CHAPTER 2

Background & Related Work

This chapter provides an overview of state-of-the-art in the context of this thesis and presents some background information. We present the background of adult literacy case study in Section §2.1 and summarize literature review in Section §2.2. We then analyze the existing work from the perspective of adult literacy in Section §2.3. In Section §2.4, we critically analyze existing work from educational technologies and software engineering viewpoints to address scale and variety. We end the chapter by presenting the open research problem motivating this thesis.

2.1 Background - The Adult Literacy Case Study

Literacy is one of the key factors in defining socio-economic progress of a country and is vital for a major country like India. On the other hand, India has the highest number of adult illiterates in this world amounting to 37% on this globe [25]. The National Literacy Mission of Government of India has been striving to address this challenge since 1988 [72]. According to NLM, literacy is defined as “acquiring the skills of reading, writing and arithmetic and the ability to apply them to one’s day-to-day life” and more specifically the focus has been on functional literacy that includes:

- Self-reliance in 3 R’s (Reading, wRiting, aRithmetic)

- Becoming aware of the causes of deprivation and moving towards amelioration of their condition by participating in the process of development

- Acquiring skills to improve their economics status and general well-being

Teaching adults requires a different pedagogy and is often considered as andragogy in the field of learning sciences [73]. In [73], Merriam defines an adult learner as someone
who has (i) an independent view of learning (ii) extensive prior experience (iii) dynamic learning goals (iv) focus on application of knowledge for practical purposes and (v) gets motivated for internal factors. UNESCO has proposed *Belem* framework to support adult learning at a global level [74]. NLM at the national level has researched and proposed Improved Pace and Content of Learning (IPCL) as a uniform methodology for teaching 3Rs to adult illiterates in India [26]. It was designed with the intent of providing a base instructional design for official Indian Languages and allows content creators to adapt it for varied contexts across India. Some key aspects of IPCL methodology are:

- Uniform basis for all official Indian languages
- Sustain learners' motivation
- Flexible for adapting the instructional material as per local needs
- Learning by entertaining
- Thematic focus (for different focus learners like women, farmers and so on)

The instructional material (called as *primer*) based on IPCL for different languages is subsequently produced by 32 state resource centers (SRCs)\(^1\) across India as shown in Figure §2.1. Each of the primer is divided into three parts and each part is divided into

\(^1\)http://www.nlm.nic.in/dir.htm
approximately 9 to 12 lessons and each lesson has content focusing on Reading, Writing and Arithmetic.

The instructional process using IPCL can be summarized as:

- Starting from common words and phrases known to people of a linguistic region, segment them to discover syllables
- Juxtapose syllables to form words through word play
- Segment syllables and continue the above till we have irreducible phonemes
- Identify the irreducible phonemes with phonetic alphabets
- Discover rules for combining alphabets to reconstruct syllables
- Discover rules to combine scripts of the phonetic alphabets
- Play with these rules
- The full alphabet is learnt by the end of the entire course

2.2 A Summary of Literature Review

Despite several advances of research in educational technologies and using ICTs for adult literacy [75], India is still home to the largest number of illiterates in this world [25]. There is a broad spectrum of work that could be related to research in this thesis. However, as shown in Figure §2.2, we consider related work from the perspectives of educational technologies and software engineering.

2.3 Approaches for Adult Literacy

The UNESCO CONFINTEA at an international level [76] and NLM at national level\(^2\) have devised several initiatives to battle the challenge of adult literacy in India in the past several decades [72]. India has a long history of using ICTs for adult literacy [27] [77] [78]. A radio forum to reach adult learners was experimented as early as 1976 and satellite televisions are used in [27] with computer and laptop based solutions for literacy in [29] and [79] respectively. TCS, an Indian Software Consultancy Services Company has been contributing to adult literacy since 2001 [29]. They have developed eLearning Systems for 9 Indian Languages and also for languages like Urdu, Moore, Spanish and Arabic [29]. Figure §2.3 shows the screenshots of their eLearning Systems, which are used by teachers

\(^2\)http://nlm.nic.in
in the classroom in conjunction to physical books. An approach based on same language subtitling for songs delivered on television increased motivation of learners [80] [81] but focused only on reading skills and is not interactive. The Bridges to the Future Initiative (BFI), is a multinational effort that aimed at improving literacy using technology [82] but the focus was on children rather than adult literacy population. It was designed only for one South Indian language (Telugu) because of resource constraints [82]. Hole-in-the-Wall project is another successful initiative based on minimal invasive education but was aimed at children [83].

To harness the emergence of mobiles in developing countries for literacy, a few approaches based on mobile-tablets have been proposed mainly to impart reading skills [84]. A landscape research review of mobiles for reading outlines the need for extensive further research to validate the effectiveness of mobile technologies [84][85]. A study focusing on adult literacy using mobile phones shows promises as well as several challenges [86], mainly in terms of developing the mobile apps for varied languages. Visibility of alphabets on low-end mobile phones is another issue with use of mobile phones in the context of adult literacy even though it can be addressed if smart phones are available at lower cost in the future. A report from Indian journal of adult education summarizes the use of ICTs for adult literacy and their inadequacy for mass scale of India [78]. Initiatives like “EduTab” device focus on facilitating adult literacy in India [87], but their effectiveness from pedagogy perspective is unknown as they use their own instructional process and material. A review of tablet software for improving adult literacy suggests the use of games
for increasing learner engagement [88] but the tablet software is designed for English and requires significant development effort if it has to be designed for the scale and variety goal of this thesis.

A study from 2011 census data emphasizes the inadequacy of current programmes for adult literacy in India and anticipates that it might take 2050 to achieve 100% literacy rate using current approaches [89]. A research agenda post 2015 for learning and literacy lists 10 key priorities emphasizing the need for technology to be available in the local language of instruction particularly in developing countries [90]. The article also underlines the need for basis of pedagogy for ICT-based solutions for improving quality of instruction in literacy [90], which is severely lacking in most of the current technologies [90].

Of the existing approaches, we rely on TCS’ technology for teaching adult illiterates as they are based on IPCL, field tested for 9 Indian Languages and made around 120,000 people literate in the last 15 years across India [29]. Figure 2.3 shows the comparison of results without and with technology for adult literacy through experiments by TCS. On the other hand, an analysis of the literature on technologies for adult literacy alleviates the following key concerns relevant for this thesis:

- Teaching adult illiterates requires a different pedagogy [91] [26]
- Lack of pedagogical basis for ICTs dents quality of instruction [20]
Existing work focuses on designing educational technologies for one or few languages whereas the need is for approaches that work for the scale of 22 Indian Languages and variants

- Existing work does not address the needs of varying instructional goals, process, content and other aspects

## 2.4 Approaches for Scale and Variety

This thesis is primarily concerned with facilitating the design of educational technologies for scale and variety, where scale represents the number of systems to be developed and variety represents the different kinds of systems to be developed in education domain and more specifically in the context of adult literacy in India. As described in Section §1.5, this thesis cuts into the areas of instructional design, ontologies and software product lines.

The role of technology in education seems to be emerging since decades [92] and there has been an extensive literature on trying to understanding its varied roles, potentials, issues and challenges on the way [93][94][95][96][97] and ways forward [17]. While there are several issues and concerns that restrict the use of technology in education [98] [64], one major concern is the immense effort for development of technologies based on instructional design [99] while another critical concern is diminishing quality of instruction [20]. In this
section, we discuss existing literature related to these aspects from the perspectives of educational technologies and software engineering.

2.4.1 Patterns

Bednar et al. have stated that "... effective instructional design is possible only if the developer has reflexive awareness of the theoretical basis underlying the design . . . [it] emerges from the deliberate application of some particular theory of learning" [100]. This strong need to have a pedagogical basis for design of educational technologies has been emphasized in the literature by several researchers [101] [21] [102] [103] [104]. A critical and detailed analysis of the need to bridge learning theories and technology enhanced learning environments is elaborated in a 2014 journal article [105]. To address some of these concerns, patterns were proposed as a potential solution to capture best practices of teaching [106]. The core idea of patterns and pattern languages is the encapsulation, modeling and delivery of expert's knowledge and best practices to novices in a discipline. Essentially, patterns are derived from experiences and provide abstract representations of recurring solutions to recurring problems in a given context [8]. The roots of patterns are claimed to be in the field of architecture [8] and extensively practiced in software engineering mainly for improving quality of software design and facilitating reuse [107] [108].

The Pedagogy Patterns Project was a major effort to capture best practices in the area of teaching and learning as a way to document best advices for teachers and support quality of instruction [106] [109]. The E-LEN project is another initiative aimed at providing pedagogically-informed technology and experiences as pattern languages for new institutions mainly focusing on learning management systems [66]. There is also extensive work on patterns and pattern languages for different aspects of teaching and learning [110] [102]. A pattern language for creative learning is presented in [111] and for adaptive learning in [112]. Laurillard has created pedagogical patterns using a design science approach [113]. Patterns and pattern repositories for person centered e-learning were proposed in [114]. More recently, patterns derived from practitioner workshops were documented in [115]. While existing literature on patterns emphasizes the need for capturing best practices in teaching and learning, the focus has been mostly on pedagogy and technology aspects are largely ignored. Even in research that considered technology, there is a huge gap between domain (teaching and learning) and technology patterns motivating further research. The key focus in this thesis is to leverage the potential of patterns for modeling instructional design and use that base for design of educational technologies. Chapter §3 of this thesis elaborates our pattern-oriented design.
2.4.2 Learning Objects, Standards and Repositories

There has been extensive research on learning objects in the domain of technology enhanced learning to facilitate reuse [46] and reduce effort during development of educational technologies [16]. Literature has a number of definitions for learning objects [116] each of them using varied terminologies like learning components, knowledge components, content objects but a consensus on their definition is yet to be achieved [117]. It was observed by Reigeluth and Nelson that teachers often break instructional materials into small, reusable chunks such that they can reuse these materials for other instructional contexts [118]. A widely used definition describes learning objects as any kinds of resources (like books, audio video lectures, animations and so on) that can be reused to support learning [116]. However, along with significant research progress on learning objects, there is severe criticism on learning objects from many perspectives [54][56]. Even attempts to clarify the definitions of learning objects have led to the criticism that “there are said to be as many definitions of LOs as there are users” [54]. However, the emergence of learning object metadata standard from IEEE Learning Technology Standards Committee [119] led to a common definition across many sectors. It defines a learning object as “any entity, digital or non-digital, which can be used, reused or referenced during technology supported learning”. A heavy focus on reuse of learning objects from a technology perspective [120] has led to severe criticism from learning perspective [52] [121] [53] [55] [122]. In addition, Wiley has pointed that automated assembly of learning objects is not always possible [123]. Another critical issue was the lack of explicit contextual information for describing, searching, adapting learning objects through learning object repositories [54]. There have been significant efforts that resulted in the creation of several learning object repositories worldwide [124]. McGreal has presented a typology of different types of learning object repositories [125]. A practical analysis of learning objects and repositories revealed that reusing learning objects is still an elusive concept and their benefits in practice still largely depend on the context [56].

2.4.3 Learning Designs, Standards and Repositories

Koper has stated that it is not enough to have learning objects and metadata, but instructional value of learning objects should also be considered for e-learning [126]. To address some of these concerns with learning objects, an initiative was started by the Open University of the Netherlands (OUNL) in 1998 which resulted in a formal educational modeling language [49]. EML was iteratively refined for about three years by a number of experts from diversified backgrounds such as educational technologists, ICT-experts, XML-experts, etc. A working definition was proposed where “an EML is a semantic notation for units of learning to be used in elearning to support the reuse of pedagogical entities like learning designs, learning objectives, learning activities, etc.”. In this definition, a unit of
learning describes the learning design, the resources and the services needed in order to achieve one or more interrelated learning objectives and can be viewed at different levels of granularities like course, module, lesson or curriculum. This idea of a formal educational modeling language has garnered interest from several quarters and a survey of EMLs has geared towards a clear specification of requirements for such a language. These efforts have translated into what is called as IMS Learning Design which was later adopted as a standard [37] that aims “to provide a containment framework of elements that can describe any design of a teaching-learning process in a formal way”.

There have been several initiatives to improve educational modeling languages in several forms like a cognitive approach in PALO [34], a separation of concerns approach in poEML [33], a lesson markup language LMML [127], a visual language for designing instruction like E2ML [128], several approaches based on IMS-LD [70] [129], COLLAGE focusing on collaborative learning [130] and so on. These approaches were supported by tools like ReCourse Editor [131], ReLoad Editor [131], ASK-LD Editor [132] and so on. A classification framework for EMLs was presented in [31] and a number of visual editors for learning designs were reviewed in [32]. A classification and analysis of learning design tools into standards-based, generic form-based, theory-based, knowledge-based has motivated the need to have software design that is linked to theory and practice from a pedagogical perspective [133]. Based on lessons from these earlier efforts, tools like LAMS [38] and The Learning Designer [39] were designed to be intuitive to teachers. A team-based approach for modeling learning designs through an integrated learning design environment is proposed in [40][134]. To facilitate reuse of learning designs, several learning design repositories have emerged similar in spirit to learning object repositories [129]. Boyle proposed a layered approach towards integration of learning design and learning object perspectives [135]. Sampson and Zervas proposed a hierarchical framework and supporting tools to facilitate open access to education and learning in the context of open educational resources [36]. In his survey of ICT-based tools for supporting instructional designers and delivery of learning systems, Paquette underlines the need for a knowledge based instructional design and the need for application of software engineering approaches to address the increasing complexity of instructional design and engineering [136].

Amidst this rapid progress, researchers have continuously identified several challenges of IMS-LD [137], its expressiveness [138], conceptual complexity [139] [140], lack of authoring tool support [41][141]. Prieto et al. have used five learning design tools to model a sample “healthy eating” lesson and found that different tools are designed for different purposes with different levels of granularity for different stakeholders and have varied representations [142].

An analysis of existing literature on learning designs and tools reveals that most of the efforts in this direction are either too focused on pedagogy or on developing tools for
specific contexts. It is here that thesis focuses on applying software engineering principles towards systematic modeling of instructional design.

### 2.4.4 Ontologies for Instructional Design

Since Gruber's definition of ontology as "a formal, explicit specification of a shared conceptualization" [9], ontologies have gained immense importance in several domains for its wide range of applications [143] [144] like in software engineering [145], enterprise modeling [146], requirements engineering [147]. These ontologies are of different kinds ranging from informal light weight ontologies to formal ontologies depending on the degree of formalism and the power of expressivity [148]. Happel et al. have discussed the advantages of ontologies over conceptual models and meta-models [149] as follows:

- Enable new and efficient way to the information reusability.
- Enable to extend easily.
- Provide consensus on the understanding of domain knowledge.
- Support better understanding of domain knowledge.
- Define problem and solution domain knowledge separately.
- Assist in analyzing the structure of domain knowledge.
- Facilitate a machine to use the knowledge in an application.
- Share common semantics among people and applications.

In the domain of education, ontologies have gained immense importance with applications ranging from explicit representation of domain knowledge to automatic generation of personalized content [150]. Mizoguchi and Bourdeau have identified four key requirements of instructional authoring systems (i) adaptivity (ii) explicit conceptualization (iii) standardization to facilitate reuse (iv) theory-awareness, and proposed knowledge and ontological engineering as a potential solution to cater to these requirements [151].

One particular use of ontologies that is of interest to this thesis is to model instructional design theories and learning design standards [152] during design of educational technologies. A 10-year research effort has resulted in creating a comprehensive ontology covering instructional design knowledge for various instructional theories and adhering to learning design standards [153]. SMARTIES is a scenario-based instructional authoring tool based on this ontology and advocates the design of educational technologies based on educational theories modeled as ontologies to facilitate quality of instruction. However,
the inherent complexity of the ontology and SMARTIES tool made it tough for its practical usage [154].

While focusing on quality of instruction is one aspect, using ontologies in education to facilitate reuse is another critical research direction that received extensive attention in the literature [151]. Devedzic explored the notion of ontologies for intelligent tutoring systems (ITS) based on inspiration from software patterns in 1999 [155]. Ontologies to formalize learning object content models have been proposed in [156]. To facilitate flexible content reuse, the Abstract Learning Object Content Model (ALOCoM) ontology and a set of supporting tools were proposed in [156]. Amorim et al. have proposed a learning design ontology based on IMS LD specification through a set of 20 design and run time axioms [42]. The basic premise of this ontology was to explicitly and precisely address the drawbacks of IMS LD specification [42]. But isolated research on learning objects and learning designs have made reuse difficult motivating the need for a bridge ontology focusing on context [43]. A formal ontology was presented for representing instructional design methods and provides a rule catalogue to verify the conformance of ontologies for a particular instructional design theory [157]. An ontology and a software framework focusing on competencies was discussed in [158]. However, the creation of these ontologies is not based on patterns, which is the case in this thesis. Furthermore, the existing ontologies are not aimed at scale and variety, which is the need in this thesis.

2.4.5 Software Reuse for Design of Educational Technologies

Development of software components for the domain of education started way back in 1999 [159]. But the use of software engineering approaches in educational technologies has garnered significant attention with the advent of reuse of learning objects [45]. Design principles from software engineering were borrowed to facilitate reuse of learning objects [47]. However, this emphasis itself has led to severe criticism on software engineering being misused in the context of learning objects from a learning perspective [54]. Researchers have used model driven development to facilitate reuse of learning objects [160]. Dodero et al. further proposed a model-driven approach to learning design, a domain-specific language and a tool based on this approach to facilitate modeling of learning designs [161]. A model-driven development approach for learning design using the LPCEL Editor was proposed in [162]. But despite the advantages of these generative approaches, it was noted that the complexity of authoring process increases because of model development required from domain experts [163]. The term educational software engineering was coined in [164] but the focus has been on games for software engineering education.

One major direction of research that is relevant to this thesis is the application of software product lines for accelerating educational technologies. A software architecture for design of e-learning platforms is proposed in [58]. Pankrautius has proposed a software product
line approach for digital information products in [57]. A software product line approach towards automating the development of a family of eLearning Systems for adult literary in India was proposed in [7]. Even though these approaches show significant productivity improvements in terms of reducing effort [7], none of them are based on principles in the domain of education creating a significant gap between instructional designs and the software platforms that are built on them.

2.5 An Open Research Challenge from Literature Review

Analyzing literature from the perspectives of educational technologies and software engineering for design of educational technologies for scale and variety, we see limited existing work for adult literacy case study as the focus was not on scale and variety, which is the crux of this thesis. Even when the research was applied for cases other than adult literacy, the focus has been on either educational technologies or on software engineering and not both, presenting the need for this thesis and hence the problem statement.

*How to facilitate design of educational technologies for scale and variety in the context of adult literacy in India while maintaining quality of instruction?*