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Design and development of a digital life logging system for management of lifelong learning experiences

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Abstract

In this study, a life logging system is designed, developed and tested for management of the lifelong learning experiences. In the first stage, theoretical foundations of lifelong learning experiences have been searched and then an applicable and expanded approach is acquired by putting together major informal learning theories. After that, a life logging system that captures webcam images and screenshots from individual's desktop, laptop and tablets spontaneously is developed in order to save these learning experiences. System is expanded to architecture which enables the user can interpret his/her personal experiences, develop personal knowledge base, signification and management of learning experiences. Design based research approach is used in study and results of sixteen month old development-trial period are discussed.

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Keywords: Life logging; lifelong learning; recording of learning experiences; management of learning experiences

1. Introduction

Lifelong learning is a process which starts at individual's birth and continues until his/her death. When lifelong learning is considered, we encounter with very long time periods. Infinite number of variability and contents are placed in individuals' lifelong learning history such as lecture notes which belong to his/her college days thirty years ago, ability he/she gained twenty years ago during in service training, the museum he/she visited ten years ago during a foreign holiday and the book he/she reads right now. This variability will continue increasingly both in

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present and future learning. Individuals usually do not realize the importance of management of personal learning processes spread through all of the life experiences. In formal education environments, this function is mainly left to the institutions and instructors and learners are expected to fit in these processes. On the other hand, when lifelong learning and especially informal learning is considered it is clear that an individual, who is not under the supervision of an institution or instructor, needs efficient methods and tools to manage his/her learning processes. Based on this idea, a research project coordinated by the author of this article and supported by Anadolu University has started in order to design and develop a technological infrastructure, which enables individuals to manage their lifelong learning experiences. Formation of learning experiences has been examined at the first stage of the research project and an approach for *recognition and description of learning experiences*, which includes steps such as realization, recording, interpretation of these experiences, definition of the contexts formed by them and creation of a personal knowledge base by using these contexts, is obtained (Mutlu, 2013a). After that, informal learning theories in literature have been examined and by developing a synthesis of these theories *expanded informal learning model* is obtained. A useful classification for explaining the meaning of informal learning experiences is offered with the help of this model. Then, by using "recognition and definition of the learning experiences approach", "expanded informal learning model" and basic management concepts to manage these learning experiences, is offered (Mutlu, 2013b). The method which includes steps such as (a) *recording*, (b) *interpreting*, (c) *forming a personal knowledge base*, (d) *signification*, (e) *planning, controlling and evaluation* provides individuals opportunity to manage their lifelong learning experiences. On the other hand, technological designs to apply these approaches and methods are made too. At first, a multiple device based life logging system is developed (Mutlu, 2013c). And then, a system for *management of the life experiences* is developed in order to enable interpreting the experiences captured (Mutlu, 2013d). Another study, made towards this aim, is a personal knowledge base design which enables users to define contexts among the life experiences recorded and helps them to form a personal knowledge base from these contexts (Mutlu 2013e). Finally, a holistic approach which is based on management of the experiences belonging to personal knowledge work in a study that examines the close relationship between learning and personal knowledge management, is obtained (Mutlu, 2014).

In this study, a system is designed and developed to manage the lifelong learning experiences by using the theoretical and technological studies within the scope of this research. With this aim, the problem of the research is defined and a design based research method is scrutinized. In the following sections, the theoretical framework used for management of lifelong learning to solve the problem are discussed together with the expectations towards this framework Then, a system for management of the lifelong learning experiences is designed and trial cycle is activated until an applicable system is obtained. The obtained findings are discussed by evaluating the individual tests of the system developed. As a result, findings of the system developed and the expectations of the theoretical model are compared, possible the future research and development activities and other possible fields of application of this system is reviewed.

2. Method

2.1. Problem

In this study, design and development of a life logging system is aimed to manage the lifelong learning experiences. This study is focused on design and development; application of the system by lifelong learners and evaluation of the system is not included.

2.2. Design based research

Because of the fact that the problem undertaken is about design and development of a system used in learning area, design based research method which is widely used for this kind of problems is used. Design based research is defined by Wang and Hannafin (2005) as a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories. Fundamental steps of the design based research method are applied to the problem of the study as mentioned below:

- *Analysis of the current problem by researchers and applicants:* In this step, the conceptual framework is defined by analyzing the fundamental concepts of management of the lifelong learning experiences such as learning, lifelong learning, life-wide learning, life-deep learning and learning experiences.
- *Development of solutions by using technological innovations and existing design principles*: By considering the developments in life logging systems and personal knowledge base tools, an applicable method is developed for management of the learning experiences.

- *Cyclical development and trial process to find the solutions*: Towards the design principles defined in previous step, the software to capture and manage learning experiences has been developed and tested.
- *Reflection to produce design principles and enhance solution implementations*: In order to help determination of the startup design principles of more complex problems related to this field, design and development processes of this study, reports related to the development, test and re-evaluation cycles, products obtained and supportive materials are documented and published.

Details of these steps are discussed in following sections.

3. Analysis of problem

Learning is the act of acquiring new, or modifying and reinforcing, existing knowledge, behaviors, skills, values, or preferences and may involve synthesizing different types of information. It does not happen all at once, but builds upon and is shaped by what we already know. To that end, learning may be viewed as a process, rather than a collection of factual and procedural knowledge (Schacter et al., 2011:264). Learning is a process which starts at birth continues until death (time scale axis) and occurs every place during day consciously or unconsciously (space axis). This educational fact that covers entire life is named as *lifelong learning*. Learning can occur in an education institution in a planned way or via communication with the individual's environment on his/her own. This space which contains all the learning types from *formal learning*, *non-formal learning* and to *informal learning* is named as *life-wide learning.* The distinction between formal and non-formal learning environments is about where learning takes place. Formal learning occurs within institutions established primarily to deliver education and training, often leads to recognized outcomes and qualifications. Non-formal learning has intended education and training outcomes; however, the setting is out of the dedicated learning institutions, most often in places where learning is not the primary business. Informal learning is distinguishable by an absence of primary intent. It can occur almost anywhere, but as a by-product of other activities. It is often unplanned and without explicit emphasis on learning, yet may still lead to the acquisition of valuable skills, knowledge and attitudes (Clark, 2005). *Life-deep learning*, which leads people what to believe, how to behave, how to judge himself/herself and others, embraces all the religious, spiritual, ethical an social values (Banks et al, 2007). Formation of all these values are closely related to other experiences a person has and roles a person takes. An individual's objective perception of self with an integrated approach happens by a detailed examination of his/her past and inner world. This kind of examination can be achieved with the help of evaluation of different unstructured private information such as memories, journals, diaries, comments, personal notes etc. In formal learning environments, learning activities, which are determined at the instructional design, underlies the learning process. Learner can repeat these learning activities in order to correct his/her deficiencies in his/her learning process retrospectively. In informal learning environments there are not any similar pre-designed learning activities, at most cases, individuals do not realize they are having learning process at that point. Because of this, to use a more common concept such as *learning experience* instead of "learning activity" is more suitable. Learning experience is defined by Mutlu (2013a) as physical, mental, emotional, spiritual, religious, social or virtual events or activities we attend or exposure and make us acquiring new, or modifying and reinforcing, existing knowledge, behaviors, skills, values, or preferences. Because of the fact that learning experience states an attitude which is both active and passive, it can be matched with events and activities that occur at the three dimensions of learning such as lifelong, life-wide and life-deep, and it should be handled together with the other contexts such as place, time, other people, the emotions he/she had, which are related to the life experiences. So it must be handled with the other environments bounded with the other life experiences.

4. Design a solution for problem

The analysis, made in previous sections for lifelong learning experiences, shows us that learning experiences are a subset of the life experiences and it is hard to isolate them from life experiences. In order to overcome this difficulty an approach which enables individuals to arrange their life experiences is developed.

4.1. An approach to realize and define learning experiences

In order to realize and define the learning experiences an approach which consists steps such as *recording of life experiences*, *interpreting life experiences* and *constructing a personal knowledge base* by using these records is suggested (Mutlu, 2013a).

4.1.1. Record of life experiences

The traditional method to record life experiences is to keep a diary. Today, technologies named as *life log* or *life logging* are being designed to make this transaction spontaneously. Origins of life logging researches are based on

Vannevar Bush's recommendation of a device which is called as *Memex* and records everything an individual sees, hears, in 1940 (Bush, 1945). This vision started to get real in 1980s via wearable computer researches of Steve Mann. In 1990s the studies of a number of researchers, Mann was also among them, caused improvements in augmented reality (Mann, 2004). Today one of the members of this group, Thad E. Starner is the manager of Google Glass Project (Kress and Starner, 2013). In 2000s Aizawa was able to record all communication information, location information and biological information such as heart beats besides sound, photographs and videos via a wearable computer (Aizawa et al., 2004). At the same time Microsoft developed a wearable camera named as SenseCam, which capture images continuously. With the contribution of this camera and other Microsoft researchers, researcher Gordon Bell developed a system which records wide range and variability of data such as the things he hears, reads, watches and self-tested it (Gemmell et al., 2002). Microsoft SenseCam has been used in numerous life logging researches during 2000s in Oxford, England and positive results obtained especially on patients with Alzheimer's (Hodges et al., 2011). In 2013 Autographer which is based on SenseCam architecture and a kick start project called as Narrative (Memoto) started to popularize wearable cameras. Today, field of wearable sensors has been expanded gradually and both companies and the researchers working on this field are merged under the concept of "quantified self" movement.

4.1.2. Interpreting life experiences

According to Teraoka (2012) there are three layers for recording and management of personal experiences such as *logs*, *activities* and *episodes*. So, the records belonging to life experiences can be interpreted as activities and episodes after their review. In addition to Teraoka, Mutlu (2013a) defined another layer named as *story* above the episode layer and used it for interpretation process of life experiences.

Activities: According to theory of activity, human activities are consisted of actions, actions are consisted of operations. Actions are behaviors which are done for achieving a goal. Operations are routine processes done for making actions. People usually do not realize the operations they made (Kaptelinin, 2013). Spontaneous life logs are usually evidential for either operation or the action. After long time, it might be hard to remember an activity by looking at a single log. Because of that, life logs should be scanned in every few days to recognize the life experiences. A daily activity list should be made to interpret the perceived experiences. Within this period, it should be considered that intercepted experiences may occur simultaneously such as reading a book during a journey (Mutlu, 2013a).

Episodes: According to Tulving (1983), episodes include information such the location of an event, who was present, and what occurred before, during, and the after the event. When they are discussed in scope of life logging, episodes are written by interpreting contexts of intercepted activities take place, time, other people and feelings which happen during a certain month or months. Matching episodes with a certain month or months will enable us to use these months as contexts. Evaluating daily activities in this way, after a month is important to review an individual's life and enable him/her to direct it. Several episodes usually happen in a month (Mutlu, 2013a).

Stories: Stories are meaningful summaries of life logs (Byrne et al., 2011). Stories usually contain intercepted episodes during longer time periods. There is an episode which determines the beginning and ending of each one of these stories. Matching stories with a certain year or years will enable us to use these years as contexts. Several stories usually happen in a year (Mutlu, 2013a).

Episodic memory is the memory of autobiographical events (times, places, associated emotions, and other contextual who, what, when, where, why knowledge) that can be explicitly stated. It is the collection of past personal experiences that occurred at a particular time and place (Schacter et al., 2011:240-241). Episodic memory can be supported by recording life experiences continuously on life log basis (Lee and Dey, 2008). *Autobiographical memory* is a memory system consisting of episodes recollected from an individual's life, based on a combination of episodic (personal experiences and specific objects, people and events experienced at particular time and place) and semantic (general knowledge and facts about the world) memory (Williams et al., 2008). The individual can strengthen his/her autobiographical memory by interpreting data occurred during his/her life experiences which are recorded via life logging (Doherty et al., 2012).

4.1.3. Constructing of personal knowledge base

The most fundamental summarization to process raw life experiences in order to obtain information that can be used for other purposes is to list them under various categories. The architecture named as *life experiences management framework* and suggested by Mutlu (2012a), shows us that the information gathered via life experiences can be listed under seven common lists and their sub-lists such as *places*, *events*, *people*, *behaviors*, *emotions*, *features* and *assets*. Personal knowledge bases are defined as is an electronic tool used to express, capture,

and later retrieve the personal knowledge of an individual (Davies, 2011). By using his/her life experiences, an individual can obtain the inventory of his/her life by using these seven groups of lists. This inventory help individual to balance his/her life, do his/her own life coaching, manage his/her personal development and lifelong learning processes.

Even though formal learning is usually young individuals' field of interest, with the help of lifelong learning, learning process gains became important for every age group. Studies show that as age grows, episodic memory weakens and its place is taken by semantic memory. This shifting happens as removing the specific temporal and spatial contexts from memories in episodic memory and causing these memories to become semantic memories (Piolino et al., 2002). To record and interpret life experiences and create a personal knowledge base approach can ease the management of lifelong learning processes of elderly people by supporting both their episodic and autobiographic memories.

4.2. Expanded informal learning model

It enables us to capture and define all the life experiences which also include learning experiences that contain suggested steps which are "recording of life experiences", "interpreting life experiences" and "creating personal knowledge base by using these records". While individuals can recognize their planned and deliberate learning experiences, they may not realize learning experiences happened unconsciously and unplanned.

In his study, which is published in 2000 and updated in 2004, Eraut suggested a typology for informal learning. In this typology which is divided into three categories such as "implicit learning", "reactive learning" and "deliberative learning" by considering the level of intention of learner. Implicit learning happens without any intent and awareness for learning. At one extreme there is implicit learning, at the other there is deliberative learning in time specifically set aside for that purpose. Reactive learning is near-spontaneous and unplanned, the learner is aware of it but the level of intentionality will vary and often be debatable. Other dimension of the informal learning is about timing of the episodes on which the learning focused. Episodes related to learning might have happened in past, happening now or will happen in future. Here the difference is about an episode and its temporal differences. Even though context of learning is always present; focus of the learning might be past, present or future. In other words, the experience which caused learning might have happened in past, is happening now or will happen in future (Eraut, 2000; 2004)

Schugurensky (2000) defined three status of informal learning by using the taxonomy of intention and cognition of which he named as "self-directed learning", "incidental learning" and "socialization". Self-directed learning refers to 'learning projects' undertaken by individuals (alone or as part of a group) without the assistance of an 'educator' (teacher, instructor, facilitator), but it can include the presence of a 'resource person' who does not regard herself or himself as an educator. It is both intentional and conscious. It is intentional because the individual has the purpose of learning something even before the learning process begins, and it is conscious, in the sense that the individual is aware that she or he has learned something. Incidental learning refers to learning experiences that occur when the learner did not have any previous intention of learning something out of that experience, but after the experience she or he becomes aware that some learning has taken place. Thus, it is unintentional but conscious. Socialization (also referred to as tacit learning) refers to the internalization of values, attitudes, behaviors, skills, etc. that occur during everyday life. Not only we have no a priori intention of acquiring them, but we are not aware that we learned something (Schugurensky, 2000). Schugurensky realized that the fourth type of learning can be suggested as conscious but unintended learning according to the typology he offered. But he also said that conceptualization of this type of learning is hard and any example of intentional learning can also be conscious too (Schugurensky, 2000).

Bennett (2012) extended Schugurensky's (2000) conceptualization of informal by recommending "four part model of informal learning": a) self-directed learning, which is conscious and intentional, b) incidental learning, which is conscious and unintentional, c) tacit learning, which replaces socialization and is both nonconscious and unintentional, and d) integrative learning, which is non-conscious and intentional. According to this model, self-directed and incidental learning are conscious activities, which can be observed easily and clearly. Bennet re-named "socialization" item in Schugurensky's model as "tacit learning". In this type of learning, individual learns something in social environments without intention before he/she knows it. Bennett added the fourth type of which Schugurensky avoided as "integrative learning" to his model. Integrative learning is defined as a learning process that combines intentional nonconscious processing of tacit knowledge with conscious access to learning products and mental images. For Integrative learning Bennet's examples are finding solutions to the problems via tacit knowledge, creative processes, self-driven solutions like intuition and finding the solution of the problem during a

break after working on it. For integrative learning Bennett defines two sub categories as "information shifting" and "sublimation" (Bennett, 2012).

By applying Bennet's four part model of informal learning to Eraut model Mutlu obtained *expanded informal learning model*. With this aim he added Eraut's matrix which contains "implicit", "reactive" and "deliberative" learning types and three time levels "integrative learning" column which is borrowed from Bennett. Reactive learning is re-named as *incidental (reactive) learning* and while Eraut claims that there can be different levels of intention in this model, in expanded model it is assumed that this type of learning is totally intended. Eraut's deliberative learning type is re-named as *self-directed learning* as same as Bennett and Schugurensky. On the other hand, instead of intention, *planning situation* is used to consider if the individuals planned informal learning beforehand or not. While forming his typology Eraut does not reference level of consciousness directly instead he uses being aware of or not. In the suggested model, taxonomy is formed between *level of consciousness* and *planning situation* by taking level of consciousness into account as it is used by Schugerensky and Bennet (Table 1). So, learning types such as *implicit (tacit) learning*, *integrative learning*, *reactive (incidental) learning and self-directed learning* is determined from informal learning experiences of individual's lifelong learning process and a framework which will help individual to gain awareness towards his/her previous, present and future learning experiences (Mutlu, 2013b).

Table1. Expanded informal learning model

Learning Types	Implicit (tacit) learning	Integrative learning	Reactive (incidental) learning	Self-directed learning
Level of consciousness	Unconscious	Unconscious	Conscious	Conscious
Planning situation	Unplanned	Planned	Unplanned	Planned
	In implicit learning there is no intention to learn and no awareness of learning at the time it takes place (Eraut, 2000). *In tacit learning*, learning takes place in social environments unconsciously (Bennett, 2012). *Socialization* refers to the internalization of values, attitudes, behaviors, skills, etc. that occur during everyday life. Not only we have no a priori intention of acquiring them, but we are not aware that we learned something. (Schugurensky, 2000)	*Integrative learning* is a learning process that combines intentional nonconscious processing of tacit knowledge with conscious access to learning products and mental images (Bennett, 2012).	*Reactive learning* is near-spontaneous and unplanned, the learner is aware of it (Eraut, 2000). *Incidental learning* refers to learning experiences that occur when the learner did not have any previous intention of learning something out of that experience, but after the experience she or he becomes aware that some learning has taken place (Schugurensky, 2000).	*In deliberately learning*, there is a definite learning goal and time is set aside for acquiring new knowledge (Eraut, 2000). *Self-directed learning* refers to intentional and conscious 'learning projects' undertaken by individuals (alone or as part of a group) without the assistance of an 'educator' (Schugurensky, 2000)
Time of focus				
Past episode(s)	Implicit linkage of past memories with current experience (Eraut, 2000).	Change of point of view towards a previous problem.	Brief near spontaneous reflection on past episodes, events, incidents, experiences (Eraut, 2004).	Discussion and review of past actions, communications, events, experiences (Eraut, 2004).
Current experiences	A selection from experience enters episodic memory (Eraut, 2004).	Intuiting solution of a current problem	Noting facts, ideas, opinions, impressions, asking questions; observing effects of actions (Eraut, 2004).	Engagement in decision making, problem solving, planned informal learning (Eraut, 2000).
Future behaviour	Unconscious expectations (Eraut, 2004)	Realizing a problem which will gain importance in future	Recognition of possible future learning opportunities (Eraut, 2004).	Planning learning opportunities, rehearsing future events (Eraut, 2004).

4.3. A Method for management of learning experiences

For management of learning experiences a five stepped method which is formed by three sections is suggested (Mutlu, 2013b). First section of the method is taken from "an approach for realization and description of learning experiences" developed by Mutlu (2013a), for the second section of the approach "expanded informal learning model" is used. Third section of the method contains functions belong to the management theory. Steps of the suggested approach for management of learning experiences are given below:

- Record, interpretation and creation a personal knowledge base (Stage 1-2-3)
- Signification (Stage 4)
- Planning, monitoring and evaluation (Stage 5)

In "an approach for realization and interpretation of learning experiences" Mutlu (2013a) suggests that foreseen learning experiences are a part of life experiences, if we record life experiences precisely, learning experiences can also be capture. By interpreting life experiences, which have caught via portable life logging cameras, with different time layers such as "activities", "episodes", and "stories" it is possible to realize most of the learning experiences and interpret them. By using obtained raw data and information gathered via interpretation and also with the help of personal knowledge base lists such as "environments", "events", "persons", "behaviors", "emotions", "features" and "assets"; learning experiences will be exposed via cross-references and recorded. In final step, a mechanism which can define future, current and previous situations of learning experiences is used.

- Stage 1: User records images belong to his/her experiences via life logging applications that work on multiple devices.
- Stage 2: On life logs "activities", "episodes" and "stories" are created as soon as possible.
- Stage 3: Personal knowledge base lists are created and updated during certain time intervals by using this information.
- Stage 4: At certain intervals learning experiences are scanned with the help of life logs, activities, episodes, stories and personal knowledge base lists. Determined learning experiences are tagged as "formal learning", "non-formal learning" and "informal learning". By scrutinizing "informal learning" experiences we try to interpret them while tagging them as "implicit (tacit) learning", "integrative learning" "reactive (incidental) learning" and "self-directed learning".
- Stage 5: Actions such as monitoring the current, evaluating previous and planning the future is carried out by scanning records belong to previous, current and future learning experiences. Users can use headlines such as "goals", "road maps", "design ideas", "drafts", and "things left for upcoming projects/versions" for "lists towards future". For "lists towards current situations" headlines such as "things have done", "version diary", "problems/mistakes", "completed", "canceled" can be used. For "lists towards past" names such as "achievements", "failures", "abilities/qualifications" will be enough.

5. Development and test phase

"Learning experience management method" which is suggested in previous sections, can be applied by using a pencil and a paper by individuals during their daily lives. But this isn't practical and sustainable. In this section, an information system which consists of four parts and designed for application of management of learning experiences will be examined. Even though, first three items of the information system is developed during previous studies by the author of this study, last item is developed and tested in during this study.

5.1. Life logging layer

In order to remember the details of an experience lived, every moment of this experience must be recorded. It might be considered that, this problem can be solved by simultaneous video and audio recording of whole life of the individual. But this time we face with the timing problem caused by scanning all the records. In order to overcome this problem, it is suggested to record photo of life experiences every thirty seconds (Hodges et al., 2006). If an individual records his/her photos every thirty seconds via his/her wearable camera every thirty seconds, he/she will have approximately 2000 photos each day. Scanning these photos can be done quicker than scanning a video with the same length.

Studies towards using life logging systems in education mostly focus on recording physical learning experiences via life logging cameras (Ogata et al., 2011). Subjects such as distance learning experiences carried out by individuals in virtual environments, educational activities they do on their own, experiences in social learning environments and capturing informal learning experiences are genuine subjects which are not researched much. When it is considered that most of the learning takes place at virtual environments today, it is required to take

regularly and automatically screenshots of the computers used in addition to camera images. With the help of a system which records key images for later retrieval of learning experiences and contextual data contains date, hour and minute of the image obtained, individual can realize his/her learning experiences and remember information which enables him/her to access to the educational content belongs to the time of this experience.

By using this approach Mutlu (2013c) developed a life logging system to record learning experiences of individuals' learning processes. With this aim, physical and virtual environments are taken into account and a life logging system is designed to record the learning activities take place in these environments simultaneously and autonomously. With the help of this system, it is possible to put together all the images capture every thirty seconds by the screenshot and camera capture software that works on multiple devices such as desktop computers, laptops, tablets, smart phones and wearable cameras and stored on cloud infrastructure (Figure 1).

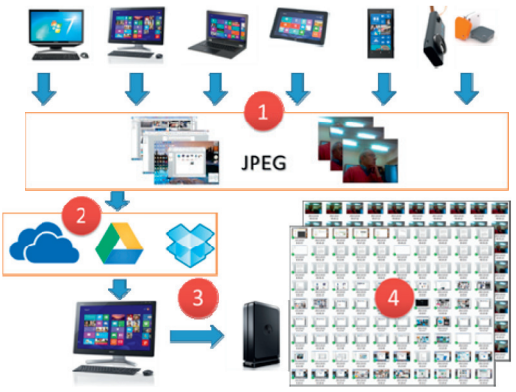

Fig.1. A multi-device based life logging system.

In life logging system, screenshot and camera capture software which can work on desktops, laptops, tablets and wearable life logging cameras captures camera and screen images in jpeg format at every thirty seconds (1). They record the images in the folder of the cloud storage services such as OneDrive, Google Drive or Drop Box (2). Images on cloud environment are downloaded to working computer via software developed for this purpose in a folder named with time stamp and capture device tag (3). Images can be browsed by Windows Explorer as sorted according to year, month, day and name of the capture device.

5.2. Experience processing layer

In another study carried out by Mutlu (2013d) a system suggestion is made for the users who can benefit to manage their life experiences. For this aim, a life logging layer which records life experiences in virtual and physical environments via screenshots and camera captures and experience processing layer which enables users to manually interpreting their experiences on different time spaces (Figure 2).

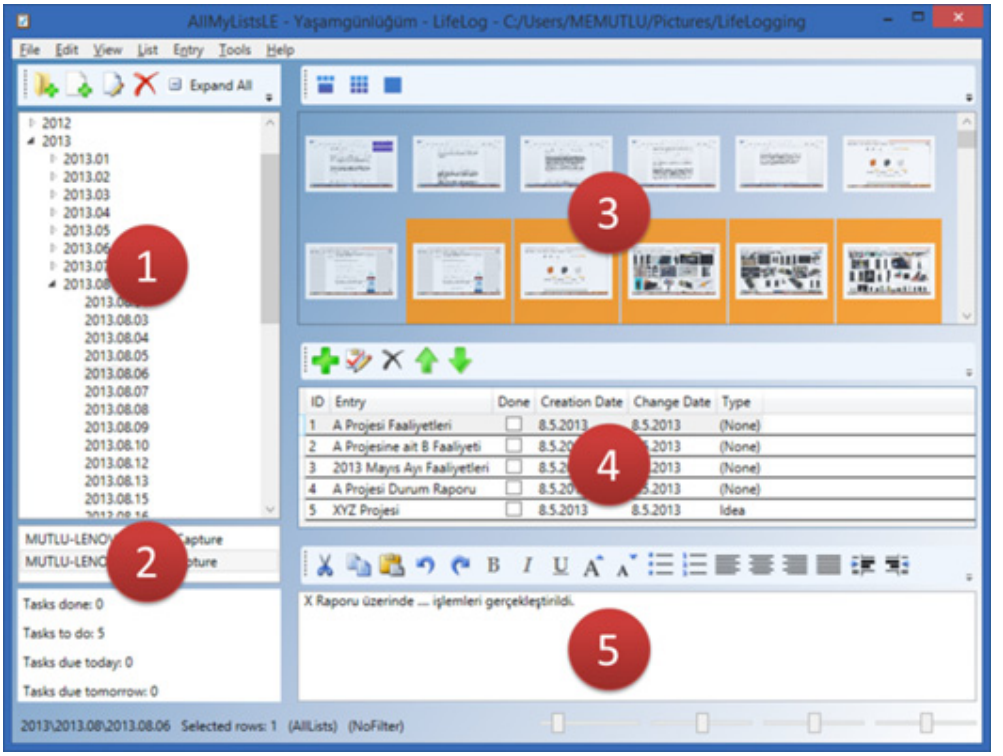

Fig. 2. Screenshot of experience processing software (AllMyListsLE).

In experience processing layer, when AllMyListsLE software is executing, it reaches the images obtained via life logging layer automatically and lists these images to the user as a calendar three which contains year-month-day nodes (1). User picks up a device from list of devices for a specific date (2). Chosen screen or camera shots are browsed as full day view or hour view and list view or tile view (3). User can create one or more comment item/items for a chosen day or one or more images in it (4) and rich text format contents can be entered this item (5). User also have facilities such as find, search, list, entering multiple contexts and filing operations via menus.

5.3. Personal knowledge base layer

In another study carried out by Mutlu (2013e), a personal knowledge base system integrated with a life logging system which enables individual to record all of his/her information, study experiences via screenshot or camera shots and software belonging to the system designed is developed. In this design, a knowledge base layer is added to the life logging layers and experience processing layer two of which are previously developed.

In order to create the knowledge base layer, a new version of AllMyListsLE software is developed which enables it to manage MyList lists besides MyLog lists. In this structure, MyLog lists are the lists which are used for record and management of the images and comments related life experiences. MyList lists are the lists which are used for create entries of personal knowledge base (Figure 3).

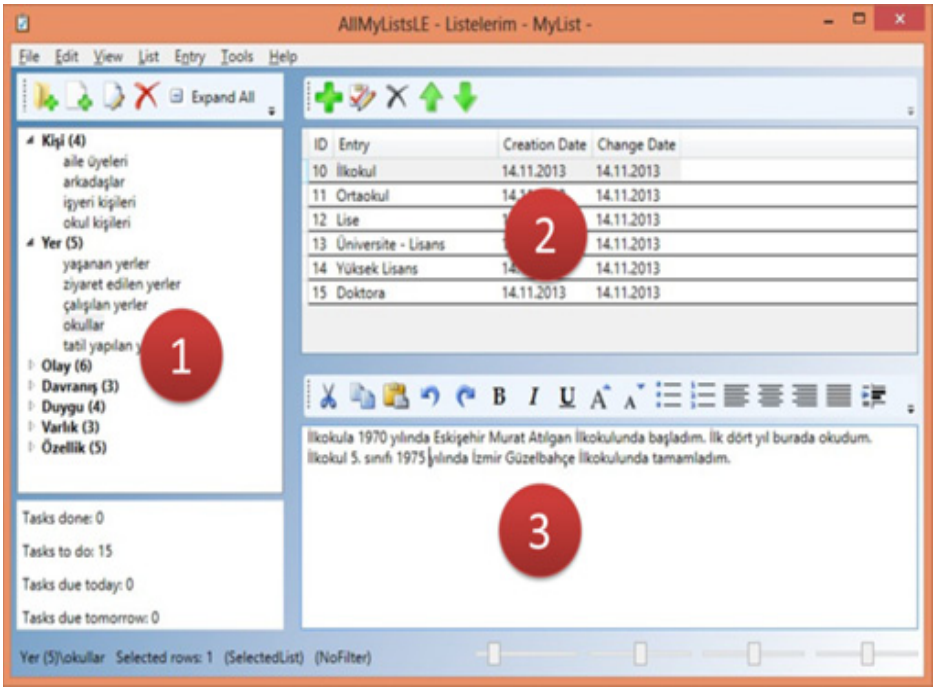

Fig. 3. Personal knowledge base layer.

When AllMyListsLE software is executing for MyList lists, interface of the software changes and a three that contains nodes and sub-nodes created by the user is loaded (1). User can create one or multiple comment entries for each of nodes/sub-nodes chosen (2); changes such as add, delete and change can be done on these nodes and rich text format entries can be enter to these items (3). User can enter additional information such as finishing time, reminder, priority, type and prepare managerial lists towards planning, control and evaluation with the help of these.

The most important feature of the personal knowledge base items is to enable users to create hierarchical lists related to recorded life experiences such as person, place, etc. While a user is commenting on his/her life experiences on MyLog lists, he/she can create a personal knowledge base derived from all of his/her life experiences via MyList lists. Mutlu (2012a; 2012b) suggested the lists and their sub-lists given below for main contextual lists.

- Lists of people (family members, friends, colleagues, school friends, etc.)
- Lists of places (the places we have lived, visited, worked, studied, etc.)
- Lists of events (educational events, healthcare events, family events, business life events, etc.)
- Lists of behaviors (habits, routines, cultural behaviors, etc.)
- Lists of emotions (happiness, regrets, doubts, etc.)
- Lists of assets (objects, properties, cultural assets, etc.)
- Lists of features (hobbies, achievements, abilities, issues, priorities, etc.)

5.4. Learning experiences management facility

In order to apply 4th and 5th stages of *the management of learning experiences method*, two enhancements are made to the three layered system which is developed during previous and contains “life logging”, “experience processing”, and “personal knowledge base” layers. First of these is the feature of entering comments related with the learning types. This transaction is done in “Type” field of the entry. So users can scan their life experiences and tag the comments belong to their learning experiences as “formal learning, “non-formal learning” and “informal learning”. Also, they can make a more detailed tagging for informal learning types such as “implicit (tacit) learning” or “integrative learning”, “reactive (incidental) learning” or “self-directed learning”. This feature enables us to list a lot of learning experience entries spread around a long period. So, individual can find the existence of learning experiences he/she missed more easily and add these entries to his/her list.

Second enhancement enabled user to add blank year-month-day nodes related to past and future. These nodes without images can be used for planning, monitoring and evaluation. So user can transfer stories from memories of certain episodes of previous years or out sources. Similarly system can be updated by logging plans related to upcoming months/years.

Similarly in order to monitor the present term they can add entries such as “stories of the year”, “plans of the year”, “months of the year” to the year node; “episodes of the month”, “plans of the month” and “weeks of the month” to the month nodes. User can plan future without leaving MyLog environment with the help of these entries, monitor his/her current situation and evaluate his/her past.

5.5. Development and test cycles

During the development and test cycle of the digital life logging system, which consists of four elements and designed in previous section, the development and test cycles given below is applied in order to get a useful version (Table 2).

Table 2. Development and Test Cycles (December 2012 – March 2014)

Components of the System	Period
Life Log Software	Development and Tests: December 2012 – September 2013 on 125.000 images
Life Experiences Management Software	Development January 2013 – May 2013; Tests May 2013 - September 2013 on 125.000 images
Personal Knowledge Base Facility	Development May 2013; Tests June 2013 – October 2013 on 158.000 images
Learning Experiences Management Facility	Development: May 2013; Tests June 2013 – March 2014 on 480.000 images

The experiences belong to first three steps are covered enough in previous publications. The experiences belong to the final step will be only covered here. Personal experiences had as a whole system since March 2014 can be summarized below:

Logs: Screenshots and camera shots from seven different devices such as two workstations and a laptop in the office, a desktop computer and a workstation at home, one more laptop, a tablet and a smart phone are derived between December 2012 and March 2014. On March 2014, half million images are obtained and they take more 25 GB space of the working computer.

Comments: Since May 2013 activities, episodes and stories are entered to the logs which have been captured previously. This transaction is also applied to the previous logs between December 2012 and May 2013. So more than 1.000 activities, 100 episodes and 10 stories have been defined and traced during 16 months.

Personal knowledge base: During this term, 843 nodes and 1117 entries have been collected on personal knowledge base in form of MyLists structure which is obtained from contexts related to experiences. These entries not only consist data limited with these 16 months but also cover all the contexts related to life as long as they are remembered.

Learning experiences: Among current experiences significant learning experiences belong to that day have been tried to be determined so more than 400 learning experience is tagged in 16 months.

Planning-controlling-evaluation: Future planning and evaluation activities are carried out by opening the MyLog nodes which belongs to 2014 , previous and following three years and months of these years and entries created such as episodes of the year, plan of the year, months of the year, episodes of the month, weeks of the months.

6. Evaluation and findings

Last step of the design based research approach is defined as reflection to produce design principles and enhance solution implementations. With this aim, while development and trial cycles of the system have been implementing, components of the system are used individually during personal life and observations belong to this usage has been noted. Moreover, design, development and test reports of the research is published in various papers and articles and Project documents are offered on blog and wiki pages of the project manager. In following sections, evaluations obtained for each of the components during the 16 months long research are formed together.

6.1. Life Log Software

Benefits and Problems: Since the first day, it has been tested, life logging software started to produce benefits and it is commonly used for retrieving and evaluating learning experiences and projects worked on a specific date in past. Especially carrying out the design, development and trial processes of multiple software projects developed on multiple computers smooth existence of life logging systems is effective. Different users on different computers can use life logging software by logging into their accounts and the images belong to them are saved on their own OneDrive accounts during their usage. So images belong to different users won't be mixed. On the other hand, sometimes it is observed that OneDrive cloud storage service is not sufficient for data synchronization at this intensity (Mutlu, 2013c).

Existence of different usage patterns is realized during first trials with life logging software (Mutlu, 2013c).

- *First usage pattern*: Long term archive support for users who use limited number of devices. In this usage type, for example a student can evaluate all the educational activities on his/her laptop belong to whole semester.
- *Second usage pattern*: It is organizational support which is provided for people who use multiple devices at the same time. In this usage pattern, for example a software developer can coordinate his/her activities by scanning his/her life logs on five computers every day.
- *Third usage pattern*: It is usage of the system as urgent memory support. This usage type is used only when it is needed (for example when the correspondence between two people is needed or a new document is found etc.).

6.2. Life Experiences Management Software

The findings given below are determined as a result of the use of AllMyListsLE experience processing software (Mutlu, 2013d).

- *Instant use*: Instant use is effective for retrieving the details of a previous experience.
- *Life archive*: a complete inventory of life experiences had in physical and virtual environments can be prepared and a useful life archive is obtained.
- *Permanent remembrance*: Because of the fact that visual evidence of daily activities provide more permanent remembrance, it is possible to comment on these experiences even after for a long time.
- *Usage on multiple devices*: It is seen that the system is efficient especially for coordination of activities which require working on multiple computers.
- *Personal performance*: Existence of daily activity lists provides opportunity for evaluating personal performance.
- *Take advantage of previous experiences*: Reviewing similar experiences by using images and activity logs of the previous experiences prevent waste of time and energy.
- *Stories belong to the life*: It is realized that life is composed of either sequential or parallel stories. The relationships between different roles and stories become less complex. The uncertainty and blur between future, present and past are decreased.

6.3. Personal knowledge base facility

The results mentioned below are obtained as a result of use of personal knowledge base layer (Mutlu, 2013e):

- A safe and practical knowledge base is developed which doesn't put any restrictions on personal information sources even though it records all the information experienced in this study, focuses on contexts rather than content so it can provide the required flexibility for filtering personal information.
- The prepared personal knowledge base enables people to log their comments on activity, episode and story levels by using visual evidence belong to internalization, externalization, combination and socialization steps of knowledge creation process.
- By using time dependent logs, activities, episodes and stories, personal knowledge base items which are independent from time, are formed. The personal knowledge base obtained provides suitable infrastructure for management of software development projects.

In order to conversion the tacit knowledge to explicit knowledge, the strategies given below are applied during personal use (Mutlu, 2013e).

- *Direct recall*: Via records and comments belong to experiences (activities, episodes and stories) retrieval and record of tacit knowledge, ability, behavior, value and preferences are enabled.
- *Indirect recall*: Unnoticed relations are revealed via cross-references between MyLog and MyList lists that belong to the experiences.
- *To see the bigger picture composed of all the information*: By determining personal road map and personal digital stories, the opportunity of defining future for a long time via previous periods is obtained.

These are also among the opportunities provided by personal knowledge base (Mutlu, 2013e):

- If an individual is working on more than one project and research at the same time, the burn out sense and alienation brought by his/her busy schedule can be overcome by evaluating his/her position objectively with the help personal knowledge base based on life logs.
- Another acquisition realized during trials are that the approach enables person to have the information belongs to him/her via an integrated approach. With the help of the system, the individual can determine the fields he/she underestimated or lied heavily on so he/she can balance the areas which forms his/her life.

6.4. Learning experiences management facility

With the help of the suggested architecture, almost all of the life experiences of an individual can be captured, recorded, recognized and interpreted. Also formation of personal knowledge base and management of this information among these experiences can be enabled. While traditional personal learning management studies focus on deliberate and conscious activities, this study enables us to evaluate all of learning experiences of an individual with classifying them as planned, unplanned, conscious, unconscious.

Learning requires focusing on. On the other hand administrative activities require focusing too. These two processes are required not to collide with each other. The architecture suggests an opportunity to overcome this problem by focusing on learning activities and management of these activities on different levels. The applied management approach is focused more passively on recording experiences lived and management of personal learning experiences by using these experiences.

Awareness towards the learning experiences a user had can be increased by applying learning experience management process. So he/she can see how many implicit learning experiences he/she had, he/she can get new results by integrating different learning experiences, he/she can place unplanned learning activities more easily to his/her road map, he/she can support his/her planned and deliberate learning experiences together with his/her unplanned and unconscious learning experiences (Mutlu, 2014).

6.5. Weaknesses

The observed weaknesses of the system developed for management of learning experiences can be summarized below:

- *Restrictions of the operating system*: Because of the fact that sub system of life logging of the system is developed only for Windows 8 and Windows Phone 8, it is not possible to get any screen or camera shots from iOS, MacOS and Android.
- *Memory restrictions*: AllMyListsLE software may slow down when browsing more than 120 pictures on computer screen. It is not possible to browse images belong to multiple devices simultaneously. Developments can be done to overcome these restrictions of the system.
- *Usage restrictions*: Dependence on working computer (for Mylog lists), low level resolution of the images recorded, synchronization problems of cloud computing system, difficulty of integrating the images recorded previously to the system, lack of graph structure of personal knowledge base facility, differences of usage environments of MyLog and MyList lists.
- *Privacy problems*: The system should be discussed according to safety of the personal information recorded, problems caused by making record in public places and privacy of the records which shouldn't have been recorded.

6.6. Costs

- *Duration of the learning and adaptation period*: It is not easy for a participant to use each of the five stages of management of the learning experience method at the same time. Instead, if he/she starts using the system gradually in one-two months gradually, it would be easier to get used to, adopt and sustain the system.
- *Period of time required for keeping up the system*: There is not any significant amount of time for an experienced user with reflexes for starting and stopping the record of camera and screen shots. Controlling the transporting of the images from cloud to computer, interpreting the daily activities, updating activities, episodes and stories one hour will be enough for each week. On the other hand, the time spent on using the system to support daily life will be increased in accordance with the benefits user get from the system. Lastly, an additional can be spared to plan, control and evaluate the yearly, monthly and weekly activities. Maximum amount of time to sustain the system every week is three hours.
- *Hardware costs*: Because of the fact that the system designed will be working on computers with existing Windows 8 or higher versions and smartphones, there is not seen any costs for recording devices. If extensive

recordings are made with four devices at the same time, 200 GB will be enough to store 10.00 images daily and 4 million images yearly. When it is considered that the cost of a portable storage device with 1 TB (100 GB) capacity is 100 USD average, there is not any significant costs for using this system.

7. Conclusion

The system designed has been developed incrementally for 16 months and each step of it evaluated individually. At this point, the system has not been fully tested with all of its features together with sufficient number of users during sufficient amount of time yet. During individual trials, it is seen that workflow of the model suggested during design phase can be carried out smoothly via software obtained during development phase and it is enough for recording personal experiences and working on them. Application oriented research should be done for observation and evaluation of the effects of personal knowledge base formed as a result of the usage of this system on interpretation-trial-evaluation process.

- Enhancing of the usability of the system: It is required to design and carry out studies based on case studies and action researches which monitors and evaluates applicants in detail in order to enhance the usability of the system. As a result of these studies modifications can be done for enhancing the process and updating the software towards this.
- In order to test how much of the user expectations satisfied with this model and determine the contributions made to management of lifelong learning experiences of individuals, applications should be performed on large user groups with different roles and these user should be surveyed. So, the existence of different usage patterns can be found.
- Researches related to adaptation and usage of the system developed on different fields such as management of personal projects, support of biological memory, goal management and personal development management, personal information management, self-supervision, self-monitoring, recording of user experiences, personal healthcare management can be done.

It is possible to develop the system in the areas mentioned below:

- Textual search can be done on past experiences by scanning the screenshots caught via optical character recognition software and indexing them.
- By applying face recognition and image recognition feature on the camera capture images, it is possible to tag past experiences automatically.
- By using tree and graph approaches together, a semantic hypertext space which enables us to visualize the relationship between all of the experiences recorded and their relationship with the contexts they are within.
- A portable version of the system which works on USB stick can be developed in order to mobilize the system.
- The R&D activities can be done for transforming personal knowledge base systems based on life logging to life long memory support systems and then transforming them into personal AI systems gradually.
- Life logging system can be enhanced with different types of sensors such as audio, video, GPS, environment and biological etc.

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