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Mapping Student Information Literacy Activity against Bloom's Taxonomy of Cognitive Skills

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Abstract
This paper introduces a model of information literacy which maps the activities that students undertake against Bloom's taxonomy of cognitive skills.

Firstly, the paper summarises the authors' underpinning research in this area. Secondly the paper proposes a model of information literacy and compares this with existing models of information literacy. Thirdly, each stage in the proposed model is articulated in more detail and the required cognitive skills for each stage are identified. Finally, the paper examines the implications of the model on how, and by whom, information literacy is delivered and supported in an academic context.

Keywords
Information literacy model, cognitive skills, Bloom's Taxonomy

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1. Introduction
The University of Worcester is a small, though rapidly growing HEI (Higher Education Institution), currently with about 8,200 students, of whom about 6,700 are undergraduate. In 2008–09, 37% studied part-time and 69% were mature (21 and over). This profile means that students at the university have a diverse range of academic backgrounds, and some students require or seek considerable levels of support. A proportion of the university's students are not academically committed and similar to the student named 'Robert' by Biggs (2003, pp. 3-5). Biggs advocates that students who come under the 'Robert' category require support to respond to and engage with higher cognitive activities and are more likely to do so if exposed to active methods such as problem-based learning.

A series of collaborative projects between two of the authors (a computing lecturer and a member of library staff) resulted from concern about the quality of the research referenced in the assignments that students were submitting. As the library began to invest in e-journals and other online resources, it was assumed that these would be particularly suitable for computing students, and that therefore the use of journals would increase. However, assignments continued to rely largely on lecture notes, unrefereed websites and a few set texts, with little evidence of wider independent research and reading. The decision to actively promote e-journals and support their use by undergraduate computing students provided an opportunity to evaluate the resulting effect on student learning. The result was a measurable improvement in the ability to retrieve information as evidenced by a greater tendency to use journals and advanced search techniques (which was reported by the students), and better-quality bibliographies. (Colvin and Keene, 2004; Colvin and Keene, 2006)

Despite the increased use of journals, there was still a tendency for students to rely heavily on websites, many of which were of questionable quality. This led to a second project which aimed to encourage students to evaluate the quality of resources and where we continued to emphasise the techniques which had worked so well in the previous project. These included: timely and collaborative delivery of teaching; reinforcement in subsequent weeks by the lecturer; and explicit learning outcomes in the assessment. The second project reported a significant improvement in the range and quality of sources in the bibliographies, and the students' self-reported selection and evaluation of information resources suggested higher information literacy levels. (Colvin and Keene, 2006)

However, a number of differences also emerged during this second project. Encouraging students to use e-journals had proved fairly simple, since it was a case of demonstrating mechanistic processes and providing the incentives and reminders to use these resources. In comparison it proved much harder to support students to evaluate resources in a way that encouraged deep learning, and several different approaches had to be tried. The initial approach was to talk to students about evaluation criteria and their importance, before giving them worksheets with examples. This did not engage the students and the sessions ultimately evolved into the format described in the next paragraph. It also seemed easier to engage 2nd or 3rd year students compared to 1st year students, regardless of educational background and entry qualifications (Colvin and Keene, 2006).

It became clear that the most successful strategies were those which took a student-centred approach that enabled students to appreciate the relevance of evaluating resources, and helped them develop appropriate criteria for evaluation, a process which they would be likely to continue to use in future learning contexts. Ultimately, contextualised learning activities were used where students were given a number of relevant scenarios, each with a number of possible outcomes. They discussed these in small groups before feeding back the reasons for their decisions, enabling key principles to be drawn out by the session leader. Examples of the resources used can be found in the toolkit developed by the authors (Colvin and Keene, 2005). Brown, et al. (2003) came to a similar solution when leading sessions on information evaluation with undergraduates studying on teacher training courses at the University of Oklahoma. These undergraduates also engaged poorly with lists of evaluation criteria and became much more involved when given a meaningful task, in this case to produce lesson plans for the students they taught.

The students' responses to different approaches caused the project team to start thinking why students engaged more actively with meaningful retrieval and evaluation activities, and then more broadly about the relation of information literacy to learning and teaching. This led to the development of an iterative model which recognised the difficulty of different aspects of information literacy and which identified the cognitive skills employed at each stage. This model is examined in Section 2.

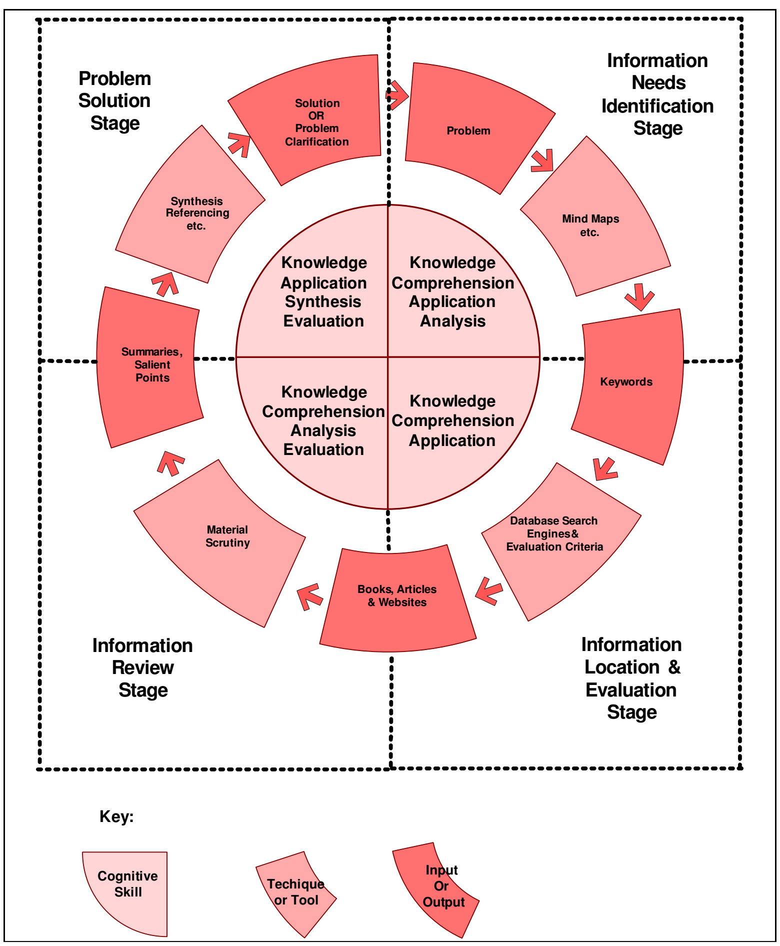
2. Overview of the Model

The paper proposes a holistic model of information literacy, named 'Colvin-Keene Model' that is illustrated in Figure 1. This model identifies the cognitive skills employed in each of its four stages and includes all the aspects of problem-solving (Altshuller, 1997) that students are expected to engage with. Problemsolving is an iterative process and the inclusion of this iterative process in our model requires that the model is also iterative.

For the sake of simplicity, the diagram depicting our model (Figure 1) only connects stages sequentially. This diagram does not incorporate the complexity that reverse progress and links between non-sequential stages would entail. For example, failure in the Information Review stage might require one to move back to the Information Needs Identification stage.

The execution of the Colvin-Keene model begins with the Information Needs Identification stage initiated by the introduction of a problem requiring solution. This problem is analysed, using techniques such as mind mapping, to identify information needs usually articulated as keywords. The Information Location & Evaluation stage requires students to locate and evaluate appropriate sources (e.g. books, articles) that potentially satisfy their information needs and then to retrieve those sources that are believed to be suitable. The Information Review stage firstly involves reviewing the retrieved sources and identifying relevant and useful extracts. These extracts might then undergo a transformation into a more functional format (e.g. a summary of salient points). The Problem Solution stage involves synthesising retrieved information to obtain a solution, evaluating the appropriateness of this solution and articulating this solution using techniques and conventions such as referencing and report structures.

Figure 1: Colvin-Keene Model



There are a number of well-established models or frameworks for information literacy, for instance the Seven Pillars of Information Skills produced by SCONUL (Society of College, National and University Libraries) in the UK (SCONUL, 1999), and the Australian and New Zealand Information Literacy framework (ANZIIL) (Bundy, 2004) which is derived from the Information Literacy Competency Standards for Higher Education created by the Association of College and Research Libraries (ACRL, 2000) in America. Andretta (2005) argues that these IL frameworks provide a similar definition of IL consisting of the identification of an information need followed by access, retrieval and ethical use of the information for a specific purpose. However, ACRL and ANZIIL go into considerable more detail with ACRL proposing 5 standards and 22 performance indicators, while the Australian and New Zealand framework is organised into 6 standards with 19 learning outcomes. The SCONUL model gives some examples for 5 of the 7 pillars, although a full set of performance indicators for this model is developed elsewhere (Godwin, 2002). Overall, the Colvin-Keene model maps well against the broad concepts expressed in the established frameworks referred to above, whilst not elaborating on some points. For instance, our model does not articulate the need for information, assuming that this is a given in the context of a student carrying out an academic assignment. It also does not directly refer to the need to manage information found, which is covered by all 3 other frameworks.

The Colvin-Keene model, like the NHS Scotland information literacy process model (Craig and Westwood, 2009), represents information literacy as a cycle, in comparison to the linear presentation of the models mentioned above. However, both frameworks by ACRL and ANZIIL emphasise the iterative nature of information gathering e.g. ACRL standard 1.4 expects students to re-evaluate the nature and extent of information need. ACRL and SCONUL also stress that students should be continually increasing their level of information literacy.

Some teaching programmes encourage students to ‘close the loop’ by assessing what they have done and learned, such as the MOSAIC tutorial at the Open University (Dillon et al., 2003) and the online guidance aimed at school students given by the Australian Capital Territory Libraries (2004). However, other information literacy programmes are constructed in a more linear and sequential fashion which reflect the format of the models they are based on and appear to give less emphasis to the iterative processes involved in problem solving. Examples of these are Pilot, the online tutorial at the Queensland University of Technology (2009), and the online Information Literacy tutorials found at McHenry County College Library (2005) and at Cranfield University (2007).

The Colvin-Keene model does differ from the established models in that it focuses on the process a student may go through whilst working on an assignment, rather than trying to deconstruct and list all aspects of information literacy that an individual may use at different times. However, its stages pull together numerous standards or outcomes from the other frameworks. For instance, the Information Location & Evaluation stage contains the following aspects of SCONUL’s pillars 2-4:

- the ability to distinguish ways to address the information gap;
- the ability to construct strategies for locating information;
- the ability to locate and access information;

This difference in emphasis again raises questions about the effectiveness of teaching programmes which focus separately and consecutively on each standard or pillar, rather than emphasising that they are part of an integrated whole process with which a student can identify. Todd (2000: p.169) considers that very often the focus of information literacy research is "not on the process but on the actions" and that "end states are articulated as abilities to apply a range of intellectual skills or information skills". Limberg (2000) also expresses concerns about the tendency for 'various components of information seeking to be taught as consecutive steps' and identifies a gap between a student's learning outcomes and information seeking behavior which focuses on search processes or skills.

The other major difference between previous models and the one presented in this paper is that the Colvin-Keene model identifies the specific cognitive skills employed by students to undertake each of the activities that comprise the stages of information literacy in the expectation that this helps to evaluate how Information Literacy skills are delivered and supported. As Kuhlthau et al. (2008) point out, many authors have recognised that there are cognitive aspects in information seeking. The work of Kuhlthau has been influential is this area over three decades and examines, amongst other things, the interrelationships between physical, affective and cognitive aspects (Kuhlthau, 1988; Kuhlthau, 2004). Kuhlthau et al. (2007 pp. 24-28) consider the cognitive development of children and how this influences their use of information, while Todd (2000) promotes the importance of considering cognitive processes, such as the need to understand people's existing knowledge and how they process information within a personal context. Bawden (2001), on the other hand, stresses the importance of critical thinking or analysis skills in his review of concepts of literacy.

However, very few references have been found which directly link aspects or skills of information literacy to specific cognitive skills, or which identify the difficulties of employing these cognitive skills. Not only does the SCONUL model (SCONUL, op. cit.) not refer to cognitive skills, but the descriptors often emphasise or refer to activities that, from Bloom's perspective, entail low level cognitive skills. For instance, Pillar 5 emphasises the need for knowledge of media operation and software, while the authors of this article suggest that more emphasis could be placed on evaluating information in this Pillar. The ACRL model does refer to cognitive skills in regard to the identified outcomes for each standard, explaining that "both "higher order" and "lower order" thinking skills [..] are evident throughout the outcomes" (ACRL, op. cit.). The example they give of a "lower order" thinking skill is the ability to "identify keywords, synonyms, and related terms for the information needed". The ACRL model recommends that appropriate assessment methods are used for the thinking skill associated with each outcome, but no detail about the types of suitable assessments and teaching approaches is given in the document. To ensure that librarians consider cognitive skills as part of their information literacy programmes we believe that they need to be familiar with Bloom's taxonomy and the associated teaching and assessment methods.

One example was found in the literature which related cognitive skills to information literacy. An information literacy module at the University of Botswana used the six topics of the Australian Capital Territory information literacy model (Australian Capital Territory, 2004) as the basis of the sessions (Mutula et al., 2006). The six levels of Bloom's taxonomy (Bloom, 1956) were then built in as an over-arching framework with the idea that each session developed on the previous one and required students to use progressively higher level skills. However, it appears that the Bloom levels were not used to indicate the difficulty of the information literacy skills, in the way the Colvin-Keene model does, but related instead to the difficulty of the assignment given to the students. For instance, the first topic required students to determine their information needs, locate and retrieve information and identify relevant keywords. But it was the students' knowledge and understanding of the information they found using these skills which was assessed. It is interesting that both the Botswana team and the ACRL standards regard identifying keywords as simple. It is the authors' belief that this is not the case, since a degree of analysis of the problem is required to identify appropriate keywords. This view is supported by our students' feedback generated during a focus group where this part of the information retrieval process was discussed. For example, one student claimed "*it took me another half day to learn how* [to develop the technique of selecting keywords that produced predominately relevant search results]", thereby suggesting that the identification of keywords is a complex process to learn.

3. Detailed View of the Colvin-Keene Model

This section analyses and summarises the range of activities involved in the Colvin-Keene model of information literacy and identifies the cognitive skills that are required by these activities (Tables 2a–2d). The cognitive skills identified are referenced against Bloom's taxonomy and the reader may wish to contextualise this section by cross-referencing with Bloom (ibid), or one of the many online sources that articulate Bloom's taxonomy (e.g. Berkeley, 1967). Bloom's taxonomy was selected by the authors as it is well known and it has been widely used for instructional design purposes (Moseley et al, 2004). The fact that the taxonomy was published in the 1950s does not concern the authors who agree with the sentiments expressed in Moseley et al. (2004) that the taxonomy "[..] shows few signs of its age".

The following problem, suitable for a computing undergraduate student, is used throughout the rest of this paper to demonstrate the application of the Colvin-Keene model and show how it helps students to develop information literacy skills.

> For the conceptual database design provided, implement and document a multi-user client-server database system using Microsoft SQL Server. Your database should provide secure access for the different views of the data. You are required to submit design documentation to the prescribed house style, to demonstrate the system and to write a critical evaluation of the security measures that have been implemented.

The successful completion of this problem by an undergraduate student would, in the opinion of the authors, require the student to undertake information literacy and problem solving skills.

3.1 Information Needs Identification Stage

This sub-section analyses the activities required of students in the Information Needs Identification stage and identifies the cognitive skills involved. The activities and cognitive skills are cross-referenced and summarised in Table 2a.

Table 2a: Summary of Cognitive Skills employed in Information Needs Identification Stage

Stage: Information Needs Identification		**Cognitive Skill (Bloom's Taxonomy)**
Decomposition of Problem	Analysis of problem to identify its key elements	**Analysis** (4.10 Analysis of Elements)
	Analysis of problem to identify relationship between key elements	**Analysis** (4.20 Analysis of Relationships)
	Analysis of problem to identify boundaries around scope of the problem	**Analysis** (4.10 Analysis of Elements)
	Awareness of problem domain	**Knowledge** (1.30 Knowledge of the Universals and Abstractions in a Field)
Analytical Tools and Techniques	Awareness of software availability	**Knowledge** (1.12 Knowledge of Specific Facts)
	Use the techniques and associated tools	**Knowledge** (1.25 Knowledge of Methodology) **Application** (3.00 Application)
Analysis of Information Needs	Scrutiny of key elements to identify information needs	**Knowledge** (1.30 Knowledge of the Universals and Abstractions in a field) **Comprehension** (2.00 Comprehension)
Keyword List	Articulation of information needs as keywords	**Comprehension** (2.10 Translation)

3.1.1 Decomposition of Problem

For a suitably abstract problem, this stage firstly requires analysis to identify the key elements of the problem, to identify the relationships between elements and to identify any boundaries around the scope of the problem. The predominant cognitive skill employed in the identification of the key elements of a problem and in the identification of the scope of the problem is analysis, and more particular the cognitive sub-skill '4.10 Analysis of Elements'. The identification of relationships between elements also requires the employment of analysis, but in this case the sub-skill '4.20 Analysis of Relationships'.

A student without an awareness of the problem domain ('1.30 Knowledge of the Universals and Abstractions in a Field') will probably not identify many key elements, relationships and boundaries. This is illustrated by the difficulties that such a student would experience in identifying the following from a decomposition of the sample problem:

- key element: transforming E-R diagrams into table structures
- relationship between key elements: correspondence between database security facilities provided by Microsoft Server and optimal database security
- problem boundary: performance is outside the scope of this problem

3.1.2 Analytical Tools and Techniques

A number of techniques (e.g. mind mapping, mental mapping, mental modelling) exist to aid the initial analysis of the problem and computer-based tools are available that support the implementation of these techniques. Awareness of associated software availability ('1.12 Knowledge of Specific Facts') is required and awareness of how to use the techniques and associated tools ('1.25 Knowledge of Methodology') should underpin the application of these techniques and tools ('3.00 Application').

3.1.3 Analysis of Information Needs

Each key element of the problem requires further scrutiny in the context of the scope of the problem to establish the associated information needs. For our sample problem the associated information needs for the element transforming E-R diagrams into table structures might include how to ensure referential integrity or the implementation of many-to-many relationships.

For a student with a grounding in the subject domain ('1.30 Knowledge of the Universals and Abstractions in a Field') and an understanding of the problem domain ('2.00 Comprehension') this process should be relatively straightforward.

3.1.4 Keyword List

A proportion of the identified information needs may be readily available (e.g. owned books), but other information will necessitate sourcing. To facilitate this sourcing it is customary to articulate the information needs as a keyword list by employing tools such as thesauri ('2.10 Translation'). Such a keyword list should include a variety of both synonyms and alternative spellings to enable a student to effectively and efficiently interact with catalogue search engines that are invariably employed at the next stage of the proposed model. The following list of alternatives are applicable to our example undergraduate problem - entity model; E-R model; entity-relationship model; conceptual model.

3.2 Information Location and Evaluation Stage

This sub-section analyses the activities required of students in the Information Location and Evaluation stage and identifies the cognitive skills involved. The activities and cognitive skills are cross-referenced and summarised in Table 2b.

Table 2b: Summary of Cognitive Skills employed in Information Location and Evaluation Stage

Stage: Information Location and Evaluation		**Cognitive Skill (Bloom's Taxonomy)**
Location of Sources	Awareness of suitable Literature databases	**Knowledge** (1.12 Knowledge of Specific Facts)
	Employ a variety of Literature database search engines using • Keywords • Boolean Operators • Phrase/Proximity Searches to locate potentially useful material	**Knowledge** (1.25 Knowledge of Methodology) **Application** (3.00 Application)
Initial Evaluation of Located Sources	Evaluate abstract against • Relevance • Timeliness • Authority • etc.	**Knowledge** (1.24 Knowledge of Criteria & 1.30 Knowledge of the Universals and Abstractions in a field) **Comprehension** (2.20 Interpretation)
Retrieval of Sources	Retrieve article, book etc	**Knowledge** (1.25 Knowledge of Methodology) **Application** (3.00 Application)

3.2.1 Location of Sources

Firstly the student will need to be aware of available tools (e.g. catalogue search engines, literature database search engines) that are suitable for locating available sources (e.g. books, articles) satisfying the identified information needs. If the student is not aware of these search tools, it is likely that information about such tools is readily available in Library Information Sheets or on Library web pages ('1.12 Knowledge of Specific Facts').

Locating these sources may entail employing ('3.00 Application') a variety of techniques such as Boolean operators, phrase searching and proximity searching with a number of different search engines. Clearly the student needs to be aware of a range of advanced search techniques, be aware of situations where each is suitable and be able to employ these with different database search engines ('1.25 Knowledge of Methodology'). Efficient searching also requires that the student determines the most appropriate search technique for particular situations. Anecdotal evidence collected during our research also suggests that some students do not engage with these advanced search techniques, relying instead on simple keyword searches, while others still rely on serendipity, physically browsing through book and journal shelves.

3.2.2 Initial Evaluation of Located Sources

Usually the search process will provide abstracts or summaries of located sources to enable an initial evaluation of suitability against criteria such as relevance, timeliness and authority ('1.24 Knowledge of Criteria'), although it is also suggested that problem domain awareness ('1.30 Knowledge of the Universals and Abstractions in a Field') is required to evaluate material written at an abstract level effectively against the relevance criteria. The evaluation process entails comprehension ('2.20 Interpretation'). The authors believe that this process is better mapped to comparing cognitive process described by Anderson and Krathwohl (2001) in their recent revision of Bloom's taxonomy.

3.2.3 Retrieval of Sources

The retrieval process ('1.25 Knowledge of Methodology' & '3.00 Application') can be seamless and fast when accessing e-journals but might also involve, inter alia, searching a library shelf or placing an inter library loan request.

3.3 Information Review Stage

This sub-section analyses the activities required of students in the Information Review stage and identifies the cognitive skills involved. The activities and cognitive skills are cross-referenced and summarised in Table 2c.

Table 2c: Summary of Cognitive Skills employed in Information Review Stage

Stage: Information Review		**Cognitive Skill (Bloom's Taxonomy)**
Identification of Relevant Extracts	Identify relevant extracts from retrieved material	**Analysis** (4.10 Analysis of Elements)
Detailed Evaluation	Evaluate extracts for detailed relevance and summarise salient points	**Knowledge** (1.30 Knowledge of the Universals and Abstractions in a Field) **Comprehension** (2.10 Translation) **Evaluation** (6.00 Evaluation)
Evaluation of Sufficiency of Aggregated Information	Review sufficiency of aggregated information	**Evaluation** (6.00 Evaluation)

3.3.1 Identification of Relevant Extracts

This stage will firstly involve reviewing ('4.10 Analysis of Elements') the retrieved sources and identifying relevant extracts (e.g. paragraphs from articles, sections from books). Although this might be undemanding for a well indexed textbook, the process can be far more demanding for, say, journal articles that might have a focus outside the problem domain and will certainly not be indexed.

3.3.2 Detailed Evaluation

Extracts are subject to more detailed scrutiny that can result in a summary of salient points or summary annotations ('2.10 Translation'). Some sources may be discarded if detailed scrutiny ('6.0 Evaluation') suggests, for example, that the previous evaluation of their relevance turned out to be incorrect. It is interesting to consider the level of problem domain awareness ('1.30 Knowledge of the Universals and Abstractions in a Field') needed for this detailed scrutiny at this stage to be effectively completed. Certainly authors of journal papers or academic books in technical fields such as computing include related subject matter in their scripts with a high expectation of the reader's subject knowledge and understanding.

3.3.3 Evaluation of Sufficiency of Aggregated Information
This should be followed by an evaluation ('6.00 Evaluation') of the aggregated extracts to ensure that sufficient information exists to support meaningful problem solving. A deficiency of material will usually require the student to revisit the Information Location and Evaluation Stage. In the sample problem, such a deficiency might, for example, be insufficient information on implementing security in Microsoft SQL Server.

3.4 Problem Solution Stage

This sub-section analyses the activities required of students in the Problem Solution stage and identifies the cognitive skills involved. The activities and cognitive skills are cross-referenced and summarised in Table 2d.

Table 2d: Summary of Cognitive Skills employed in Problem Solution Stage

Stage: Problem Solution		**Cognitive Skill (Bloom's Taxonomy)**
Plan of Solution	Analyse problem to identify output requirements and to plan solution strategy	**Synthesis** (5.20 Production of a Plan, or Proposed Set of Operations).
Creation Solution	Create a solution, using inter alia, retrieved extracts Evaluation of completion of solution	**Knowledge** (1.30 Knowledge of the Universals and Abstractions in a Field) **Application** (3.00 Application) **Synthesis** (5.00 Synthesis) **Evaluation** (6.10 Judgements in Terms of Internal Evidence)
Documentation of Solution	Write up solution using conventions and techniques such as • Report structuring • Referencing	**Knowledge** (1.21 Knowledge of Conventions) & (1.25 Knowledge of Methodology) **Application** (3.00 Application)

3.4.1 Plan of Solution
This stage may be initiated with an examination of the problem to confirm the requirements of the problem specification and to plan a strategy for deriving a solution ('5.20 Production of a Plan, or Proposed Set of Operations').

3.4.2 Creation of Solution
Creating the solution ('5.00 Synthesis') will involve synthesising retrieved information and applying a variety of problem domain specific techniques, such as process modelling, within the context of the sample problem ('3.00 Application'). Employing such problem domain specific techniques implies the need for problem domain awareness ('1.30 Knowledge of the Universals and Abstractions in a Field').

Initial attempts to solve a non-trivial problem are likely to be unsuccessful, but will clarify the problem and/or highlight any flaws in the initial information needs analysis. Hence a cyclic process will ensue, terminating when a solution is produced that meets completion testing criteria ('6.10 Judgments in Terms of Internal Evidence'). Anecdotal evidence from our research indicates that some students pay little attention to evaluation and we suggest that this process is critical in both preventing unnecessary development and avoiding sub standard solutions (Keene et al., 2008).

3.4.3 Documentation of Solution

Finally the student needs to articulate this solution by applying conventions such as referencing conventions and also by employing tools such as word processing and presentational software ('1.21 Knowledge of Conventions', '1.25 Knowledge of Methodology' and '3.00 Application'). For our example problem, this may require students to be aware of and able to apply technical documentation conventions, referencing conventions and presentational software. This is the final step in the cycle and again anecdotal evidence from our research suggests that, for many students, time and deadline pressures undermine the diligence that is needed to complete this write-up and presentational process.

4. Implications for Delivery and Subsequent Support of Learning

In addition to the cognitive skills required there are many other factors that will influence how, and by whom, information literacy is delivered and subsequently supported in an academic context. These include established ways of delivering and supporting the information literacy needs of students within a particular institution, institutional policies and strategies, student preferences and perceptions, resource pressures and accessibility. However, the authors believe that the cognitive skills that students practice in particular activities in the problem solving cycle are one of the critical factors that must be considered to enable students to realise their full learning potential. Although the deliberations below concentrate on this one factor, it is acknowledged that the other influencing factors will need to be accommodated in learning delivery and support design.

Analysing the cognitive skills that underpin the curriculum design is not original. Anderson et al. (2001) offer examples of how such an analysis can be employed to devise learning activities and assessment. Their approach, like the approach proposed in this paper, also employs Bloom's taxonomy, albeit in a revised state. This is perhaps not surprising considering David Krathwohl's substantial contribution to Bloom's taxonomy (Bloom op. cit.). Also, like Anderson et al. (2001), we perceive alignment between the level of cognitive skill required and the learning activity as being crucial. This alignment is illustrated in our experience detailed below.

Our research (Colvin and Keene, 2006) suggested that where an activity requires subject domain awareness (Knowledge of the Universals and Abstractions in a Field - Knowledge 1.30) then delivery and subsequent support of learning is most effective when carried out by a team that includes subject expertise such as specialist subject librarian or academic. This approach enables contextualised delivery that emphasises the importance and relevance of the process to students and targeted subsequent support for those students who find tackling subject domain problem solving challenging. Although introductory material might be successfully delivered with generalised examples, we question whether such generalised examples will encourage and allow students to analyse at any appropriate depth, to allow them to fully appreciate and absorb this activity. When supporting students outside the classroom situation, a subject aware advisor should be capable of spotting mistakes in a student's solution and of analysing these mistakes to identify the difficulty that the student is encountering. Such support can be seen as offering scaffolding in a student's 'zone of proximal development' (Vygotsky, 1978) and exemplified by teaching students to analyse a problem through the identification of the key elements and the relationships between these elements.

Our experience of delivering higher order cognitive skills (4.0 Analysis, 5.0 Synthesis and 6.0 Evaluation) is that student centred learning activities that exploit the benefits of collaborative learning are successful in encouraging students to employ these higher order cognitive skills (Colvin and Keene, 2006). This experience is consistent with the advice that has been offered in texts aimed at supporting higher education lecturers with their teaching, e.g. Gibbs and Habeshaw (1989). This suggests that one should not rely solely on lectures, worksheets and online tutorials for activities in the problem solving cycle involving the use of higher order cognitive skills. Activities that require students to exercise higher order cognitive skills include breaking down a problem, evaluating extracts for detailed relevance, reviewing the sufficiency of aggregated information, how to analyse a problem to identify output requirements, planning a solution strategy, creating a solution and evaluating whether a solution is appropriate. A further implication is that one-to-one support is most effective for many students who, in the post-delivery phase, find practicing these higher order cognitive skills challenging.

There are a number of activities that oblige students to carry out a number of prescribed steps (1.25 Knowledge of Methodology & 3.00 Application). These steps are typified when students employ a variety of literature database search engines using keywords, Boolean operators and phrase/proximity searches to locate potentially useful material. Generally, our research experience (Colvin and Keene, 2004) parallels our expectations for delivering such cognitive skills and suggests that a mixture of lectures, demonstrations, online tutorials and exercise worksheets is effective for delivery and that online tutorials and worksheets are effective for post-delivery support. Similarly, where students require knowledge of information (1.12 Knowledge of Specific Facts), such as knowledge of available literature search engines, this can be effectively delivered for the majority of students via online and paper factsheets.

Comprehension is considered to be a low-level cognitive skill (Bloom, op cit). However, our research (Keene et al., 2008) demonstrates that the delivery of these activities should include a substantial element of student-centred activities, enabling students to create their own understanding (Biggs, 2003). Such student-centred activity could be delivered by traditional, eLearning or blended learning approaches. The cause for students experiencing difficulties when implementing this activity is likely to be a lack of understanding rather than a lack of knowledge and so it is suggested that subsequent support is available on a one-to-one basis to complement the use of any worksheet and online tutorial support that may be available for post-delivery support. An example of where students require comprehension is when they articulate their information needs as keywords (2.10 Translation) in the Information Needs Identification stage.

5. Conclusions

The paper proposes a model of information literacy that is broadly consistent with the concepts expressed in established frameworks. It is suggested that the proposed model differs from established frameworks in two ways. Firstly, it includes a holistic view that embeds information literacy in the problem solving cycle, rather than trying to deconstruct all aspects of information literacy that an individual may use at different times. Secondly, the model emphasises the relevant cognitive skills exercised by students at each stage in the information cycle.

The analysis of these cognitive skills exercised by students at each stage in the information literacy cycle proposed that the full range of cognitive skills is employed. This analysis also suggested that different approaches to delivery and post-delivery support are appropriate for different information literacy activities, depending on the cognitive skills that students employ in the respective activities. Firstly, where an activity requires subject domain awareness then delivery and subsequent support of learning is most effective when carried out by a team that includes subject expertise e.g. specialist subject librarian or academic. Secondly, the delivery of activities that involve higher order cognitive skills is most effective when delivery includes a significant element of student centred learning activities that exploits the benefits of collaborative learning. Thirdly, where activities oblige students to carry out mechanical steps the employment of a mixture of lectures, demonstrations, online tutorials and exercise worksheets for delivery and online tutorials and worksheets for post-delivery support is effective. Finally, the teaching of activities that require comprehension is most effective when this includes a substantial element of student centred activities to enable students to create their own understanding.

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