology, volume 16, issue 3, p. 297-320, 2006

[9] M. Schuver-van Blanken, Aviation Training Devices: Matching Learning and Fidelity, presenation retrived February 4 2016 from http://www.navnin.nl/NIN/Downloads/AVIGEN%202010%20-%20LVNL%20Aviation%20Training%20Devices.pdf

[10] G. Muller, Experiences of Teaching Systems Architecting;; INCOSE 2004 in Toulouse, 2004

[11] G. Muller Didactic Recommendations for Education in Systems Engineering, INCOSE 2005 in Rochester, 2005

[12] G. Muller, "Systems Architecting: A Business Perspective" CRC Press, Boca Raton, 2011

[13] G. Muller, CAFCR: A Multi-view Method for Embedded Systems Architecting; Balancing Genericity and Specificity; PhD thesis TU Delft 2004.

[14] G. Muller, System and Context Modeling -- The Role of Time-boxing and Multi-view Iteration, by Gerrit Muller; Systems Research Forum Vol. 3, No. 2 (2009) p139-152, 2009.

[15] G. Muller, System and Context Modeling; Visualizations of Where, When, and How ,INCOSE 2010 in Chicago, 2010.

[16] G. Muller, Teaching conceptual modeling at multiple system levels using multiple views, CIRP 2014 in Milan, 2014.

[17] G. Muller, Challenges in Teaching Conceptual Modeling for Systems Architecting, ER 2015 in Stockholm, 2015

[18] M. Sharples et al., Innovating Pedagogy 2012 Exploring new forms of teaching, learning and assessment, to guide educators and policy makers, Open University Innovation Report, 2012

[19] M. Sharples et al., Innovating Pedagogy 2015 Exploring new forms of teaching, learning and assessment, to guide educators and policy makers, Open University Innovation Report 4, 2015

[20] P.Guo, Optimal Video Length for Student Engagement, retrieved from Internet 5 February 2016 http://blog.edx.org/optimal-video-length-student-engagement, 2013

[21] R. Greenfeild, The Internet's Attention Span for Video Is Quickly Shrinking, retrieved from Internet 5 February 2016, http://www.thewire.com/technology/2013/08/internets-attention-span-video-quickly-shrinking/68114/, 2013

[22] C. Moskowitz, Mind's Limit Found: 4 Things at Once, retrieved from Internet 5 February 2016, http://www.livescience.com/2493-mind-limit-4.html, 2008

[23] H.N. Mok, Teaching tip: The flipped classroom. Journal of Information Systems Education, 25 (1), 7-11, 2014

[24] A. Squires et al., Investigating an Innovative Approach for Developing Systems Engineering Curriculum: The Systems Engineering Experience Accelerator, American Society for Engineering Education, 2011

APPENDIX A LIST OF VIDEOS IN FIRST EDITION

TABLE I. LIST OF VIDEOS IN FIRST EDITION

1.1	Learning by Reflecting	https://youtu.be/Gb8epKYLhz0
1.2	Business Context	https://youtu.be/7KiPquDsO7U
1.3	System of Interest	https://youtu.be/c1GfOZ7zXKg
1.4.1	Business Context - Process View	https://youtu.be/8Ikt6YiAXR4
1.4.2	Business Context - Solution Creation	https://youtu.be/v6cl2Y26IbM
1.5.1	Architect - Role and Task	https://youtu.be/AWc3bGbTRpc
1.5.2	Architect - Way of Working	https://youtu.be/wNqY8ZMI4Bg
1.6	Architect - Challenges and Dilemmas	https://youtu.be/TKgfYXkOE4Q
2.1	CAFCR+ - Introduction	https://youtu.be/ICCGkWvFVaM

APPENDIX B LIST OF COURSE EVALUATION QUESTIONS

All questions use a 5-point Likert scale, with the answers: strongly disagree, disagree, neither disagree nor agree, agree, strongly agree.

Questions related to the teacher:

A.1 Explains the objectives of the course clearly

A.2 Is prepared for the class

A.3 Presents material in an organized manner

A.4 Has command of the subject

A.5 The guest lecturers were effective during the course

A.6 Successfully communicates the subject

A.7 Is fair and consistent

A.8 OVERALL The Instructor was an Effective Teacher

Questions related to the course:

B.1 The course is well structured

B.1 The course material (notes and books) is well organized

B.3 The material was adequately covered in the allotted time

B.4 The course was structured to facilitate discussion and participant contribution

B.5 The subject matter has significant relevance and usefulness to my organization

B.6 I can apply what I have learned in this course on projects (underway or future) in my organization

B.7 The course would enable me to enhance my future career objectives

B.8 OVERALL This was an Excellent Course