ABSTRACT

This paper explores software design methodologies in the context of business simulation design and proposes a methodology - the rock pool method that provides structure while maintaining creative freedom.

Developing computer simulations for management development and business education present particular software design problems. On one hand, for computer software development there is a need for a rigorous, structured approach. But, equally, creating simulation models that deliver learning in an effective, efficient and consistent way is a creative process.

The "rock pool" metaphor was chosen because the process can be likened to exploring the rock pools on a beach after the tide has receded. Each rock pool represents a stage in the design process. Within each rock pool there are several design elements (the rocks) but these are not processed in a predefined order and are revisited several times. Although moving between rock pools is systematic, the order the rocks are explored within a rock pool depends on the simulation and the movement between rocks is based on creative needs.

The methodology is explored in the context of the development of a complex entrepreneurial planning simulation (Strategic Exploration of Entrepreneurial Directions (SEED)) for students of science, technology and medicine and other simulations.

INTRODUCTION

General software design methodologies divide into traditional, rigorous methodologies and the more recent "lightweight" or agile methodologies.

Traditional (Highsmith 2002) or "heavyweight" software design methodologies are rigorously structured. They are exemplified by the waterfall method (Brooks, 1995). These methods involve working sequentially through a series of stages at the end of each the stage is approved before moving on to the next stage. In the context of computer simulation the Stairway Methodology (Allwood, 2001) is a rigorous software method (RSM) where there are five main stages (definition, formulation, evaluation, modification and completion) and within each of these there are several steps that are cycled through.

More recently agile (lightweight) methodologies (Poppendieck, 2003) have appeared such as Extreme Programming (XP) (Beck 2000) and Feature Driven Development (FDD) (DeMarco, 1999) where the design process is not rigorously structured. Rather, it is a feedback based process (Anderson, 2003) where the working software is delivered in stages and where the software evolves through frequent refactoring (rework and redesign based on software usage experience to simplify the software). It is argued that this approach is better at dealing with the complex adaptive system of software development (Anderson, 2003). In the context of gaming and simulation design the process is suggested as a spiraling cycle of goal setting, action through technique and interpretation of results (Bizzocchi, 2003). And, Jones (1998) states "Authorship is not sequential. Teachers love aims, but authors love ideas much more. To stipulate that an author should start then follow it by devising parameters is, to my mind, unrealistic and inefficient". But, as this statement is made in the context of students designing and running their own simulations, it is likely that the feedback process inherent in lightweight methodologies is necessary for these naïve designers to learn about the simulation design process.

Anderson (2003) suggest that the choice of software methodology depends on the maturity of the application and whether the project must be delivered holistically or can be delivered incrementally. Anderson shows these in a two by two grid (Figure 1)

<table>
<thead>
<tr>
<th>Holistic Delivery</th>
<th>Immature</th>
<th>Mature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agile Process</td>
<td>RSM Process</td>
<td></td>
</tr>
<tr>
<td>Partitioned Delivery</td>
<td>Lightweight Agile Process</td>
<td>Either Agile or RSM</td>
</tr>
</tbody>
</table>

Figure 1: Maturity/Delivery Matrix
their nature, business simulations are immature products where each new simulation may require a considerable innovation. (Where innovation is necessary because of continuing technological change, changes in the use of technology for education, changing business processes and structures and widening application of simulation). But in terms of the delivery dimension, it is not usually possible to deliver a new simulation in stages. Thus computer business simulations fall into the top left-hand corner of the matrix, where Anderson suggests that agile methods are most appropriate as these utilize feedback to handle the immaturity of problem specification.

This paper suggests a middle road where, at a macro level the design process is a rigorous software methodology but at a micro level it is agile. The Rock Pool Method combines both heavy and lightweight methodology using a rigorous structure where the simulation is developed through several major stages (rock pools) but within each rock pool development is unstructured and agile. Experience developing several simulations suggests that the agile, lightweight approach within a rock pool is appropriate to the immature (creative) nature of simulation design. And the rigorous structure imposed by the rock pools ensures that a sound simulation is developed.

The Rock Pool Design Method metaphorically proposes that the design process is one that involves moving progressively and sequentially between rock pools where each rock pool represents a major design stage. And where, within each rock pool, there are several design elements, each represented in the metaphor by a rock. At an individual rock pool stage, reflecting the intrinsically creative nature of computer simulation design, design is not a sequential process and does not have a defined starting point. Rather, depending on the simulation, its purpose and the designer, a rock pool development stage can start with any rock. As the development progresses the designer moves between rocks revisiting each several times. When a rock pool’s design tasks are complete, the designer moves on to the next rock pool.

DEFINITION

The "need definition" rock pool consists of four elements:

a. Specifying the Target Audience(s)
b. Defining Learning Objectives
c. Settling Duration
d. Defining Manner of Use

For participants the following are important:

Range of prior knowledge and experience
Diversity of prior knowledge and experience
Maturity and expectations

Knowledge of the range of prior knowledge and experience provides a basis to assess the need for participant and tutoring support. The diversity of knowledge and experience shows the extent to which prior participants can share knowledge and act as a learning resource. Maturity and expectations indicates the extent to which participants can handle the pressures of the activity, ambiguity and uncertainty. Thus range and diversity of prior knowledge and experience define cognitive support needs and maturity and expectations define affective support needs.

For the Strategic Exploration of Entrepreneurial Directions (SEED) simulation, the target audiences were university students, business people who are considering starting their own business and as a role reversal exercise for bankers and tax officers. As the prime student group would be studying science, technology and medicine rather than business the simulation would need to build in comprehensive knowledge support and help them handle the ambiguity and uncertainty associated with entrepreneurship. Further, their lack of world experience may make them uncomfortable with this form of learning (Knowles, 1998)

1. THE FIRST ROCK POOL - NEEDS

The rock pool method involves progressively moving from one to the next of the following rock pools:

1. Needs Definition
2. Simulation Specification
3. Simulation Design
4. Simulator Development
5. Simulation Validation
6. Finalize Design

And, these define the structured and sequential elements of the method.
parallel running (where the tutor runs the simulation in partnered with an experienced used).

b. Defining Learning Objectives is a wider definition than just defining learning (knowledge acquisition or even skill development) needs. Hall (1996) uses a five dimensional model:

- Knowledge Exploration
- Skill Development & Practice
- Motivation/Behavioral Needs
- Assessment
- Enhancing Learning

For the SEED simulation, the knowledge to be explored was that associated with planning an entrepreneurial start-up company (the entrepreneurial ideal) and developing entrepreneurial skills (analysis, decision-making, etc.). Motivational needs included “enhancing the entrepreneurial culture” and providing a learning activity that was engaging and fun. Although, the simulation would not be formally examined, on an informal basis participants should be able to assess their current levels of business knowledge and use this to decide personal development plans.

c. Setting Duration involves deciding the amount of time that can be budgeted for the simulation. After deliberation, the duration for the SEED simulation was to be one day (six hours). As complexity is highly correlated with duration (Hall & Cox, 1994) this would limit the number of decisions and the size of the simulation model.

d. Defining Manner of Use involves defining the way that the simulation would be used and Hall (1996) suggested the following taxonomy of use (Figure 2):

- As a course element
  1. Course Finale
  2. Course Starter (Icebreaker)
  3. Course Theme
  4. To Reinforce a Topic
  5. As a "Break"
  6. Standalone
  7. Stand-alone Seminar
  8. Distance/Spare Time Learning
  9. On an Assessment/Development Center
  10. At Business/Company Conference
  11. As a Promotional Contest

Figure 2: Manner of Simulation Use

For the SEED simulation, for Imperial students, it would be run as a series of stand-alone seminars. But, for prospective entrepreneurs, reflecting their situation it may be run as a distance/spare time learning activity or as a course finale.

Development sequence

These elements are not progressed in any predefined sequence nor is there any definite starting point. Rather, different simulation designs start from different starting points and progress, recursively, between the other rocks in this rock pool.

The SEED simulation's starting point was specifying the Target Audiences - university students and business people whom are considering starting their own business. But the development of other simulations involved other starting points. The designs of Financial Analysis (1985) and SMART (1987) both had their starting points the Definition of Learning Objectives. Product Launch (1977) and Executive Ladders (1993) both had Duration as the design starting point. The Challenge Series (Management (1986), Retail (1987) and Service (1989)) were developed for use as part of an international promotional contest and so had Manner of Use as their starting points.

Generally, after defining the first rock to visit the others are visited immediately. For instance, for the Challenge Series, immediately after defining the Manner of Use the duration was settled. Also, this stage involves moving between and revisiting elements. For the SEED simulation, the duration was initially to be one & a half days but later reduced to one day (6 hours). This required revisiting the learning objectives (but equally might have meant redefining the manner of use). Also, while defining needs, account was taken that the SEED simulation might be used with prospective entrepreneurs, on a distance learning basis, and, perhaps as a management contest.

Stage outcomes

At the end of this stage there is a need to examine how the elements relate to each other and resolve any conflicts. For instance, the target audience coupled with learning objectives for the SEED simulation meant that its scope would stretch the knowledge base of the participants. Because of this, it would be necessary to build in significant participant support (in the form of business advice). Further, the short duration (a day) coupled with the Learning Objectives would cause a major development problem. And, this was amplified by the fact that the simulation would be run in a single, undivided session. (If the simulation had be spread, in separate sessions over several weeks, the participants would have the opportunity to reflect and, possibly, budget extra time.)

2. THE SECOND ROCK POOL - SIMULATION SPECIFICATION

This rock pool consists of these elements:

- a. Define issues
- b. Decide simulator type
- c. Decide Delivery mode
- d. Decide version(s)
- e. Decide business scenario

- a. Defining issues involves translating the learning objectives into business oriented issues that are appropriate to the target audience. For the SEED simulation the issues
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included market selection, pricing, promotion, working capital and venture funding. The issues define the discussion areas for the team and hence the areas where deep cognitive processing occurs.

b. Deciding simulator type involves deciding the structural aspects of the simulation. Biggs (1990) suggested one way of classifying business simulations was total enterprise and functional. Where total enterprise simulations attempt to replicate a whole business. In contrast functional simulations replicate in detail a particular function (such as marketing or operations).

Hall (1996) expanded on this with a taxonomy of model based simulations (Figure 3).

1. Total Enterprise Simulations
2. Functional Simulations
3. Concepts Simulations
4. Planning Simulations
5. Analysis Simulations
6. Computer Enhanced Role-plays

**Figure 3: Simulation Taxonomy**

Concepts simulations are short simulations that address one or a very limited range of business concepts (such as the Product Life Cycle). These simulations involve progressing through several simulated time-periods but there are other processes. Planning simulations generally involve using the simulation model to investigate several "What-If" scenarios and determining the "best". Analysis simulations involve performing a series of analyses (on sales or inventory data etc.). Based on this analysis participants recommend and defend business policies or forecasts. Computer enhanced role-plays utilize simulation models and databases to support the negotiating parties.

Initially, it was felt that the SEED simulation was a planning simulation where participants would utilize a what-if model to determine the best plan. But beside the need to perform What-If analyses, it was necessary for the participants to experience the planning process and especially the time taken to develop a business plan. This meant that participants were only allowed to make a limited number of analyses before a simulated month passed. In turn, this meant that participants had to balance the risk of an incomplete and inadequate plan against being "fast to market" - a situation that was magnified by the seasonal nature of the market and the need to become established before the seasonal peak.

c. Decide Delivery mode involves who uses the simulator. Elgood (1997) and Biggs (1990) divide delivery modes for computer simulation into those where the trainer rather than the participants use the hardware and where it is used directly by the participants rather than the trainer. Total enterprise simulations tend to involve all teams competing in the same marketplace and this means that the same simulation model must process the decisions from all the teams and so it is the trainer who uses the computer hardware Biggs (1990). In contrast, for simulations such a Product Launch (1977), Sales Calls (1983) and Operations (1983) the competitive aspect of the marketplace is simulated by the model and the hardware is used directly by the participants.

As the SEED simulation addresses planning issues it is non-competitive between teams and it is fitting for each team to make direct use of the simulator. Also, as the teams can work asynchronously, this shortens the simulation's duration. However, set against this is the fact that direct use of the simulation can change team behavior (Coote, 1985) and the software must be designed to minimize this risk (Hall, 1995).

d. Decide version(s) involves deciding the versions the simulation will have. For instance, the Management, Service and Retail Challenge simulations were originally designed for use in a managerial contest. But they were developed assuming that they could also be used on business & financial appreciation courses, on assessment & development centers, stand-alone, as a course finale and as a course theme. This range of use helps define the decisions and reports provided by the simulation.

For SEED, the different target audiences and manner of use conjoined and so it was decided to create a single version. (If different uses were desirable then several versions would have to be developed ranging from basic (for the contest) through more complex versions with additional decisions and reports.) However, it may be that at a future time, versions will be created with different tax structures and in different languages.

e. Deciding the business scenario involves deciding the industry to be simulated (Teach, 1990). Often the type of organization that will be using the simulation predetermines this and this was the case for CISCO (1988), Casino Challenge (1990) and Profess (1998). (Where CISCO addressed the issues facing construction companies; Casino Challenge the issues facing casino management and Profess the issues facing the sales management of a financial services company.)

But, for the SEED simulation, although the target audience did not predefine the business scenario, there were several factors that made the choice important. First, because of the age of the target participants, it was necessary for the simulation to be engaging and the product or service should be "real". But because of its entrepreneurial nature the product could not be an existing product. It must be a product that might exist because of market needs but does not because of technological or economic factors. Taking into account prior knowledge & experience, it needed to be a relatively simple business in marketing, operational and financial terms. That is to say the market structure and marketing mix should be simple and manufacture should consist of a single process with few component materials. Also, it should take into account the scientific and engineering background of the participants and the product should be high tech and thoroughly modern! The product chosen was a soft toy (like a teddy bear)
incorporating electronics to link it to a normal home PC and allow it to communicate with a small child (aged between two and five). It would be used as a companion for the child and, via the PC, provide early learning. Reflecting its high-tech aspect the product is the Cuddl-Etoy! The scenario explained that the Cuddle-Etoy was developed after a failed University project (where the toy was developed as a collaborative project involving maths, engineering and medical students as an aid to diagnosis for very young children). A project that failed because of difficulty with sterilization and the screaming fits when the child had to give up the toy after the diagnosis session! At the second pilot we illustrated the product with several real cuddly toys. Immediately on arrival, two female students annexed these, but since they were destined for a member of the academic staff they had to be retrieved.

**Development sequence**

Again, there is no defined starting "rock" in this rock pool. For the SEED simulation the starting point was defining the scenario. In contrast, the starting point for the development of Financial Analysis (1985) was to define the issues that had to be considered when making a business plan and the scenario was of minor importance. Equally, manner of use may mean that the starting point is deciding the simulator type. For instance, as the Challenge Series (1986, 1987, & 1989) was developed as part of a management contest the simulation had to be competitive with the decisions of one team interacting with the others and where business issues secondary and the business scenarios of no importance.

**Stage outcomes**

At the end of this stage the key structure of the simulation is defined and specified. This may be used to search for and select a suitable existing simulation or as the basis of the development of a new simulation (as was the case with the SEED simulation).

### Marketing Plan

<table>
<thead>
<tr>
<th></th>
<th>Plan 1</th>
<th>Plan 2</th>
<th>Plan 3</th>
<th>Plan 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Market Served</strong></td>
<td>Learning</td>
<td>Learning</td>
<td>Companion</td>
<td>Autistic</td>
</tr>
<tr>
<td><strong>Launch Month</strong></td>
<td>July</td>
<td>July</td>
<td>July</td>
<td>July</td>
</tr>
<tr>
<td><strong>Number in Range</strong></td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><strong>Sell to Retailers</strong></td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Web Site</strong></td>
<td>Full</td>
<td>Full</td>
<td>Full</td>
<td>Full</td>
</tr>
<tr>
<td><strong>Web Price</strong></td>
<td>64.99</td>
<td>64.99</td>
<td>64.99</td>
<td>64.99</td>
</tr>
<tr>
<td><strong>Recommended Retail Price</strong></td>
<td>64.99</td>
<td>0.00</td>
<td>64.99</td>
<td>64.99</td>
</tr>
<tr>
<td><strong>Price to Outlets</strong></td>
<td>44.99</td>
<td>0.00</td>
<td>44.99</td>
<td>44.99</td>
</tr>
<tr>
<td><strong>Advertising Spend</strong></td>
<td>5000</td>
<td>5000</td>
<td>5000</td>
<td>5000</td>
</tr>
<tr>
<td><strong>Public Relations</strong></td>
<td>Both</td>
<td>Launch</td>
<td>Both</td>
<td>Both</td>
</tr>
<tr>
<td><strong>Enhanced Web Site</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Point of Sale Display</strong></td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Packaging</strong></td>
<td>Fancy</td>
<td>Plain</td>
<td>Fancy</td>
<td>Fancy</td>
</tr>
</tbody>
</table>

|                      |        |        |        |        |
| **Table 1: Sample Marketing Decisions**
b. **Decide Results** involves determining what results are produced by the simulation model and these can be divided into the categories:
- I. Results for the participants
- II. Results to reconcile results
- III. Results that comment on team performance
- IV. Results that explain the model
- V. Results that validate models

Participant Results are those that will be provided to the participants as the simulation progresses. Reconciliation Results are those that can be used if necessary to help answer participant questions about accounting and operational models. The comments provide feedback that is not quantitative and exact but is qualitative and fuzzy. The model explanation reveals to the designer and the tutor how the model is responding to decisions such as price and promotion. The validation results are provided (during the design stage) to help the simulation designer explore model behavior and these are expanded on later (3d).

b. **Create models linking decisions & results** involves developing the logic and algorithms that link the decisions and results and defining the data associated with these.

\[
\text{Decisions} \Rightarrow \text{Model} \Rightarrow \text{Results} \\
\text{Data} \Rightarrow \text{Model} \Rightarrow \text{Results}
\]

Figure 4: Linking decisions and results

At this stage the model algorithms are researched and described and if necessary **prototyped** on a spreadsheet. As the SEED simulation was complex several models were prototyped (Figure 5)

<table>
<thead>
<tr>
<th>Innovation Diffusion Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outlet Penetration Model</td>
</tr>
<tr>
<td>Price/Margin Sensitivity</td>
</tr>
<tr>
<td>Production Cost/Investment</td>
</tr>
<tr>
<td>Production Volume/Cost Analysis</td>
</tr>
<tr>
<td>Office Investment</td>
</tr>
<tr>
<td>Selling Method Analysis</td>
</tr>
</tbody>
</table>

Figure 5: Prototyped Models

c. **Create validation & quality assurance support** involves creating routines and reports that reveal explicitly how the models work. With SEED, translating marketplace decisions into sales demand was very complex with multiple interacting factors that affected demand. Thus, as part of the validation and quality assurance process the individual market responses were captured and were made available in a report. A second example, was the reconciliation of creditor changes. Some of the reports used during the design process to **drill down** into the model are shown in Figure 6.

Figure 6: Reports to check and explain results

Table 2 details the Outlet Sales Audit showing how sales, number of outlets, etc. developed over time (taking into account seasonality and penetration).

d. **Developing preliminary documentation** involves recording and describing the decisions, results and models. This may take place before, concurrently or after particular decisions, results and models have been designed. The documentation separates into three parts - the participants' brief, the trainer's manual and online help. If a predefined shell program had not been used a fourth document describing the technical aspects of the software would need to be developed. Also, if appropriate, for inexperienced trainers and academics it might be necessary to produce a document discussing the classroom aspects of running the simulation. Again, for SEED this document existed.

<table>
<thead>
<tr>
<th>Outlet Sales Audit</th>
</tr>
</thead>
<tbody>
<tr>
<td>July</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>Unit Sales (outlets)</td>
</tr>
<tr>
<td>Number of Outlets</td>
</tr>
<tr>
<td>Sales per Outlet</td>
</tr>
<tr>
<td>Sales Revenue</td>
</tr>
<tr>
<td>New Outlets</td>
</tr>
<tr>
<td>Initial Sales</td>
</tr>
<tr>
<td>Repeat Sales</td>
</tr>
</tbody>
</table>

Table 2: Example of design audit report
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I. Participants’ Brief
II. Trainer’s Manual
III. Online Help
IV. (Using the Software)
V. (Using Simulations)

Figure 7: Documentation Needs

In parallel to the development of the online help system the participants’ brief and the trainer’s manual were drafted. The participant’s brief is the document provided to the participants to read and become familiar with before starting to use the simulation. The trainers’ manual is for the trainers to help them understand the simulation and the learning derived from it. Additionally, at this stage, the trainer’s manual serves to document the design and both are drafts and focus mainly on the decisions, results and the model.

Development sequence

In this rock pool, reflecting the level of creativity, movement between the rocks (elements) was very complex as the decisions; results and models were refined and refactored. For instance, the first design work involved the marketplace models. But the complexity and dynamics of these meant that these were also the last to be completed. Effectively, this pool does not comprise a few large rocks but consists of several piles of weed encrusted stones with a large number of agile and elusive creatures darting between them! For the SEED simulation the starting point for a cycle tended to be defining a decision or group of decisions, deciding on how they interacted and produced results and then defining the result set. However, in contrast, for the Financial Analysis planning simulation the starting point was to define what results were to be produced and only then the decisions that impacted these. And, for the DISTRAIN (2004) simulation the issues (2a) were used to design the models and then the results and decisions were determined.

Stage outcomes

At the end of this stage an alpha test version of the simulation exists ready to refined by the next stage into the beta test version. At this stage, the documentation’s purpose is to support the designer rather than for use by the participants and the tutors. Thus, later, it must be modified and refined to be of use to the participants and the tutors.

4. THE FOURTH ROCK POOL - SIMULATOR DEVELOPMENT

This rock pool consists of these elements:

- a. Testing models
- b. Calibrate models
- c. Ramp workload
- d. Create learning & tutoring support
- e. Refine documentation

This rock pool brings the simulation to the beta test stage

a. Testing models involves ensuring that algorithmic logic and program code are correct. If logic (the algorithms) are incorrect the simulation will lack face validity (Woolfe, 1989) and this will affect learning (Teach, 1990). And if the simulation is incorrectly coded results will be calculated incorrectly and, even worst, the software may crash. Biggs and Halpen (2004) arguing a counter view about the utility of BUGS (defined by them as Basic Unplanned Glitch Situations) provide a taxonomy of problem areas.

The quality and validation support (3c) help with this process but for a complex simulation it is often necessary to develop a series of spreadsheets to reconcile results. And, for financial validity, the Balance Sheet must balance and this tests the accounting models.

b. Calibrating models involves ensuring the realism of outcomes and balancing results. In particular the balance between the ability to generate profits (profitability) and cash flow (survival) is crucial. Also, for SEED it was important that no particular plan was obviously the best. This was both to ensure adequate discussion and to ensure that the teams had to face the problem of deciding when they should choose which plan they were to go with.

c. Ramping workload involves increasing the number of decision areas or reports produced as the simulation progresses thus reducing the risk of role overload (French, 1972) in the early stages of the simulation. Teach (1990) discusses the same problem in terms of "analysis paralysis". And Hall (2004) suggests that by ramping the complexity as the simulation progresses not only is the risk of role overload diminished but learning is enhanced as the additional reports and decisions "stimulate discussion and provide the opportunities for additional cognitive development". For the original pilot of the SEED simulation workload was not ramped and, as described later, this caused role overload.

d. Creating learning & tutoring support involves defining reports, help texts and decision screens that provide information to reconcile the results, advice & explanations, knowledge support (for tasks) and identification of strengths, weaknesses and possible problems.

The standard shell used for SEED provided a full online help system with using the software, the current task, definitions of terminology and an online manual. Software help already existed but help with the current task, definitions and the online manual had to be developed as a context sensitive, hypertext database. Much of the data in the database could be copied from the draft participants’ brief and background notes. But, reflecting the difference between print media and screen display, the data was edited and abstracted.

e. Refining documentation involves taking the draft documentation created in stage 3d and editing it to improve clarity, remove omissions and incorporate the parameters determined during calibration (4b). And, now the major
development work is complete, it is appropriate to develop a Power Point brief.

Development sequence
This rock pool is closely associated with the simulation design and generally involves some movement between the two. For instance as the models are calibrated they may need to be modified. Also, as happened with the previous stages there was movement between the rocks in this rock pool. In particular, creation of learning and tutoring support was closely linked with refining the documentation. Also, as the models were tested it becomes apparent where both the online help system and the printed documentation needs to be clarified and expanded. Finally, testing and calibration are linked.

Stage outcomes
At the end of this stage the simulation has reached the beta test stage and is ready for piloting (testing with real people) and the authentication of learning.

5. THE FIFTH ROCK POOL - SIMULATION VALIDATION

This rock pool consists of these elements:

a. Pilot simulation
b. Refine and modify the simulator
c. Refine and modify documentation
d. Authentication

a. Pilot simulation involving testing the simulation with a group of forgiving participants or trainers. The SEED simulation had two main pilots with several groups of students. Piloting not only tested the robustness of the models and code and how the simulation delivered learning but also tested process aspects - workload, behavior and usability.

Although it was realistic to allow participants access to the full set of decisions from the start, on the first pilot this caused role overload (French, 1972). As this risk was considered when setting duration (1c) and again when ramping complexity (4c) we were ready to introduce the decisions in stages and this was done for second pilot.

Checking the behavioral aspects of the direct use of the simulation by the participants (Coote, 1985) was identified as a possible problem earlier when deciding the delivery mode (2c), but it did not cause problems.

b. Refine and modify the simulator involves taking feedback from the pilot and correcting logic and code errors.

c. Refine and modify documentation involves checking the completeness of all documentation (participants' brief, trainer's manual and the online help). For the participants' brief this involves improving clarity and this may mean adding to the manual or subtracting from it. Experience suggests that the design of the participants' brief is a balance between completeness and length. For, if the brief is too long it will not be read! Because there is an online help system there is the choice between adding to the paper document or to the online help or both.

d. Authentication involves obtaining the views of the participants, subject matter experts (SMEs), academics and trainers and teachers. For SEED feedback from the participants was through a questionnaire.

Development sequence
Unlike the previous rock pools where there are no defined sequences, this stage involves a repeating cycle of piloting and modification until the simulation authentically meets the needs and issues defined in the first and second "rock pools".

Stage outcomes
At the end of this stage a fully operating simulation exists and all that remains is packaging and dissemination.

7. THE SIXTH ROCK POOL - FINALIZATION

This rock pool consists of these elements:

a. Finalize documentation (participant & tutoring)
b. Finalize tutoring support
c. Dissemination

d. Authentication

a. Finalize documentation (participant & tutoring) involves editing the documentation to improve accessibility (readability, spelling, layout etc.) and incorporate the changes made during the validation stage.

b. Finalize tutoring support involves the final completion of the software. For instance, after the pilot of the DISTRAIN simulation, the reports for the trainers and the participants were modified to match the requirements of the people who were to run the simulation.

<table>
<thead>
<tr>
<th>Month</th>
<th>Planning Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>Business Research &amp; Policy Advice</td>
</tr>
<tr>
<td>February</td>
<td>As January plus Marketing decisions</td>
</tr>
<tr>
<td>March</td>
<td>As February plus Resourcing &amp; Working Capital decisions</td>
</tr>
<tr>
<td>April onwards</td>
<td>All decisions</td>
</tr>
</tbody>
</table>

Figure 8: Phased introduction of decisions and results
d. **Dissemination** to organizations, to trainers, to students (participants) and via the academic community involves writing papers (such as this), press releases, printed and electronic materials (such as a website) etc.

**Development sequence**

Again there is no defined sequence between these tasks and very often the finalized documentation and tutoring support use the same textual and graphic data in a different form. Further, for SEED some of the graphics from the PowerPoint briefing and the online help system were used on the website.

**Stage outcomes**

A complete simulation package.

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**CONCLUSIONS**

Anderson (2003) uses the Lapre and Van Wassenhove Project Matrix (2002) to suggest that the choice of appropriate software methodology depends on the degree of *Operational Learning* (experience "know-how") and degree of *Conceptual Learning* (cause and effect understanding). Where each of these rank from low to high (Figure 10).

<table>
<thead>
<tr>
<th>Conceptual Learning</th>
<th>Operational Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>fire fighting</td>
</tr>
<tr>
<td>High</td>
<td>artisan skills</td>
</tr>
<tr>
<td></td>
<td>unvalidated theories</td>
</tr>
<tr>
<td></td>
<td>operationally valid</td>
</tr>
<tr>
<td></td>
<td>theories</td>
</tr>
</tbody>
</table>

**Figure 10: Lapre and Van Wassenhove Project Matrix**

In the context of computer simulation design, the Operational Learning dimension relates to design experience. Here low Operational Learning is where the designer or designers have no or little experience of simulation design and high Operational Learning is where the designer has developed several simulations and has researched simulation design. And, the Conceptual Learning dimension relates to the *difficulty* of the current design where Design Difficulty is a combination of simulation complexity and novelty. The measurement of simulation complexity has been explored in several papers (Wolfe 1978; Pray and Gold 1982; Gold and Pray 1984) that link it to the number of decisions and software size (model size). Simulation *novelty* depends on the degree of innovation in simulation structure and the situation (industry) modeled. Two simulations illustrate this. In model terms and industry modeled, Financial Analysis (1985) is simple but the structure of the simulation was an innovation for the designer. In contrast, Foundation Challenge (2002) has intermediate complexity and a standard structure, but as it models a not-for-profit organization it was an innovation for the designer. These two examples also illustrate that the novelty level depends on the experience and knowledge of the designer and hence the amount of conceptual learning required. For the SEED simulation, the model was complex and the structure necessary to enable a complex simulation to have a short duration had high novelty.

The choice of the appropriate simulation software methodology depends on the complexity & novelty of the simulation and the experience of the developers as shown in Figure 11.

**Figure 11: The Project Matrix (modified for simulation design)**

One suggests that for simple simulations involving a few decisions and a simple simulation model a rigorous method such as the Stairway method is appropriate and desirable. Because one aspect of design difficulty is due to the *novelty* of the design to the designer, where the designers have no design experience the simulation defaults to highly novel. For this situation, a lightweight method is the most appropriate as it allows the designers to learn experientially as the simulation is created. For the situation where the simulation is novel or complex but the designer has considerable design experience the Rock Pool Method balances the rigor of structure with the creativity and flexibility necessary to learn to deal with the novelty or complexity of the simulation.

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Randolph, W. Allan and Posner, Barry Z. (1979) "Consideration in the Design of Learning Situations" Journal of Experiential Learning and Simulation 1


Wolfe, J. (1978) "The effect of game complexity on the acquisition of business policy knowledge" Decision Sciences 9(1)

The table referencing the simulations shows both complexity and novelty. Where complexity is the size of the simulation model and novelty indicates the degree to which the simulation incorporates novel features and structures. So although Management Challenge is of intermediate complexity and has a very standard generic industry model and so has low novelty. In contrast, Foundation Challenge also has a similarly intermediately complex model but replicates a novel industry. The Executive Ladders model is very simple but the simulation is very novel as it only lasts two minutes! The SEED - Entrepreneurial Planning simulation not only has a very complex simulation model but is novel because of the structure to ensure that the six hour duration is realizable.