Factors for Vertically Scalable Learner Levels of Sharable e-Content Objects

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Abstract: **Content development for e-mode of delivery systems must be specific to particular learner levels, such as: whether the learner is of the level of Diploma (lower) or Degree (middle) or Post Graduate (higher) etc. In view of developing content deliverables that are specific to levels of the e-learners, scalability would become an important criterion so that the developers could reduce their efforts through partly reusing the existing system modules. Scalability is the ability of a system, or process to handle a growing amount of work in a capable manner or its ability to be enlarged to accommodate that growth. This paper focuses on how to deliver a scalable, flexible, and yet cost-effective e-content for three different but vertically upward leaner levels namely Diploma (lower level), Degree (middle level) and Post Graduate (PG) (Higher level) of Computer Application subject content. It is proposed to introduce a base e-content object, which is recommended to be of small and reusable in nature. This base content should be editable for different learner levels for future requirements so as to make it feasible for upward vertical scaling. Even though literature on scalability of e-learning systems (for expansion to a growing number of users for the future) is available already, study on scalability for e-content that would be used by different learner levels are rarely seen. The analysis for scalability is limited to components such as file sizes and media specific data that influence developmental efforts of the e-content for the future. Certain scaling factors on these chosen components for the three delimited learner levels have been evolved through experiments. The paper demonstrates the importance of these scaling factors which would indicate whether or not the base content might become feasible to scale up vertically for higher learner levels.**

Key words: E-content; Sharable Content; Scaling factors; Learner Levels; Cognitive Structures

I. INTRODUCTION AND BACKGROUND

The benefit of e-learning is the accessibility of e-content from anywhere at any time. But e-learning might not cater for same learning styles [1], when learner levels depend on delivery styles. Another major limitation of e-course development is creating monolith digital repositories without data exchange format [2]. These issues can be dealt with through introducing reusable learning objects. Learning objects called Sharable Content Objects (SCO) can be developed in forms of independent units that can exist per se like an atom or in combination with many other entities to give a well defined meaning. For specific e-learner characteristic, personalized digital repositories or libraries from a collection of modules (SCOs) can be combined and delivered. The pedagogical instructional role when embedded in the learning objects (SCOs) would significantly contribute to the learning context [3] or in other words, to specific learner levels. It is therefore pertinent that SCOs for specific learner levels need to be explicitly designed, developed and deployed in terms of repositories as e-contents, for efficient retrieval. The paper attempts to demonstrate three vertical hierarchical learner levels, namely Diploma (lower level), Degree (middle level) and Post Graduate (PG – higher level e-learners) levels that can be represented with independent SCOs. But at the same time, designing and developing independent SCOs for these three levels would be costly and un-necessary for similar or same subject contents. However, the anticipated changes in the respective e-content might be marginal for same or similar subject contents for these levels, but the presentation styles might only slightly be different from each one. Scalability is the ability of a system to be enlarged to a new system. To determine whether the efforts needed to develop new or scaled up existing SCOs, for vertically (upwardly) higher levels of learners would be a worthwhile study, through research and hence forms the background of this paper.

A scale factor normally is a rational decimal number that is used for scaling some quantity. In the equation $y = S.x$, where S is the scale factor for x. S is also the coefficient of x, and may be called the constant of y to x. The ratio of any two corresponding values in two similar situations is called a Scale Factor. Scaling factors (or scale factor, which is synonymously used in this paper) are helpful in identifying unknown dimensions [9]. The paper attempts to demonstrate the arrival of such scaling factors for the three chosen learner levels which are obtained through experimental studies. The factors thus developed would be of immense use to new SCO developers of similar or same subject e-content for vertically upward learner levels.

II. DESIGN AND DEVELOPMENT OF SCO

‘Learning object’ cannot yet be correctly defined and it remains an ill-defined concept, despite numerous and extensive discussion in the literature [5]. Generally, a learning object could be defined as a pedagogical resource (including tools) such as the term ‘SCO’ used in this paper. It is however, but not limiting to i) Small (relative to the size of a full course) instructional component that can be reused a number of times in different learning contexts (say for different learner levels); and ii) Digital entity deliverable over the internet (which can be editable or scalable). Instruction through learning objects may represent some kind of compromise between the content-centered "learning object approach" and more activity/scenario/cognitive tool-oriented approach [8]. Learning that usually distinguishes between resources (of various sorts), services (tools) and learning activities (scenarios) is considered as the building blocks for e-Learning SCOs. In view of the above, we have considered Merrill’s approach of an instructional episode as it is particularly suited well to problem based independent learning contents [7]. As most of the ICT educational content is problem-based, Merrill’s theory is best suited for it [6]. It is deliberated in literature that cognitive structures (quantifiable portrayals of learning abilities) would be of immense use for the developments of SCOs. Therefore the cognitive structures of First Principles of Instruction (FPI) of the Merrill’s theory have been chosen for the design of the proposed SCOs of this paper. Quantifying cognitive structures of existing curricular materials of e-content [4] have indicated the effectiveness of these cognitive structures, when used as a base for similar e-content developments.

The FPI divides any instructional event into four phases, which are called: ‘Activation’, ‘Demonstration’, ‘Application’ and ‘Integration’. Central to this instructional model is a real-time problem-solving theme, called ‘Problem’. Merrill [6] suggests that fundamental principles of instructional design should be relied on and these apply regardless of any instructional design model used. Violating this would produce a decrement in learning and performance. As the four Cognitive structures listed above are quantifiable, definable and of independent entities, they are used as the foundation for the development of e-content. The four chosen Cognitive structures for the arrival of scaling factors are presented below.

A. Activation:

This is the first Cognitive Structure in the learning process. New knowledge builds on the learner’s existing knowledge. Learners recall or apply knowledge from relevant past experience as a foundation for new knowledge. This could be from previous courses or job experiences undergone by the learner. For instance, recall the old relevant information of topics(s) that are needed for understanding current topic. The importance of activation of existing knowledge has been addressed by a number of educational psychologists. During FPI’s Activation phase, prior knowledge (or experience) is recalled and emotions are triggered.

B. Demonstration:

New knowledge is demonstrated to the learner. Learners learn when the instructor demonstrates what is to be learnt, rather than merely telling information about what is to be told. The e-learner observes while the particular SCO demonstrates. The media used in the process is expected to play a significant instructional role. Explain with examples, understand information with meanings, predict consequences, order, group, and infer causes are some samples for demonstration. Demonstration focuses the learner’s attention on relevant information and promotes the development of appropriate mental models. It shows actions in a certain sequence, which can simplify complex tasks and facilitate learning.

C. Application:

The learner to his problem applies new knowledge. This is the practice phase, where learners are required to use their knowledge and skill to solve relevant problem. Some samples are: use information; solve problems using required skills or knowledge. The purpose of a practice phase in the instructional events is to provide an opportunity for learners to develop proficiency and become experts. During this phase, cognitive processes come into play; and there is a search for meaningful patterns and mental programmes that occur in the learner’s mind. This process could either be done through e-mode or through blended learning techniques.

D. Integration:

New knowledge is integrated into the learner’s terminal behaviour. This is the transfer phase where learners apply or transfer their newly found knowledge or skills into their workday practices. This is felt, if learners can a) demonstrate their new knowledge or skills, b) reflect-on, discuss their new knowledge and skills and c) create, invent and explore new ways to use their new knowledge and skills. Seeing patterns and organizing by recognition of hidden meanings, are some samples. In view of the above, the SCOs for the proposed experiments have been developed based on these four Cognitive Structures.

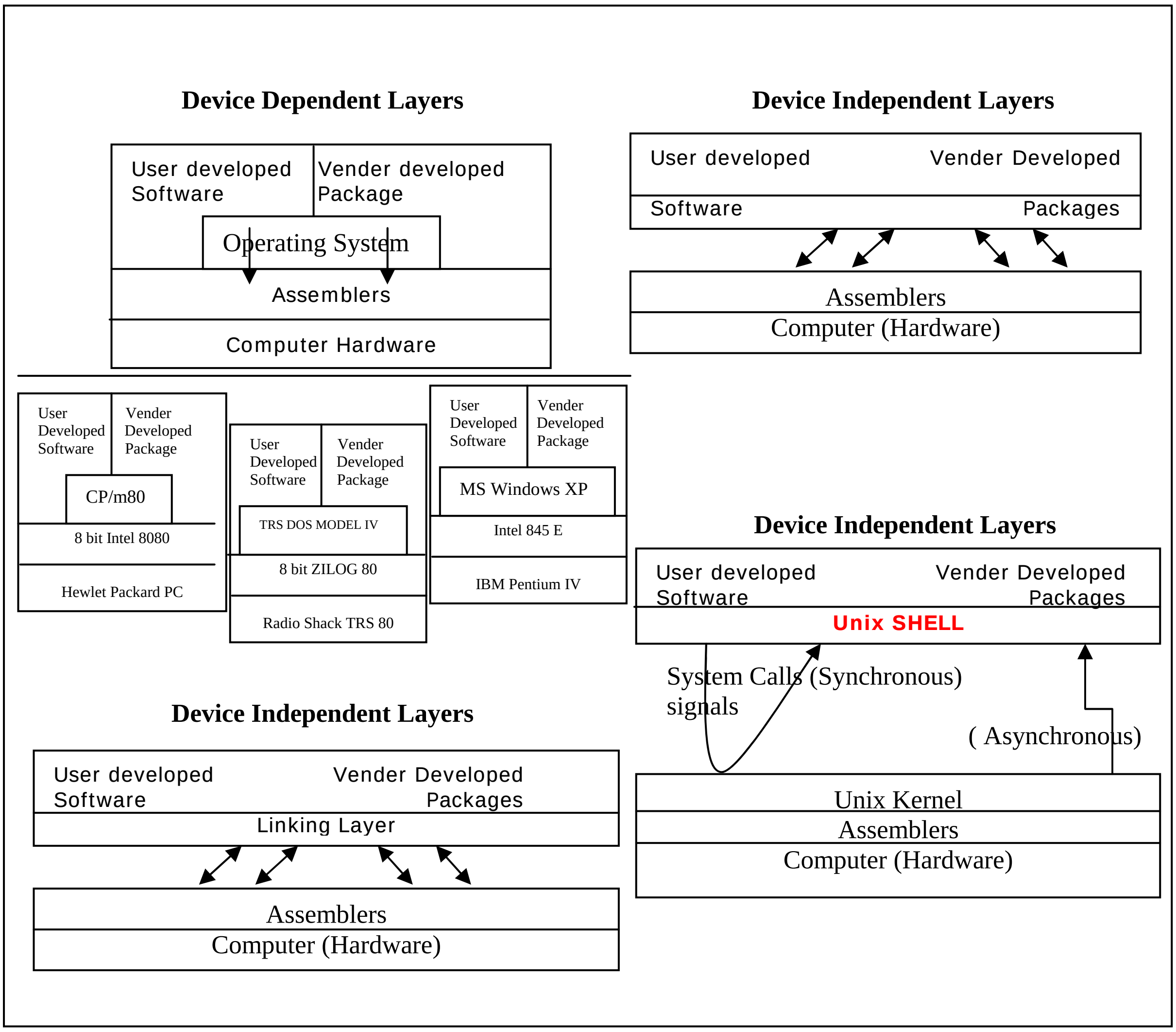

Fig. 1.0 Frames of the Base SCO on 'Device Independence' TS

III. EXPERIMENTAL SETUP

It is proposed to develop a base SCO that has the minimum quantity of instructions. The paper strongly recommends for scaling up from such a base SCO into the four Cognitive structures for a specific learner level (say Diploma or Degree), thus making a total of 12 SCOs for the chosen three learner levels (4 X 3). Scaling factors would be arrived at through the proposed experimental studies for each SCO. The work demonstrated from the results shown in this paper would form a part of a whole research work of the authors. The objective of this research is to establish the relationship between the scaling factors and the feasibility of scaling vertically upward manner according to learner levels. The experimental setup of one base SCO on the concept 'Device Independence' is shown Fig. 1.0, which indicates a series of three frames (slides arranged one below the other as shown in the Fig.1.0) which are needed for the proposed SCO.

The base SCO of the specified topic 'Device Independence' is designed in such a way that only the essentially required basic information of the topic is presented in that SCO, which is called 'Topic SCO' (abbreviated as TS). We have exhibited novelty of our research work in structuring the e-content in terms of presenting instructions through the four Cognitive structures namely 'Activation', 'Demonstration', 'Application' and 'Integration'. Therefore for every TS, there would be four Cognitive structure SCOs. In addition, one base SCO on leaner evaluation of that particular topic is also included. In total there would hence be five SCOs for each topic. As each SCO is small in size, it would not be difficult for putting the efforts in preparing new e-content through developing new SCOs by scaling up existing old SCOs. Our research therefore aims at arriving appropriate scaling factors for determining the possibility of scaling up existing old SCOs to different new SCOs, for different vertical (upward) learner levels.

For the design of SCOs for each learner levels, the base SCO of that particular Cognitive structure is scaled up (or in some cases the base SCO might itself be re-used without any modifications – indicating that it is a reusable SCO and no need to scale up). In that way the SCOs of all the four Cognitive Structures and the learner evaluation SCO would then be scaled up. All the scaled up SCOs of the four Cognitive structures for the three learner levels are not presented in this paper for saving paper space. However, the overall results are presented below.

IV. RESULTS AND DISCUSSIONS

A. Scaling Factor for Instructional Efforts (β):

A one minute duration as a fundamental unit of instruction (learning duration) is considered under a parameter ε (ε = 1, but it is a variable and if needed can be changed according to the nature of subject). One episode will have mostly one SCO. Occasionally it may have two or more SCOs. One SCO will have mostly one frame or slide. Occasionally it may have two or more frames. ζ = Total duration of SCO retention time by a learner and can be expressed in multiples of ε. The principle behind introducing this instructional duration factor is due to the nature of variable retention durations of SCOs. If the duration required for retaining a SCO of a particular learner level is more, then it would be worth scaling from its base SCO for higher level. If on the other hand, a short instructional duration episode may not be worth scaling from its base SCO, for another learner level. For example, a base SCO is designed to instruct for 5 minutes for, say, for Diploma learners; which might be worthy to scale up, rather than attempting to scale up the same base for, say a PG level, when the instruction duration required might just be one minute.

α = Developmental Scaling factor for each learning ability or Cognitive Structure ranging from 0.1 to 0.9. Ex.- When the SCO is almost reusable that requires only least efforts for modification, then α would become 0.1; whereas if an almost new SCO is demanded (virtually developing a new SCO by putting fresh efforts) then α would become 0.9 and so on. Mathematically, it is calculated as shown below: The percentage of efforts needed to increase/decrease each SCO from a base SCO is represented in a scale of 0–1. If the memory occupant size of the base SCO is 'x' and 'y' for the scaled up SCO, then (i) 'y' / 'x' * 100 = 'z' and (ii) 'z' / 100 – 1 would become the scaling factor (ratio of storage file size to actual file size is also considered, as storing format may consume effort). The effort factor of each Cognitive structure SCO is thus calculated as under.

A(α) = Developmental effort value for 'Activation'

D(α) = Developmental effort value for 'Demonstration'

Ap(α) = Developmental effort value for 'Application'

I(α) = Developmental effort value for 'Integration'.

Total Instructional Effort Scaling Factor β will become:

$\beta = A(\alpha) / \zeta_A + D(\alpha) / \zeta_D + Ap(\alpha) / \zeta_{Ap} + I(\alpha) / \zeta_{I.}$

In addition to this developmental effort scaling factor, factors for certain other issues such as new frame development and/or media developments etc., are also considered as detailed below.

B. Multiplicative Factors:

Two multiplicative factors have been considered, one for the number of new frames and media components that are used in the SCOs. Every additional number of new frames of a SCO and for every Cognitive structure of the instruction or the student's evaluation content is multiplied with this scaling factor. Similarly media consumption multiplicative factor 1 is considered for pure text; 3 for graphics; 6 for animated graphics and 9 for Video (they have been empirically arrived at by the authors on a separate research work not presented in this paper).

C. Common Factors:

It is presumed that factors for user friendly aspects such as navigational parameters, popup menus, icons, tool bars etc., are not expected to be different for different types of learner levels (it would be same for all). Similarly common frames like introduction, help menus, administrative inputs etc., will also be the same for all types of learner levels. Under these presumptions, the research study is delimited in omitting these parameters for the study. As far as scalability for learner levels is concerned, these parameters therefore would get canceled out with each other.

The four SCOs for the purpose of arriving at the scaling factors are calculated using the ratios of the disk size of the SCO and memory occupant size of the same SCO and the number of frames of SCO, in addition to the media component as explained above. Table 1.0 presents the scaling factors, thus calculated.

TABLE I
Computation of Scaling Factors for the SCO on 'Device Independence'

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
S.No	**SCO for/of**	**Size in Disk (bytes)**	**Memory Occupant Size (bytes)**	**Ratio of Disk Overload (3) / (4)**	**New Frame multiplicative factor (Add 1 for every new additions)**	**Media multiplicative factor**	**Effort Scaling Factor. Difference in % change of Base memory* in 0-1 scale**	**Effort Scaling Factor A(α) Abs [(5) X(6)X (7)]**
1	Base	69,632	68,297	1.02	1	1	0.0000	0
2	Diploma	73,728	72,140	1.02	1	1	+0.0563	0.0574
3	Degree	73,728	72,140	1.02	1	1	-0.0563	0.0574
4	PG	90,112	89,529	1.01	5	3	-0.3109	4.7101

D. Scaling Factor for Learner Evaluation Effort:

The scaling factor for each SCO of a particular learner level is computed based on the principle of developmental efforts that might be needed from the base SCO's instructional content. Or in other words, whether the base SCO is scalable for a particular learner level or not? Such an evaluation SCO for the chosen subject content is presented in Fig 2.

ACTIVATION
i/o activities are executed by library functions in 'C'? (y/n)
What is control string of output function?
What is the function name for taking an input value by 'C'?
What is the format specified for integer data type?
DEMONSTRATION
Explain with an example the formatted output for a floating number in fractional as well as exponential form.
APPLICATION
Print the string "Barbie is here" in the format"%10.3s"
INTEGRATION
What value the output would be for printf ("%d", '7');?

Fig 2.0 Base Frame of Learner Evaluation of TS

TABLE II
Learner Evaluation of TS

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
S.No	**SCO for/of**	**Size in Disk (bytes)**	**Memory Occupant Size (bytes)**	**Ratio of Disk Overload (3) / (4)**	**New Frame multiplicative factor**	**Media multiplicative factor**	**Difference in % change of Base memory* in 0-1 scale**	**A(α) Abs [(5) X(6)X (7)]**
1	Base	61,440	61,366	1.00	1	1	0.0000	0
2	Diploma	61,440	61,394	1.00	1	1	+0.0005	0.0005
3	Degree	53,248	50,053	1.06	1	1	-0.1844	0.1955
4	PG	45,056	44,856	1.00	1	1	-0.2690	0.2690

Table 2.0 presents the scaling factors, thus calculated on the learner evaluation SCO. The scaling factors derived from Table 2.0 for evaluation SCO of the TS are presented for every learner level.

Scaling factor γ of evaluation of Diploma = 0.0005, Scaling factor γ of evaluation of Degree = 0.1955, Scaling factor γ of evaluation of PG = 0.2690, SCO is reusable fully (scalable) for all learner levels as far as evaluation SCO is concerned. The total scaling factors for the TS are calculated and presented below.

Total Scaling Factors for the topic TS: S(TS) = β +γ,

S(TS) for Diploma = 3.1770+0.0005= 3.1775,

S(TS) for Degree = 0.5604+0.1955= 0.7559,

S(TS) for PG = 2.8584+0.2690= 3.1274

1) Inference:

It is clearly demonstrated that none of the learner levels is scalable effectively for the chosen topic, which is technically detailed but 'conceptual' in nature. However it is found that the scaling factor for degree is less than one; but still it is more than 0.5, which means that more than 50% of the efforts may be needed to be put for scaling up. The topic is a typical example to show how conceptually the instruction would vary between different levels of learners. The research work focuses on many similar topics of the same subject content of the authors and the research work has indicated that many topics are indeed scalable, since the scaling factors were found to be less than 0.5. A complete presentation of all the results is beyond the scope of this paper. The distribution of scaling factors for different frames of the SCO are summed up and presented in the graph shown in Fig. 3.0.

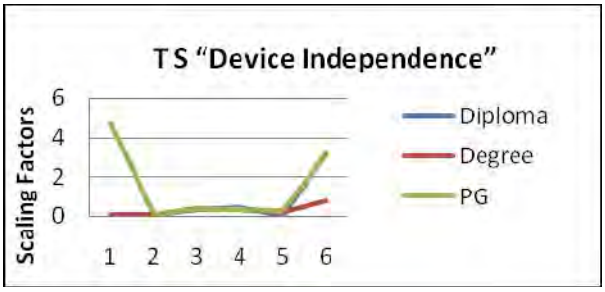

Fig.3 Distribution of scaling factors among frames of the SCO

Horizontal Axis Legend:

1: 'ACTIVATION'; 2:'DEMONSTRATION'; 3:'APPLICATION';

4:'INTEGRATION'; 5:'EVALUATION'; 6: Total factor including Retention.

Note: It is suggested to use a linear lined graph that links different cognitive structures, so that it would be possible for the reader to have a fair idea on how the scalability factors change from cognitive structure to cognitive structure. This suggestion is justified that the Cognitive structures are in general hierarchical (linear) in nature.

2) Observation:

It is observed that the scaling factors are less than 0.5 for all the portrayals except for the 'Activation' part, which is very large. This has resulted in the increase of the overall quantity of the scaling factors.

V. CONCLUSION

It is clearly demonstrated that scaling factors would indicate the possibility of scaling up new SCOs from original base SCO, when the development is strongly founded on an instructional model such as the First Principles of Instruction. It is recommended to form SCOs independently in terms of Cognitive structures for e-content of problem based subject content.

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