Teaching product development based on the concept of integration scenarios: evaluation and guidelines for application

Sanderson César Macêdo Barbalho
University of São Paulo
Engineering School of São Carlos
scmb@sc.usp.br

Daniel Capaldo Amaral
University of São Paulo
Engineering School of São Carlos
amaral@sc.usp.br

Henrique Rozenfeld
University of São Paulo
Engineering School of São Carlos
roz@sc.usp.br

Abstract: Integration scenario is an educational tool for product development qualification that was built in an attempt to overcome the difficulty of transmitting the relationship among concepts and the product development process itself using traditional teaching methods. Based on scenario proposal instructors can to use learning by doing and customized teaching techniques to qualify people on product development process. This paper presents a comparative analysis of the results of evaluations applied at the end of courses that used scenario concept. A total of 10 courses were evaluated utilizing average and standard deviation concepts. As a result of this analysis, several considerations are presented regarding the proposal of scenarios, guidelines for applying the concept, and directions for future research. In summary, the scenario method can be succesful used in courses whose main purpose is to describe the product development process or to demonstrate how the various product development concepts and techniques relate to each other. The complete scenario is not a tool recommended for in-depth teaching of specific product development techniques or methods. Addictionally, discussions should be center as much as possible on the script when the target public is composed of experienced professionals and on expository techniques with beginners.

Key words: Product Development Process, Teaching Techniques, Integration Scenario

1. Introduction

Since 1994, the Integrated Engineering (IE) research group of the Nucleus of Advanced Manufacturing (NUMA) has been developing an approach for product development teaching called integration scenarios. At first, the scenarios were built to simulate the use of computational solutions in computer integrated manufacturing (CIM). Then, in 1997, the concept was adapted for use in product development (PD) research and training. In this context, the integration scenario can be seen as a teaching proposal "based on active didactic techniques, in which the participants interact and experience situations in an environment that reproduces the conditions of a real manufacturing company" (AMARAL *et* al., 1999).

The basic principle of this approach is to create an environment similar to that of a company that develops products, like a scene in a play. The students of the courses can play the roles of the characters in this company and carry out the development activities of a fictitious product, learning new techniques and methods in a "contextualized" way and acquiring, at the end, an integrated vision of the product development process (PDP).

Over the years, several advances have been made from the original concept, while courses to assess this proposal were offered to company professionals, and postgraduate and undergraduate students. This experience is described in articles authored by AGUIAR *et* al. (1997), ROZENFELD *et* al. (1998); ZANCUL *et* al. (1998); AMARAL *et* al. (1999); and MUNDIM (2002); MUNDIM *et* al. (2002). This same proposal was also used in a professional training program for a multinational company, in which about 120 product development engineers were trained, as reported by MUNDIM (2002) and ROZENFELD *et* al. (2003).

Although the concept has been well received, there is still space for improvement. This article is part of a series of reflections aimed at evaluating the experience of applying scenarios and at defining guidelines for research aimed at the concept's evolution.

The purpose of this article is to present a comparative analysis of the results of evaluations applied at the end of each course, using a standard questionnaire. A total of 10 courses were evaluated. As a result of this analysis, several considerations are presented regarding the proposal of scenarios, guidelines for applying the concept, and directions for future research.

2. Integration Scenario for Teach Product Development

This scenario is based on some elements that make it an almost entirely real environment, i.e., a company, products, people, shop floor resources, offices, reference model, etc. The reference model describes various aspects of this process, with the purpose of supporting the exchange of information and knowledge inside the organization, based on common semantics [12].

In one scenario, the characteristics of the company, the product and the reference model can be selected according to the specificity of the learning application; in other words, if the goal is to educate the professionals of an automaker, a fictitious company will be created similar to the real automaker and a car of its product line will be chosen as an example to be developed according to its PD reference model. The elements developed for a given scenario and application can also be used in new scenarios in order to take advantage, for example, of elements already created that match the specificities of the new application. The PD scenario is an integrated structure of concepts and elements that support "experiencing" and simulation of the PDP (Figure 1).

The central element of the PD Scenario is the reference model, which is a representation of the business process. The PD Scenario presents the activities, information, resources and organization in such a way as to provide a broad vision of the PDP. Another basic element is the model enterprise, a set of descriptions of the characteristics of the simulated company, such as a description of its organizational units, the structure of the units, its employees (characters) and other information about the company that may be deemed interesting. It is also important to have a sample product. The scenario must include a description of the characteristics and specifications of that product, designs, BOM (Bill of Materials) and any other pertinent information about the product. At the base of all this is the process knowledge map included in the reference model, which describes the knowledge employed in each activity and its sources (for example: specialists and references on the subject).

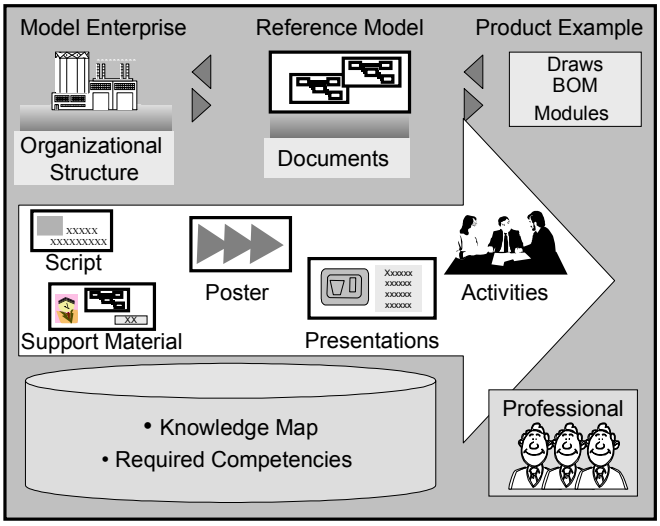

Figure 1: Concept and Elements of the Product Development Scenario

Source: CLARK AND WHEELWRIGHT, 1992.

Based on these fundamental elements of the scenario, a script can be created, i.e., a story of the development of a sample product by the model enterprise, using the PDP and the mapped knowledge. Based on the script, activities are then developed using learning by doing, theoretical presentations and support material as teaching techniques for the scenario. More details about this concept can be found on Rozenfeld et. all. (2003). The next section contains a discussion of the previous evaluations made on scenario courses.

3. Evaluation of Scenario-Based Courses

At the conclusion of each of the courses, the participants answered questionnaires containing open-ended and closed questions. One of the closed questions asked the students to give a score of 1 to 5 and was aimed at measuring the participants' level of satisfaction in regard to techniques, methods and tools used in the course, as well as the course's overall planning. The items evaluated were:

♦ **Planning-related items**: involve aspects considered basic in the preparation of a course, such as *number of hours/day, teaching material and resources utilized*. The latter refer to projectors, data show, whiteboard and pens, software programs, etc.

♦ **Content-related items**: involve aspects relating to the technical content to be broached, i.e., the *instructors' mastery of the subject matter, theoretical presentations, screen cam simulations, and movies*.

♦ **Overall methodology-related items**: these are methodology-related questions included in the questionnaire to allow the student to express the overall impact produced by the method. These questions are important because they represent a synthesis of the student's satisfaction with the course. These items were *methodology used* and the *course's dynamics*.

♦ **Specific methodology-related items**: are methodological questions relating to some element of the scenario concept, i.e., *script/characters, group activities, activities with open-ended issues and individual computer activities*.

Several evaluations of the integration scenario concept have been published. Listed below is a brief description of the main studies and their conclusions:

♦ ZANCUL et al. (1998) present an evaluation of the first official scenario-based course. The model used was a 40-hour course distributed over five days and involved a group of 5 students, who considered the following strong points: the capacity to visualize the integration and the discussions and group dynamics. The main negative aspects of the course were the excessive number of hours per day and the duration. The instructors pointed out another negative aspect which, in a way, originates from the above-mentioned points, i.e., the economic unfeasibility of multiplying the course in that format owing to the high cost of instruction. This conclusion led to a new configuration, which consisted of a 24-hour course spread over three days and groups of 15 to 20 students.

♦ AMARAL et al. (1999) describe the second official course using the integration scenario, given according to the new 24-hour model. In all, 30 undergraduate students and professionals from high tech companies participated. Their conclusions were: (1) the use of a story structured into acts and scenes was well accepted by the students, who considered it important to "visualize the integration" of the organizational concepts and structures of the PDP, to "improve learning", increase "motivation" and "integrate people"; (2) the elements of the course relating to "interaction and participation" were considered the least satisfactory; and (3) the most frequently cited positive element was the perception that PDP must be seen from a holistic focus.

♦ Analyzing six (6) courses using the integration scenario concept connected to activities of corporate education, MUNDIM (2002) and MUNDIM et al. (2002) highlight the same observations as those pointed out by AMARAL (1999), adding the following aspects: (1) the importance of adapting the course program content to the professional profile and field of action of the target public; (2) the positive impact caused by the use of different media (in this case, the Internet) on the motivation for and assimilation of the course; and (3) the fact that the courses allowed the professionals to perceive a wide range of techniques and tools used in the PDP.

The present work evaluates 10 scenario-based courses, attended by a total of 169 participants (professionals and undergraduate and postgraduate students). The courses analyzed in the above cited articles are included in this study. For first time, however, the courses are compared with each other and a correlation is made between the closed and open-ended questions in the evaluation questionnaire, which allowed one to draw up several guidelines for the application of the scenario concept. This more in-depth evaluation was conducted in three different steps: a) an overall evaluation of the performance of the courses according to the scores given by the students in response to the closed questions (item 5); b) an evaluation of the comments and suggestions offered spontaneously by the respondents to the open-ended questions (item 6); and (c) a comparison between the courses with the highest and lowest scores in the closed questions, evidencing the courses most well-accepted and least accepted by the students (item 7). Item 4 shows the profile of the evaluated courses.

4. Profile of the evaluated courses

Table 1 shows the profile of each of the courses held.

Table 1: Profile of the analyzed courses

Course	No. Of Students	No. of Hours	Duration (days)	Public	General Description
1	5	40	5	Product Development Managers, Consultants and University Professors	Course given in the original 40-hour configuration. The participants were highly experienced PD professionals (2 of them managers) and the discussions were highly productive.
2	25	24	5	Postgraduate Students, PD Managers from Small Companies, and Consultants	This course was attended by a fairly heterogeneous public of people with different levels of experience and knowledge about PD.
3	13	24	3	Company professionals from the product development area (managers and engineers)	Courses given to professionals from a single company. The groups in courses 4, 5 and 6 were more heterogeneous, containing mostly professionals from areas not directly related with PD, such as quality and production. Group 8 comprised mostly software development professionals. The company unit where the course was held develops systems for equipments.
4	13	24	3		
5	26	24	3		
6	21	24	3		
7	13	24	3		
8	22	24	3		
9	22	24	3		
10	9	24	3	Postgraduate and undergraduate students	This course was held at the university for postgraduate students.

5. Overall Course Performance

The scores attributed by the students to the closed questions measure their satisfaction with the items listed under topic 3. They offer a value relating to the students'' general satisfaction with the course. The scores given under each criterion were added and compared to the highest possible score, which was obtained by adding the scores of all the criteria, resulting in a general student satisfaction score for each course listed in Table 1. As can be seen, the average score attributed to the courses was 7.98 [out of a maximum score of 10]. Calculating the standard deviation of this sample (0.55), one has 2 courses with higher than average scores (courses 1 and 9), 2 with lower than average scores (courses 6 and 7) and the remainder lying within the interval given by the average and standard deviation.

Considering the average of the courses as a value that represents student satisfaction in relation to all the items evaluated, it can be inferred that courses 1 and 9 were the "best" and course 6 and 7 the "worst" in relation to the others, according to the participants' opinions.

Computing the average value of each item separately, we can see the score of each one in the set of courses, as indicated in Figure 2, which also shows which elements contribute positively or negatively to the courses' final average. As can be seen, of the 13 items evaluated, 7 scored above the average evaluation of the courses (7.98) while 6 scored below. Of the 7 items that scored higher, 5 (teaching material, mastery of the subject matter, resources utilized, theoretical presentations, and screen cam) are classified as planning or content items and are therefore not listed specifically with the scenario concept. These items can be understood as aspects that qualify a good course, but do not differentiate it methodologically.

The items "teaching methodology", though validating the planners' efforts in using a differentiated teaching method, is very generic in terms of identifying what it characterizes.

Table 2: Average of the course evaluations

Courses	1	2	3	4	5	6	7	8	9	10	General
Scores	8.63	7.97	8.15	7.65	7.98	6.92	7.36	8.49	8.62	8.05	**7.98**

However, it is interesting to note that this item and "course dynamics" scored within the standard deviation of the courses' average, receiving 81.4 and 75.7, respectively, which underpins the fact that these two aspects synthesize the students' overall satisfaction. Still in regard to the items that scored above the average of the courses, the data indicate that "script/characters" is the methodological element of the integration scenario concept that provides the greatest participant satisfaction.

Among the elements that scored below average, it is worth mentioning the low scores given to the practical activities, which sought to encourage students to use the concepts presented, and which were therefore strongly connected to the proposal of using active didactic techniques in the teaching process.

Calculating the standard deviation of the scores given to scenario elements (9.87%) and analyzing the elements that scored above and below the standard deviation of the average, the resulting distribution characterizes well the fact that planning and content-related aspects of the courses were generally their really strong points, since only "mastery of the subject matter", "resources utilized", and "didactic material" remained above the median level. On the other hand, only "group activities" and "number of hours/day" remained below the average minus the standard deviation, corroborating the afore-mentioned reflections.

The data in Table 3 illustrate this difference in variability even more clearly, showing the maximum and minimum scores for each element of the scenario and the standard deviation along the courses. The greatest variations appear for the items that are the least well ordered in terms of contribution. These items also show the largest standard deviations. As can be seen, the items showing the largest deviation and variation are also aspects that are more dependent on the execution of the courses. In other words, there is a basic difference between the items scoring highest and those scoring lowest in Table 3: the highest are strongly dependent on the moment of the course, the students' participation and the quality of the execution of what was planned, while the lowest are aspects that vary little with the quality of execution. For instance, the item "instructors' mastery of the subject matter" is a given and holding the course can contribute but little to a significant increase in the instructor's knowledge of the subject matter. The same reasoning can be applied to the items "resources", "material", "movies", "screen cam", and "theoretical presentations".

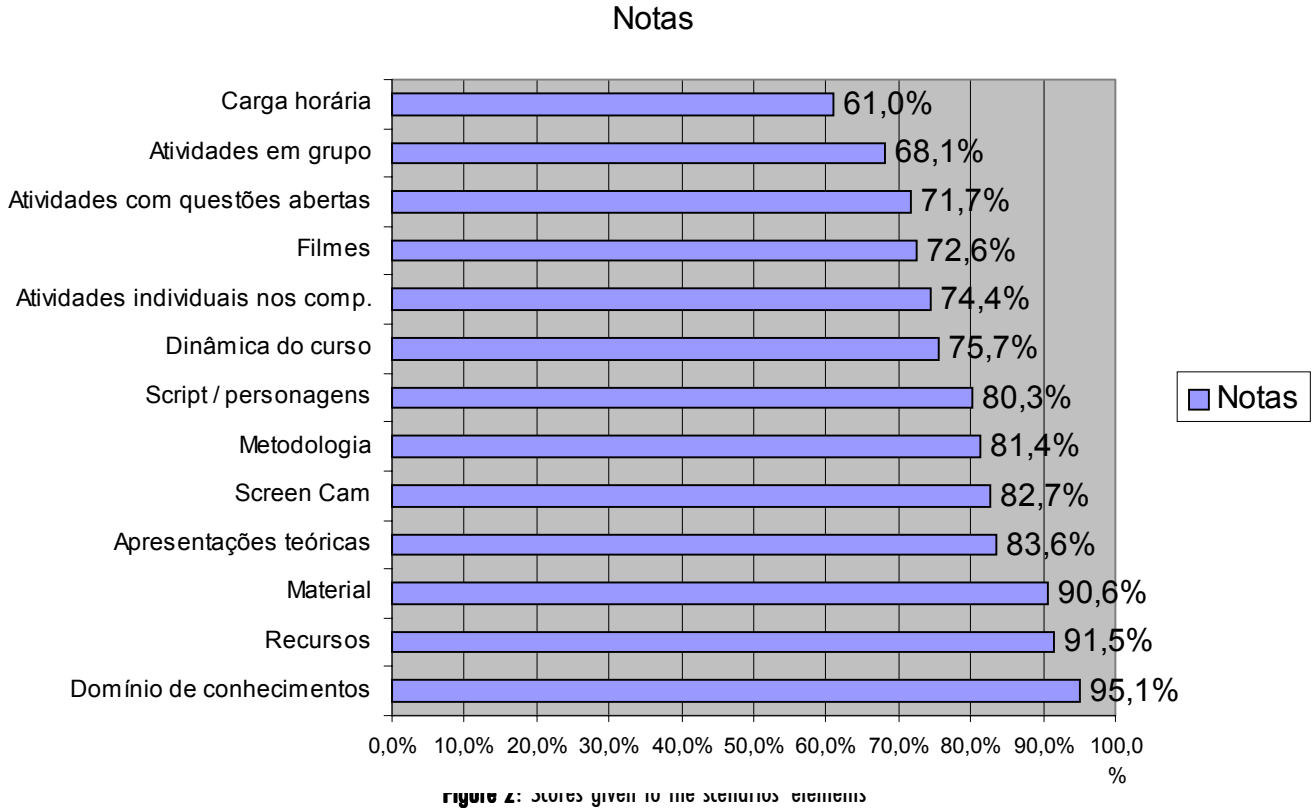

Figure 2: Scores given to the scenarios' elements

Table 3: Difference and standard deviation of the course elements evaluated

Elements	General	Deviation	Difference
Group activities	68.1%	14.4%	36.9%
Number of hours/day	61.0%	13.3%	40.8%
Activities with open-ended issues	71.7%	11.1%	28.8%
Course dynamics	75.7%	11.1%	31.3%
Methodology	81.4%	9.7%	26.6%
Individual computer activities	74.4%	7.9%	11.2%
Script / characters	80.3%	7.5%	21.0%
Resources	91.5%	7.1%	20.7%
Material	90.6%	7.0%	22.3%
Movies	72.6%	6.1%	21.5%
Screen Cam	82.7%	4.9%	12.9%
Theoretical presentations	83.6%	3.7%	12.2%
Mastery of subject matter	95.1%	3.4%	11.4%

"Group activities", "number of hours/day", "activities with open-ended questions", "methodology" and "course dynamics", on the other hand, are more dependent on the execution. That is, despite planning efforts, some aspects of the course vary considerably in execution time because they basically depend on student participation, their interaction with the content and with the instructors; hence, their evaluation is strongly influenced by the impressions they caused on the individuals at the moment they took place, such as practical activities, or by the overall experience of the course, such as number of hours/day, dynamics and methodology.

6. Positive and negative aspects pointed out by the students

The two main open-ended questions asked the participants to identify the main positive points perceived during the courses. Tabulating the data of all the courses and grouping the occurrences of the same theme, a list of 33 positive aspects was drawn up from a total of 407 occurrences. A Pareto analysis allowed the identification of the seven most representative items, i.e., items that, by themselves, represent over 80% of the occurrences of positive aspects identified in the questionnaire. Table 4 presents the seven most significant items. These data can be interpreted as the positive aspects generated by a course with a score within the standard deviation of the average (Table 1), or whose elements have scores presented in Figure 2.

As can be seen, the item "global vision of the PDP" alone represents over 1/5 of the occurrences. This predominant perception among the courses' participants can be attributed to various reasons: (1) the story (narrated and synthesized on panels and in the script), whose objective is mainly to provide an overall view of the PDP; (2) the instructors' concern, given their education, regarding the aspects of correlation between the techniques and methods transmitted during the course; (3) the very fact that, during the course, mention is made of the importance of a global vision of the PDP, particularly in the presentation that defines this business process; and (4) the number of different concepts, techniques and methods presented during the course, which may, by association, create a feeling of a global vision even if the correlation among these tools has not been made explicit. The positive evaluation of this item is believed to be due to a combination of these reasons, with 1 and 2 reinforcing the usefulness of the Integration Scenario approach and the others reflecting the influence exerted by the instructors.

Considering that other elements intrinsically related with this aspect appear among the main ones, such as didactics and script, which scored 5.4 and 6.7%, respectively, one can conclude that the most probable hypothesis is that the story contributed in some way to a global vision of the PDP. Considering, also, that the positive items that follow the global vision are precisely Technical Content, Level of Concepts and Instructors' Knowledge, it is clear that the students legitimated the instructors' knowledge and may, therefore, have been easily influenced, which leads one to believe that at least one of the explanations 3 and 4 (previous paragraph) may have influenced the perception of the global vision.

A comparison of Table 4 and Figure 2 reveals a good congruence between them, indicating that the result of the question is trustworthy. It should be noted that the highest scoring items in these closed questions, Mastery of Subject Matter, Resources and Didactic Material, also appear as

Table 4: Positive aspects

Positive aspects	Occurrences	Representativeness	Accumulated
Global vision of the PDP	84	20,6%	20,6%
Technical content	68	16,7%	37,3%
Level of concepts	50	12,3%	49,6%
Knowledge of instructors	48	11,8%	61,4%
Didactic material	36	8,8%	70,3%
Didactics	26	6,4%	76,7%
Characters and story	23	5,7%	82,3%

Table 5: Negative aspects of the courses

Negative aspects	Occurrences	Representativeness	Accumulated
Time scheduling	80	30.7%	30.7%
Deficiency in practical activities	30	11.5%	42.1%
How the script was used	20	7.7%	49.8%
Little space for participation	14	5.4%	55.2%
Lack of group dynamics	13	5.0%	60.2%
Didactic material	13	5.0%	65.1%
Didactics need improvement	13	5.0%	70.1%
Physical space	12	4.6%	74.7%
Excessively generic	11	4.2%	78.9%
Detailed and end evaluation	9	3.4%	82.4%

positive aspects. The elements with intermediary scores, such as Methodology and Script/Characters, also rank low among the positive scores for the open-ended questions. This confirms that the script and methodology, innovative items of the Integration Scenario proposal, contributed to the course, albeit less significantly than the traditional items of teaching approaches, such as didactic material and instructors' explanations.

In short, the evaluation of the positive aspects allows one to hypothesize about the unanimity of the participants' judgment that the course contributed to provide a holistic vision of the PDP, and that this is due to a combination of the courses' innovative use of script/characters, the instructors' influence during the presentations, and the didactic material and resources utilized.

Similarly to the positive points, the evaluations contained an open-ended question asking the participants to identify **negative** aspects of the course. The answers were tabulated, grouping similar answers together. In all, 30 items were mentioned with 261 occurrences. These results, if compared against the evaluation of positive aspects, resulted in 9.1% fewer items and a 35.6% lower occurrence than the positive items. This allows one to conclude that the courses produced more positive responses than negative ones, confirming the hypothesis that the courses were positively assessed by the participants and were therefore well accepted.

As in the case of the positive aspects, the negative responses were tabulated so as to consider a percentage of occurrences in relation to the total. Thus, as Table 5 indicates, 10 negative aspects represent more than 80% of the occurrences.

The importance of the item “time scheduling”, which represents almost one third of the occurrences, is coherent with the data shown in Figure 2, which indicate the number of hours/day as a less satisfactory element of the scenario.

Similarly, the aspect "deficiency in activities/practical examples" is directly correlated with "group activities" and "activities with open-ended issues", which were the other two lowest scoring elements of the scenario, according to afore-mentioned graph. These inferences indicate the questionnaire's validity for use as an overall course assessment tool and as feedback in the planning of future events.

It is interesting to note the presence of the aspect "how the script was used". An analysis of the responses of each course revealed that complaints about the "script" involve "reading of the script" and the "little space for active participation". Therefore, it can be inferred that the complaints were not against the existence of the script but referred to the way it was used.

An integrated analysis of the data indicates that the participants scored the "script" above the elements' average score, as shown in Figure 2, and specified the "scrip/ characters" as one of the main positive aspects. However, they consider that better use could have been made of the "script", suggesting that the narrative use of the script is not very satisfactory, particularly if the script is read by the instructor. According to the participants, the script can be used as an element of active participation in the course, allowing the students to influence the progress of the story, or to incorporate the characters without a preestablished script at some points of the course. These aspects must be taken into account in planning the next events, though it should be noted that the use of a narrative script is directly correlated with the transmission of a holistic view of the PDP, which may not be the case if the script is used more "openly". Another obstacle is the time that would be required for a more open experience involving the product development process.

A complete analysis of the positive and negative points of the proposal is given in BARBALHO *et al.* (2003b). The next topic discusses the differences between the best and worst courses, based on the difference between them and the overall average satisfaction of the participants.

7. Comparative Analysis of the Courses Above and Below the Average

To help understand why some of the courses scored substantially higher than others, a comparative analysis was made of these events. This analysis was briefly described in BARBALHO *et al.* (2003a). Figure 3 illustrates the contribution of each of the 13 elements evaluated in the questionnaire for the group of 10 courses studied.

The graph in Figure 3 can be interpreted as a contribution of each element evaluated for a course whose final average (from 1 to 10) was 7.98. Thus, in the general analysis, the contribution of the item "Movies" represents 7.76% of the value of the general average, while "Resources" contributes with almost 10.34% of this value. The reason this graph was introduced in the comparison was the differences in the contribution of the elements that contributed most and those that contributed the least. As the graph indicates, "Mastery of the subject matter" contributed with 10.55% of the final score, while "Number of hours/day" contributed 6.77%, resulting in a difference in contribution of 3.78 points. In the highest scoring courses there is a difference of at most 2.79 points between the highest scoring and the lowest scoring item, while this difference in the two courses that scored the lowest was 4.76 and 4.61, respectively (average of 4.68). Therefore, the best courses presented lower variations among the evaluated elements. These variations among the elements were up to 2/ 3 higher in the worst courses compared with the best.

In other words, the best courses showed greater equilibrium in their planning and/or execution, producing a more homogeneous participant satisfaction with the various elements. In practice, this equilibrium is often manifested by letting a practical activity last longer than planned to enable the students to conclude it, by aborting a given activity due to the time it requires or because it was planned to take place close to break or meal times, by reducing the content of presentations that have already been discussed in the classroom, by allowing the extension of discussions arising from practical activities, from presentations or from the script, and so on.

Table 6 compares the scores of the elements evaluated by course group. The items are presented in increasing order of their scores. The two last lines show, respectively, the average of each column and its standard deviation. The third column shows the "significance of the best", i.e., how much higher the best courses scored over the average of the courses in each evaluated element. The measure of significance shows an average of 6.2%, meaning that the best courses exhibited scores 6.2 percentage points above the general average, which shows a standard deviation of 4.4%. These data allow one to infer which items are significantly differentiated in the best courses in relation to

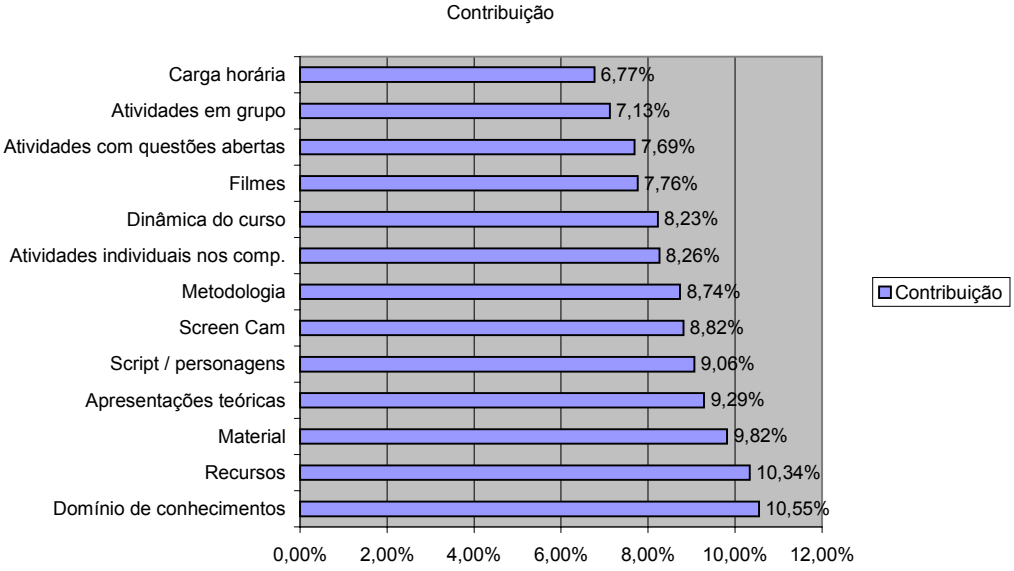

Figure 3: Graph of the contribution of the elements to the courses' overall score

the average, which is obtained by adding the standard deviation to the average and checking which items score above this result.

From this procedure it can be concluded that only the item "Number of hours/day" is significant of the difference between the average and the best courses. The item "Methodology" is quite close to the limit of significance (10.6%), followed by "Group Activities" and "Course dynamics". At the other extreme of significance (the least significant) are the items "Movies", "Mastery of subject matter", and "Theoretical presentations". Lying within the average significance, this growing list is completed by "Screen cam", "Resources" and "Material".

In short, the significance of the aspects that differentiate the best courses from the general average follows an inverse distribution from that presented in Table 2, i.e., the aspects whose scores varied most among the 10 courses are precisely those that showed a significant difference among the courses considered superior. This analysis also allows one to infer that the aspect "Number of hours/day", more than "Methodology" or "Course dynamics", reflects the participants' overall assessment of the courses. Since this is

Table 6: Comparison of the scores given to the courses

ELEMENTS	SCORES BY GROUPS			Significance of the Best	Comparison of best and worst
	General	best	worst		
Mastery of subject matter	95.1%	96.1%	91.3%	1.0%	4.7%
Resources	91.5%	95.2%	84.5%	3.7%	10.7%
Material	90.6%	96.1%	82.7%	5.5%	13.4%
Theoretical presentations	83.6%	85.4%	78.1%	1.8%	7.3%
Screen Cam	82.7%	85.5%	77.4%	2.7%	8.1%
Methodology	81.4%	91.4%	69.4%	10.0%	22.0%
Script / characters	80.3%	88.4%	76.1%	8.1%	12.3%
Course dynamics	75.7%	84.5%	60.9%	8.9%	23.7%
Individual computer activities	74.4%	80.0%	**nda**	5.6%	**nda**
Movies	72.6%	73.3%	65.4%	0.7%	8.0%
Activities w/ open-ended issues	71.7%	79.0%	57.1%	7.3%	21.9%
Group activities	68.1%	77.3%	55.7%	9.2%	21.5%
Number of hours/day	61.0%	77.0%	57.6%	16.0%	19.4%
Average	79.1%	85.3%	71.4%	6.2%	14.4%
Standard deviation	9.8%	7.8%	12.0%	4.4%	6.9%

a planning item, this highlights its importance in relation to the category's other items.

Although the significance analysis indicates the importance of the differentiating aspects of the scenario proposal in the participants' final assessment of the course, the comparison of the highest and lowest scores makes this even clearer. This analysis can be observed in column 4 of Table 6, where the best and worst data are compared by the difference in scores attributed to each element for the group of 10 courses. On average, the elements of the best courses were given 14.4% higher scores than the worst, with a standard deviation of 6.9%. These values indicate that there is an upper average evaluation limit whose value is 21.1% and a lower limit of 7.5%. An analysis of the elements scoring above the upper limits indicates that the items "Course dynamics", "Methodology", "Activities with open-ended issues" and "Group activities", in decreasing order, can be considered representative of the difference in evaluation between the best and worst courses. This datum validates the overall method represented by the scenario (methodology), confirms the need for the course to flow harmoniously, the importance of the so-called methodology-related items in general as a synthesis of the participant's satisfaction, and the importance of the experiential aspects on the results of the training. The fact that the item "Number of hours/day" does not appear as significant of the difference between the best and worst courses is not a contradiction of the data, but a consequence of the great significance of the afore-mentioned items in the comparison of these two groups of courses.

As for the lower limit of the average of the comparison between best and worst, only the aspects "Mastery of subject matter" and "Theoretical presentations" score lower, corroborating the earlier analysis that these aspects do not differentiate the courses.

Table 7 compares the courses' positive points (considering the limit of 80% of occurrences), based on the same approach as that used to compare the scores. Column 3 indicates the significance of the positive points. Considering the upper and lower limits of significance, the item "Global vision of the PDP" stands out for lying below the lower limit, indicating that, regardless of whether a scenario-based course is "good", "average" or "poor", the method allows for the transmission of this integrated vision of the product development process.

Column 4 analyzes the variation in the representativeness of the positive aspects indicated for the best and worst courses. The average deviation is 0.5%, with a standard deviation of 5.4%. Only the item "Global vision of the PDP" falls below the lower limit of the average, confirming the conclusion of the previous paragraph. The item "Content given" exceeds the upper limit, indicating that the best courses differed from the worst in terms of the content the participants were able to assimilate, according to their assessment when questioned about the courses' positive aspects. This information is particularly important as one of the bases for the construction of a hypothesis to be tested by the use of content evaluations in future courses: the higher the participant's satisfaction with the course, the greater the content he assimilates.

Lastly, Table 8 shows the comparative data of the courses' negative aspects indicated by the students. Using an approach similar to that described for Table 6, one can infer that the "time schedule" is considered a more significant negative aspect in the overall evaluation of the courses than in the "best" courses. In other words, the best courses displayed less representativeness in this aspect, which is coherent with the data and reflections deriving from the item "number of hours/day" in Table 6. In contrast, the item "Use of the story in the course" is a negative aspect that is significantly present

Table 7: Comparison of the open-ended questions: positive points

Positive aspects	Representativeness			Significance of the best	Variation in Representativeness
	General	Best	Worst		
Content given	16.7%	22.9%	14.1%	6.2%	8.8%
Consolidation of the culture	12.3%	18.8%	21.2%	6.5%	-2.5%
Global vision of the PDP	20.6%	16.7%	22.2%	-4.0%	-5.6%
Mastery of the subject matter	11.8%	14.6%	15.2%	2.8%	-0.6%
Characters and story	5.7%	10.4%	8.1%	4.8%	2.3%
			Average	3.3%	0.5%
			Standard deviation	4.3%	5.4%

in the "best" courses, allowing one to infer that, although the best courses showed greater satisfaction in regard to the element "script/characters" and were considered significantly better in terms of "methodology" and "course dynamics", it may have been precisely because of this significant emphasis on methodological aspects that the participants considered the story could have been put to better use.

The data in column 4 confirm the conclusion given in the previous paragraph regarding the representativeness of the "Use of the story", leading to the conclusion that the methodological aspect was not considered relevant in the "worst" courses and, therefore, the use of a "story" does not represent a significant improvement of the course. It is also worth noting the presence of an almost totally positive significance of the negative aspects indicated in the "best" courses in relation to the other groups. This may be due to the fact that the table was built as a form of maintaining coherence with the analyses of Tables 6 and 7, which compare

Table 8: Comparison of the open-ended questions: negative points

Negative aspects	Representativeness			Significance of the best	Variation in Representativeness
	General	Best	Worst		
Use of the story in the course	7.7%	26.3%	3.3%	18.7%	23.1%
Time scheduling	29.5%	21.1%	14.1%	-8.4%	6.9%
Didactic material	5.0%	15.8%	6.5%	10.8%	9.3%
Deficiency in practical activ.	4.2%	10.5%	0.0%	6.3%	10.5%
Lack of group dynamics	5.0%	10.5%	6.5%	5.5%	4.0%
			Average	6.6%	10.8%
			Standard deviation	9.9%	7.3%

the other courses based on the "best" ones. If this comparison were made based on the "worst" courses, other items would appear as highly representative, among them "physical space", with 10.9% representativeness among the "worst", "the course leaves the group passive" (also with 10.9%), "detailed and final analysis" (6.5%), and "problems with the instructors' didactics" (also 6.5%), "lack of organization/ infrastructure" and "excessively generic" (both 5.4%). Of these, only the latter would show a parallel with the "best" (5.3%), while the others can be considered as a list of negative aspects to be avoided in future courses. The other items of Table 8 are included on this list.

8. Guidelines for Giving Courses Involving Integration Scenarios

The results discussed here demonstrate that the major differentiating factor of courses based on the scenario model is the capacity to transmit a holistic vision, i.e., the interrelations among the different product development techniques and the contingencies existing between them. This aspect needs to be properly explored. At this time, this means that, if the goal is to transmit a specific PD technique or discuss a given subject in depth, the scenario-based model is not recommended.

The best courses, 1 and 9, involved professionals experienced in product development, see item 4, which reflects the impression of the researchers who acted as course instructors to the effect that experienced product development professionals are better able to assimilate all the implications relating to the script than are students and beginners. When the target public is already familiar with the basic concepts, there is a greater probability that they will benefit more from the script, the activities and the discussions generated during the course.

Time is the main factor that requires careful planning. The results of this analysis demonstrate that this factor is the major barrier. Including all the PD-related topics in the course leads to lengthy courses and results in student dissatisfaction. On the other hand, greatly reducing the number of topics reduces the wealth of relations and, thus, the course's contribution in terms of the holistic vision.

To help solve this dilemma, the scenario's flexibility should be explored, emphasizing the story and inserting activities or presentations about theoretical concepts only when strictly necessary.

These considerations can be summarized in the following guidelines:

♦ Use the scenario in courses whose main purpose is to describe the product development process or to demonstrate how the various product development concepts and techniques relate to each other. The complete scenario is not a tool recommended for in-depth teaching of specific techniques or methods.

♦ If the group is unfamiliar with product development and has little experience, a traditional course or a longer scenario-based course including the detailed presentation of several concepts is more appropriate.

♦ Attempts should be made to set up groups that are as homogeneous as possible and to tailor the course to that specific public, reserving activities and presentations of specific concepts only for themes that are completely unfamiliar to the group.

♦ Standardizing the didactic material, such as the story, model company and presentations, is essential. This ensures the necessary flexibility to adapt the course to the participants' needs. An example of how to create and maintain this material is given by ROZENFELD *et* al. (2003).

♦ The discussions should center as much as possible on the script mainly when the target public is composed of experienced professionals.

9. Conclusions and Future Research

The analysis presented herein is the result of almost ten years of research on scenarios. It demonstrates that, despite the deficiencies identified, this teaching approach has reached a mature stage of development and that its differentiating feature is its capacity to transmit an integrated vision of PDP concepts. Therefore, this proposal can and should be applied, following the guidelines outlined under the previous item. It should be especially noted that the contribution of this proposal is significant, considering the difficulty of transmitting the relationship among concepts and the product development process itself using traditional teaching methods. Transmitting or discussing PD topics with expository classes, tests or traditional didactic activities can be highly challenging, given the difficulty of concretely discussing all the possible interrelations, with cases and possible implications.

An important contribution of this article is the detailed analysis of the problems involved in scenario-based teaching. It may be useful for researchers of engineering teaching interested in continuing their development. It was demonstrated, here, that the two main deficiencies identified are: planning time and making better use of the story. To overcome these problems, research projects could be created along two different lines. The first route would be the development of teaching techniques that allow the story to be better employed as an inducing and catalyzing element of the discussions. The second would be a study of the application of *e*-learning technologies within the scenario concept, which could render part of the story interactive or which the students could use in complement with the presential scenario in an individual timetable.

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Sanderson César Macêdo Barbalho – Integrated Engineering Group – Industrial Engineering Department – University of São Paulo – Av. Trabalhador São Carlense, 400 – São Carlos / SP.

Daniel Capaldo Amaral – Integrated Engineering Group – Industrial Engineering Department – University of São Paulo – Av. Trabalhador São Carlense, 400 – São Carlos / SP.

Henrique Rozenfeld – Integrated Engineering Group – Industrial Engineering Department – University of São Paulo – Av. Trabalhador São Carlense, 400 – São Carlos / SP.