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ASSESSMENT OF STUDENT PREPARATION FOR DISCRETE EVENT SIMULATION COURSES

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ABSTRACT

Over the past years, there has been a growth in simulation courses both at undergraduate and postgraduate levels. A discrete event simulation course, as with any non-basic course, has some prerequisites that must be satisfied by students before attending classes. Statistics, computer programming and modeling are the most important, together with knowledge on the specific field being simulated (manufacturing, logistics, etcetera). Are students sufficiently prepared to follow a course on simulation? This work is related to the construction, application and analysis of an assessment instrument to evaluate student prerequisite knowledge for a discrete event simulation course. The proposed questionnaire was given to the 5th year engineering students at the beginning of our first year (72 hours) discrete event simulation introductory course at Mauá School of Engineering. The results obtained show the importance of making an assessment evaluation in order to improve the quality of simulation learning.

1 INTRODUCTION

The growth of simulation courses both at undergraduate and postgraduate levels has been observed for more than ten years (Jacobson and Morrice 1994). This pattern is caused by the increase of simulation applications in industry and service areas and also by the increase of simulation research in academia. It is interesting to note that a simulation course is not the sole preserve of any one specific department, although it contents should be molded according to the nature of the department running it. Hence discrete event courses are given by departments such as those of Engineering (specially Industrial Engineering), Business Administration and also at Computer Science Departments (see Ståhl, 2000 for a more detailed discussion). Given this, it is clear that the profile of students could vary enormously depending on the department.

How well, then, are they prepared for this interdisciplinary subject ? Sometimes students have great problems especially regarding specific issues. For instance, engineering students tend to demonstrate high skill levels in modeling and statistics but perhaps poor programming abilities. In contrast, computer science students are literate in programming, but may show some deficiency in basic statistics, probability and also in modeling.

In order to ensure that teaching is carried out as best as is possible, it is necessary to identify the weaknesses of students at the very beginning of a simulation course. In this way, it is possible to then take effective action such as giving extra classes, orientation to self-study or other measures. This is crucial because if the basic deficiencies are not corrected, student performance may suffer.

The field of program assessment evaluation in educational environments is developing theories to better analyze several aspects of the institution, and also to provide techniques for measuring student knowledge. The main aim of this paper is to show how such an instrument was constructed, applied and analyzed to assess student knowledge regarding basic prerequisites for a simulation course.

This paper is organized as follows. Section two provides an overview of concepts on program assessment evaluation, including definitions on types of assessment instrument. Section three discusses the basic framework adopted for the evaluation of simulation prerequisites and also the instrument structure (based on this framework). Section four deals with the application methodology, and section five presents a case study showing the results obtained from the developed instrument to a class of almost 90 engineering students in their final year before beginning an introductory discrete event simulation course. Finally, section six summarizes and concludes this study.

2 ON ASSESSMENT PROGRAM EVALUATION

Assessment program evaluation can be understood as the evaluation of any aspect of an institution whose aim to correct or certify processes conducted within it and at several levels of hierarchy. Examples of assessments could be teacher and student evaluation, program and course evaluation and even a meta-evaluation (evaluation of an evaluation).

Although the literature of this field started in the 1950s, this area only saw significant growth during the last decade (Stufflebeam and Webster 1994).

We can broadly classify the type of an assessment into two categories, that is, formative and summative (Gardinier 1994). The former is focused on the improvement of a process while the second provides figures for a decision making process (for example, to approve or to reject). In both cases, any evaluation is only realized by the establishment of an evaluation instrument (Dey and Fenty, 1997), because before evaluating, it is first necessary to measure.

There are three basic types of evaluation instrument:

a) Interviews;
b) Observation;
c) Questionnaires;

Interviews are evaluation instruments in which the evaluator acquires information directly from the person being evaluated by oral means. Observation, as the name implies, presupposes a visual interaction. Questionnaires are classical evaluation instruments and contain, as the names suggests, questions to be answered. These questionnaires could be ‘open-form’ or ‘closed-form’ (Dey and Fenty 1997). The former presupposes questions whose answers are more freely given, and the closed is related to more targeted answers, by providing the person with some alternatives. Tests are classic examples of questionnaires of this kind. For a detailed description of these types of assessment instruments see Dey and Fenty (1997), while Patton (1990) compares modalities of the analysis of several kinds of these.

For this work a closed type questionnaire form was adopted in order to evaluate student prerequisites for a discrete event simulation course. The choice was made mainly because it was intended to be applied to a large population; closed questionnaires are faster to apply and get the results. However, in order not to distort the results and in order to get more subjective data for the evaluation we applied some measures that are more fully explained in section 4.

In the next section we describe the framework which steered the construction of the questionnaires.

3 BASIC FRAMEWORK FOR THE CONSTRUCTION OF THE QUESTIONNAIRE

Step one was to decide about which subjects to include as prerequisites for a first course on simulation. These prerequisites could be classified into two categories: one, technical and two, managerial. For the technical aspect, in our point of view, the basic prerequisites for a simulation course rest on three main aspects:

a) Basic Probability and Statistics
b) Modeling Skills
c) Basic Programming Logic

These subjects are supposed to be covered in previous regular courses offered to students. In the case of Mauá School of Engineering basic probability and statistics is covered by the discipline DFM-204 (Statistics), modeling skills is basically covered by DAP-301 (Operations Research) and basic programming logic is covered by DFM-211 (Computing) and recently also by DAP-311 (Information Systems). They are all one-year long, comprising 72 hours of formal classes (4 hours, weekly). It is worth noting that engineering courses in Brazil have a quite different structure to those in the US, as they are taken from those of the French model. Such courses are five years in length, with a two-year basic level instruction in physics and math, followed by a three-year technical phase. Students decide early on which subject to follow, normally at entrance or when moving from the basic to the technical phase.

Besides the required technical abilities, basic managerial knowledge (a different, somewhat subtle, knowledge that is not formally taught in any previous course) was delivered. This knowledge is of vital importance in communicating properly the results of a simulation model to managers. Clearly it is needed for all professionals in any profession but it can be focused on a specific subject to allow for a reasoned discussion of attitudes. Some knowledge of the general process of modeling and analysis of real world problems also forms part of this. We call this set of knowledge ‘BMK’ (Basic Managerial Knowledge). BMK is clearly better acquired through commonsense and exposure to real experiences and managers, but it is important for students to have a sense of it in order to fully understand all implications of a simulation study. In the case of Mauá School of Engineering, the Discrete Event Simulation Course (DAP-266 Discrete Event Modeling and Simulation), it is given in the final year of the engineering Course (5^{th}) and thus it is expected that some ‘managerial maturity’ exists, derived also from exposure to practical industry that generally begins in the first semester of the 4^{th} year.

Figure 1 depicts the basic knowledge (technical and non-technical) required for attendance at a discrete event simulation course. We called this 'tetrahedral framework', since the basis of the tetrahedron constitutes the basic technical knowledge (objective) and the last vertex the managerial and subjective knowledge for discrete event simulation.

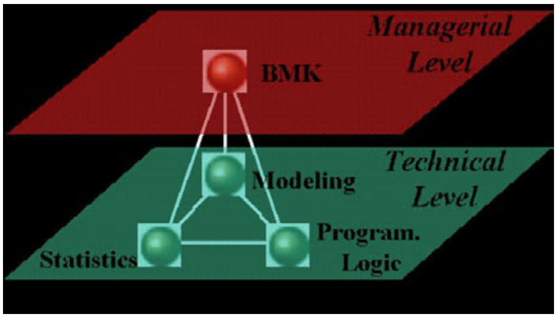

Figure 1: 'Tetrahedral Framework' Prerequisites for Discrete Event Simulation

These different types of knowledge are required in different areas of the simulation modeling process. For instance, modeling capability is required at the conceptual phase of the simulation modeling process; probability and statistics are required at the manipulation stage of the input data and during the analysis phase after the implementation of the model, verification and validation and logic programming is utilized mainly during the implementation phase. BMK is used throughout the process and to communicate simulation results.

Based on this framework, we constructed a closed form questionnaire divided into 4 parts, in which each part corresponds to a vertex of the tetrahedron. The number of questions in each part varies depending on the prerequisites (there are more questions on statistics and modeling than on logic programming and managerial aspects, based on the relevance of issues to simulation) and the total number of questions was 18. It was calculated that the answering process would not take more than 40 minutes. The questionnaire is presented in the Appendix.

The first part (Probability and Statistics) reviews basic knowledge from probability, confidence intervals, queuing theory, normal distribution, and average and standard deviation concepts. The second part tests basic modeling skills, and there are several problem descriptions where the students have to pinpoint their relevant factors. The third part evaluates basic programming logic especially with if-then clauses and finally some questions in the fourth part are designed to evaluate student BMK.

4 APPLICATION METHODOLOGY

The questionnaire shown in the Appendix was given to 84 fifth-year industrial engineering students, who were divided into three groups (approximately 28 each group).

As discussed in section 2, the choice for closed form questionnaires was made mainly according to timing constraints, since this form is easy to apply and analyze. However, it has its shortcomings, namely, that if the student does not know the right answer to the question and chooses at random one of the three alternatives, their chance of success is one in four. This naturally masks the actual results.

In order to minimize this possibility, we emphasize the formative nature of the questionnaire to the students before the application, that is, the results obtained would be used for course improvement and not for punishing them in some way. We therefore asked respondents to write 'I do not know' in the space provided, in case they not know the answer to any particular question. In addition, we strongly encouraged such a response to be used only when the student was not able to answer at all, and stressed that this should not be used as a way of finishing the questionnaire ahead of time and thus as a means of avoiding giving answers. The space provided for each question could also be utilized by the students to add any comments.

Besides these points, we divided each group (more or less 30) into 4 subgroups, and each subgroup had to begin answering the questions in a different order. For instance, subgroup 1 answered in the sequence Part I, Part II, Part III, Part IV, but subgroup 2 had to answer in the sequence Part II, Part III, Part IV and Part I. This was done in order to guarantee that each part would be responded to with the same level of attention and conscientiousness since students (like the rest of us) tend to pay more attention to the first questions and pay less to the final ones due to perhaps either tiredness or boredom.

With these methodological aspects in mind, we then asked students to complete the questionnaire. The results are shown in the next section.

5 RESULTS

As mentioned earlier, the student sample was 84 (divided into 3 group of more or less 28 students on average). The group performance regarding each part is depicted in Figure 2.

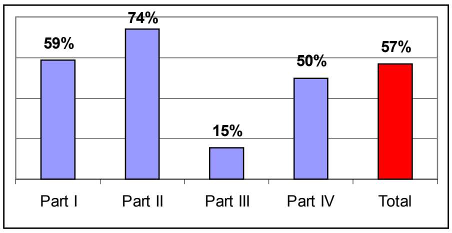

Figure 2: Results for All Class regarding each Part.

As can be seen from the results, the average student performs fairly well on the statistics part (Part I) and very well on modeling aspects (Part II). Somewhat surprisingly, they performed very poorly on logic programming. This data supports the comments of Wiedemann (2000), who notes that engineers have good mathematical knowledge and poor programming experience. Regarding part IV (managerial) the average student obtained results which were below the level that we had expected.

The weaker points of our students at the beginning of our discrete event simulation course were identified and are summarized below:

a) Part I: Notions of confidence interval and the concept of deterministic and stochastic variable
b) Part II: Queuing theory
c) Part III: Every aspect!
d) Part IV: Notions of simulation study time.

6 SUMMARY AND CONCLUSIONS

This work is related to the construction, application and analysis of a questionnaire in order to evaluate student prerequisite knowledge for a discrete event simulation course. The questionnaire was given to 5th-year engineering students at the beginning of our one-year (72 hours) discrete event simulation introductory course (DAP-266 Discrete Event Modeling and Simulation). The construction of the questionnaire was guided by three key areas, that is, the objective, the contents and the application methodology. Regarding the objective, the questionnaire was constructed as a formative instrument aimed at identification and correction or student error rather than punishment. Concerning the contents, the proposed questionnaire follows the basic simulation prerequisites framework (statistics, modeling, programming and some managerial aspects). With regard to application methodology, this was developed in order to better reflect the actual views of the students.

With the results, the teacher and the course coordinator could then think of classroom-based action aimed at correcting student error or could use the identification of the deficiencies in the knowledge of their students to provide additional, complementary knowledge in order to better mold the structure of the simulation course to student need.

In addition, we expect that this questionnaire could be used freely in other universities either to perform the same evaluation process as described here or to compare different results between different courses (engineering, business administration, etcetera). It is interesting to note that it could also be used to evaluate the prerequisites on either an introductory or an advanced discrete event simulation course, since it is focused on the evaluation on basic prerequisites.

More widely, the questionnaire could be used as a testbed to compare the results obtained by different students from different universities. We encourage anyone who can provide us with feedback and comments in order to improve this questionnaire.

For our future work, we intend to continue utilizing a form of assessment always at the very beginning of our simulation courses for pinpointing student's strengths and weaknesses. Since it is the first simulation course, we hope with the aid of this tool we are able to improve our course and minimize students knowledge gaps necessary to a good teaching and learning process.

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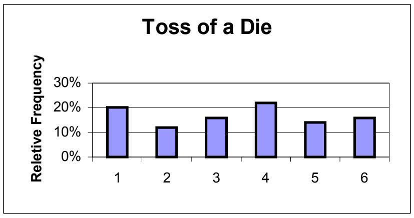
APPENDIX A: QUESTIONNAIRE MODEL

Part I – Probability and Statistics

1. A student showed the following histogram for 50 toss of die:



We could infer that:

a) The die is fair.
b) The die seems to be not fair.
c) A histogram could not represent a toss of a die
d) The sum of the relative frequency is not equal to the number of times the die was tossed.

2. A 99% Confidence Interval means:
a) The values should be between 0 and 99.
b) The value (measured, calculated) is 99% correct
c) With 0.99, the interval contains population's average.
d) With 0.99, the mean value for the population will be not contained within the given interval.

3. In a bank (with only one teller), the interval between successive arrivals is 1 minute and service time is also 1 minute. What is the average length of the queue, considering:
(i) Deterministic (and Constant) times.
(ii) The given times are the average of a negative exponential probability distribution.
a) 0,0
b) 1,1
c) Infinite, infinite
d) 0, undetermined (system becomes unstable)

4. Which probability distribution better represents the heights of people in world?
   a) Uniform
   b) Normal
   c) Exponential (negative)
   d) The heights cannot be represented by a probability distribution.
5. By measuring process times for a machine and an operator, someone obtained the following results (time in seconds):

(i)

121.4	120.4	123.8	123.1
121.9	124.1	121.7	121.9
123.4	122.8	124.6	120.7
121.5	123.1	121.0	122.9
122.9	122.3	123.5	121.6

(ii)

30.9	25.2	30.5	32.2
34.1	9.4	39.0	32.4
42.1	11.1	34.2	22.8
16.8	40.6	34.7	26.0
34.0	26.1	26.4	35.6

However, this person forgot to note which corresponds to machine time and which to operator time. By the data above, we can infer that:
   a) (i) corresponds to machine time, because variance is low.
   b) (ii) corresponds to machine time, because average is low.
   c) None of them corresponds to machine time, because the values are high.
   d) Data is inconsistent. The person made a mistake.
6. For the production of a certain shaft in an automatic lathe machine, the cutting cycle lasts 2 minutes. We can consider that this time:
   a) Follows a normal distribution with 2 minutes average.
   b) Follows a Uniform distribution, with 2 minutes average.
   c) This time could be considered deterministic and thus not stochastic.
   d) Both a) and b) are correct.
7. In the analysis of transporting time between distributions centers of a certain shop, it was found 50 values (in days) for São Paulo- Rio transportation (this time includes also legal papers processing times). With these data, it was constructed confidence intervals A and B, which correspond respectively to 95% confidence and 99% confidence. The person who was in charge of this data confounded the confidence intervals in each case. In a sheet of paper there were the following values:

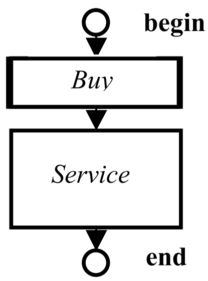
   I1–[1.45; 1.58]
   I2 –[1.42; 1.60]

   Based on the intervals above, we can conclude that:
   a) Interval I1 corresponds to B.
   b) Interval I2 corresponds to B.
   c) There is a need to give the average value in each case to identify which ones correspond to I1 and I2.
   d) It is not possible to verify this correspondence.
8. The time to execute 3 jobs was measured and the values are depicted below:
   A) 5, 5, 5, 5, 5, 5, 5, 5, 5, 5.
   B) 5, 4, 3, 7, 4, 8, 9, 3, 5, 2.
   C) 5, 9, 1, 16, 2, 1, 4, 1, 1, 10.

   In the three cases all samples have the same average value. We can affirm, without performing any calculation, that:
   a) The variance of B is higher than the variance of A and C.
   b) The standard deviation of C is higher than the standard deviation of A and B.
   c) The variance of A is higher than the variance of B and C.
   d) The standard deviation of B and C are approximately equal.

Part II – Representation and Modeling

1. In this supermarket model, there are two services bays and one queue at the service bay. Customers arrive with inter-arrival time of Uniform (1,4) and spend a Normal (6,1) time shopping. Service takes uniform (5,8) time. Customers who on arrival see a queue of more than one person waiting to be served (plus two being served) leave. The objective of the simulation is to calculate the proportion of customers who leave without purchasing anything.



   Having the following aspects:
   A) Queuing to shop at the supermarket.
   B) Queuing at the service bays.
   C) Condition leaving the supermarket if there is a certain number of customers the service queue.
   D) Condition of finding or not the product of interest.

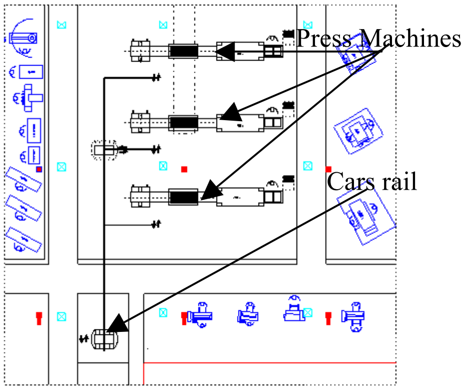
   There is a need to include in the diagram above:
   a) Options B/D
   b) Options B/C
   c) Options A/B
   d) Options C/D

2. Still regarding last question, consider also the following aspects:
   (i) Consumer Types
   (ii) Teller Operation times.
   (iii) Quantity of items that exists at supermarket.
   (iv) Number of customers on service bay queue.

   It is irrelevant to the objectives at hand:
   a) (i), (ii) and (iii)
   b) (i), (iii)
   c) All
   d) None
3. A person wishes to build a simulation model of a Barber Shop. In order to know better how it works, he spent several days observing clients movements, and take note what seemed relevant to him. The objective of the simulation model is to determine the ideal number of barbers in a peek demand day (Saturday), so that the Barber Shop has at maximum 4 customers waiting. Some of his notes is shown below:
   I) Clients have preference on John
   II) If John is busy, 50% of the clients will cut with Tom and 50% waits for John.
   III) The frequency is very heterogeneous: There are children, youngsters and elder people.
   IV) There are barbers that quickly cut the hair (do not do washing) and there are barbers that spend more time cutting.
   V) Barbers always use sterilized materials and the floor is always clean
   VI) Barbers make scales to go lunch.

   Choose the alternative that contains only relevant information for this model building.
   a) I, II, VI
   b) II, III, IV
   c) II, V, VI
   d) I, III, V
4. There is a need to calculate the numbers of automatic cars to feed metallic coils to 3 Press Machines. Feeding must be initiated as soon as the coil finishes. Figure bellows shows this system's layout. The main condition is to always have a car available to feed a press, because it is not allowed to have a press waiting for a car.

   You possess the following data:
   I) Car's average velocity
   II) Operation times for each kind of part
   III) Weight of each kind of coil (in tons).
   IV) Scrap ratio (%) generated by the process
   V) Operators Allocation table for each press
   VI) Mean time between press failures.



   Choose the alternative that contains only relevant information for model building.
   a) I and II
   b) III and IV
   c) V and VII
   d) None
5. In a launderette, customers arrive with an average inter-arrival time of 10 minutes (negatively exponential distributed) to wash and dry their clothes. After arriving, they queue for one of the 7 washing machines, which take exactly 25 minutes to wash a customer's clothes. On completion of washing, the customer unloads the washing machine contents into a basket (if one of the 100 is available) and carries the basket to a dryer. Unloading time is uniformly distributed between 1 and 4 minutes. The time to transport clothes from the washing machine to the dryer is uniformly distributed between 0.1 and 0.2 minutes. Then customers take only 2 minutes to load the clothes to the dryer. Then he waits for the dryer to dry the clothes, unload the drier and leave the launderette. The time for drying and unloading is normally distributed with mean of 7 minutes and 1 minute standard deviation. There are two dryers. A simulation model is going to be built in order to determined average time that a consumer spends in the launderette. It was formulated 3 hypothesis for this problem:

   H1) Since basket's quantity is high, they are not a constraint for the problem and therefore could be eliminated from the model.
   H2) Since clothes washing times is constant, there will never be any waiting for washing clothes and thus this could be eliminated from the model.
   H3) Since clothes transportation times inside the basket is very small (comparing to other times), this process could be eliminated.

   We can consider as plausible hypothesis in order to obtain desired results:
   a) H1 and H2
   b) H2 and H3

c) H1 and H3
d) All of them.

Part III – Logic and Programming

For question 1 and 2, consider that exists the following functions and procedures:

```
r = random(): function that returns a real number
    uniformly distributed between 0 and 1;
E = obtemPrimeiro(Queue): returns the ID of the
    first queue element to be processed;
t  = obtemTempo(Queue, E): return queue waiting
    time for element E;
n = obtemTamanho(Queue): return the current size
    of the queue (in number of elements);
k = obtemTipo(Queue, E): returns the type of ele-
    ment E for the Queue;
elimina  (Queue,  E):  destroy  element  E  on  the
    Queue;
```

1. You were contacted to improve a call center performance of a sales network. There are three kinds of customers. Customers that complain stay on the line for up to 5 minutes, after that they hang-up. Customers who needs information only wait a maximum of 20 seconds and the clients that would like to buy a product stays in the line for maximum 1 minute. The table below shows this situation.

Call	Type #	Time to Hang-up
Complaint	1	5 min
Buy	2	1 min
Information	3	0.33 min

Consider the following codes in *Pascal*, to decide who is the next client to be served.

A)

```
continua := true;
while (continua) and (obtemTamanho(Fila1) >
    0) do
begin
E := obtemPrimeiro(Fila1);
t := obtemTempo(Fila1, E);
k := obtemTipo(Fila1, E) ;
r := random();
if ( k =1) and (t>=5) then elimina(Fila1, E)
else if ( k =2) and (t>=1) then
    elimina(Fila1, E)
else if (k=3) and (t>=0.33) then
    elimina(Fila, E)
else continua := false;
end;
writeln(”Next Client =”, E);
```

B)

```
continua := true;
while (continua) and (obtemTamanho(Fila1) >
    0) do
begin
E := obtemPrimeiro(Fila1);
t := obtemTempo(Fila1, E);
k := obtemTipo(Fila1, E) ;
r := random();
if (k =1) then if (t>=5) then elimina(Fila1,
    E) else continua:=false;
if (k =2) then if (t>=1) then elimina(Fila1,
    E) else continua:=false;
if (k =3) then if (t>=0.33) then
    elimina(Fila1, E) else continua:=false;
end;
writeln(”Next Client =”, E);
```

Which ones represent correctly this process?

a) A/B
b) Only A
c) Only B
d) None of them.

2. Among the pieces that arrive in some processing phase, we have 50% of type “A”, 20% of type “B” and 30% of type “C”. “A” type pieces have processing time of 1 minute, “B” type pieces, 3 minutes and “C” type pieces, 5 minutes. Which codes correctly represents the decision for the piece’s processing times.

A)

```
E:= obtemPrimeiro(Fila2);
s:= obtemNome(Fila2, E);
if s = “A” then t = 1;
if s = “B” then t = 3 else t = 5;
writeln(”Processing Time =”, t);
```

B)

```
E:= obtemPrimeiro(Fila2);
s:= obtemNome(Fila2, E);
r := random();
if r < 0.5 and s = “A” then t = 1;
if r < 0.2 and s = “B” then t = 3;
if r < 0.3 and s = “C” then t = 5;
```

a) Only A
b) Only B
c) Both are correct
e) None of them are correct

Part IV – Managerial Aspects

1. A manager requested from his best engineer a study in order to determine, by means of simulation, if he should buy new equipment for increasing production rates. The engineer should:
   a) Decide how to perform the study and return with a “yes” or “no” answer.
   b) Prepare a questionnaire to be answered by the manager, in order that he specifies confidence intervals, statistical distributions for each process variable and simulation language to use;
   c) Perform 100 runs and present him a table with the values obtained for each run.
   d) All are correct

2. In a simulation study, the keys phases to be performed, in a chronological natural order are:
   a) Model implementation, simulation, report writing
   b) Objectives definition, data mining, modeling, implementation, simulation execution, report writing.
   c) Data Mining, Objects definition, modeling, implementation, simulation execution.
   d) None of the above
3. Your manager asked that you build a simulation model for the problem described at Part II (question 4), in order to determine the optimum coil-feeder cars number needed for the operation. You are also requested to generate results from simulation runs and take pertinent conclusions. Hence:
   a) You promise to give the results next day, early in the morning.
   b) You ask him in 1 weeks time.
   c) You ask him in 2 months time.
   d) You ask him a maximum of 1 day to do the calculations on an Excel Spreadsheet, because simulation in this case is not worth the effort.

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