Building a flexible CBT model based on structured data for the COPE app

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Abstract

Over the last few years, several research initiatives have been taken to investigate the potential of internet-based Cognitive Behavioral Therapy (iCBT) to help in addressing the growing global demand for psychologists and psychiatrists providing therapy for various types of mental distress, as the amounts people with mental problems are growing world-wide. iCBT is either given as guided (with net-based support of a therapist) or self-guided (the patient is working with the application alone). iCBT allows for the patients to carry out daily CBT activities in their own convenient hours, which can be an advantage for many.

However, drawbacks of these self-guided applications, and in particular self-guided iCBT, can be that if contents adaption and personalization of the therapy processes are not appropriately designed, then there are chances of patients losing their interest and motivation towards therapy completion using their mobile device. This calls for a new type of self-guided iCBT that is adaptive and more tailored towards the needs of each patient. In other words, to give the patients therapy that is more suited to patient's individual therapy needs, characteristics and preferences. Thus, increasing patient adherence and providing for more effective treatment outcome.

This thesis outlines a proposed model for adaptive personalized iCBT therapy for breast cancer patients that after cancer treatment are suffering from stress and other mental problems as side-effects of the cancer treatment and the process they have gone through. The main aim is the development of a design framework and building of a domain model for personalized iCBT therapy. The domain model of the iCBT therapy will be a core component in adaptive personalized iCBT therapy application to support breast cancer patient(s) with CBT content adapted to their mental health context.

The main aim of this thesis is to formulate a flexible CBT domain model for the COPE application where it provides treatment to breast cancer patient(s) with CBT contents adapted to their mental health condition and preferences. The CBT material were accumulated based on resources of previous research articles and guidance of respective domain experts. The conceptualization and domain ontology is meant to analyze the CBT materials for psychological and physical symptoms of breast cancer patient who are suffering from mental distress after breast cancer treatment.

The structured CBT materials in domain model is modelled using tool UMLet for modelling and the ontology editor tool Protege for domain ontology. The present work proposes a new ontology for CBT domain model with the goal of capturing domain knowledge in mobile iCBT environments. The previous literature study aid to construct CBT learning materials for essential mental health disorders and their symptoms. These are organized to capture essential aspects to address breast cancer patient needs that can help to build adaptive personalized iCBT self-guided therapy.

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List of Abbreviations

BC Breast Cancer

CBT Cognitive behavioural therapy

CIA Data confidentiality, integrity and availability

COPE Adaptive iCBT therapy app

DML Domain modelling language

DSM Domain Specific Modelling

FSI Fatigue symptoms inventory

GMH Global Mental Health

GUI Graphical User Interface

HF/NS Hot flashes/Night sweats

HRQoL Health-related Quality of Life

HVL Høgskulen påVestlandet

iCBT Internet Cognitive behavioral therapy

ICT Information and Communication technologies

ITS Intelligent Tutoring Systems

OWL Web Ontology Language

PMR Progressive Muscle Relaxation

PSQI Pittsburgh Sleep Quality Index

QoL Quality of Life

RQ Research Question

SLATE Science of Learning and Technology

SMART Stress Management and Relaxation Training

UML Unified modelling language

Contents

1 Introduction

1.1 Global Mental Health

Global Mental Health (GMH) is a global health program which focus on mental related illness and how to provide treatment with other improving methods for various forms of mental illness. It follows a set of general principles of global health domain and offers strategy of outline to better treatment facilities that includes identify and treatments of different forms of illness (Patel & Prince 2010). There is estimate around 165 millions of people are affected by various forms of mental illness (Kessler et al. 2012, Wittchen et al. 2011). Among mental illness, prevalent forms are stress, anxiety disorder and depression and we find these problems across the world all including Europe as shown in fig. 1.1 and 1.2. It has been observed that people are affected by illness at any time of their lives,independent of income and class country's social and irrespective of a country economy.

On economical aspects across Europe, mental health problems affects more than one out of six persons with a total cost estimated to € 660 billion in 2015. This cost amounts to more than 4 % of GDP across 28 European Union (EU) countries (OECD & Union 2018). Fig. 1.3 show that total estimated costs involving direct and indirect costs related to mental health problems. For Norway, the estimated cost for mental health related problems were estimated to be 4.97 % of total GDP cost in 2015. Also, direct (visible) and indirect (invisible) costs related to mental health treatment are expected to double in 2030. It is important that sufficient resources for mental health care must be provided to patients to reduce economic costs in the future and to avoid the cost burden of health and social care provisions, as well as other indirect costs such as lost employment.

Recently it was observed that studies performed to understand adverse mental health outcomes in breast cancer (BC) women survivors (Carreira et al. 2018). There are also sufficient proofs established that most breast cancer patients or survivors remain vulnerable to psychological disorders for many years even after treatment were completed (Andrea et al. 2016, Antoni et al. 2006, Bloom et al. 2004, Cunningham 2000, Schmidt et al. 2018). The most successful treatment for mental illness has

been the cognitive behavioural therapy (CBT) approach.

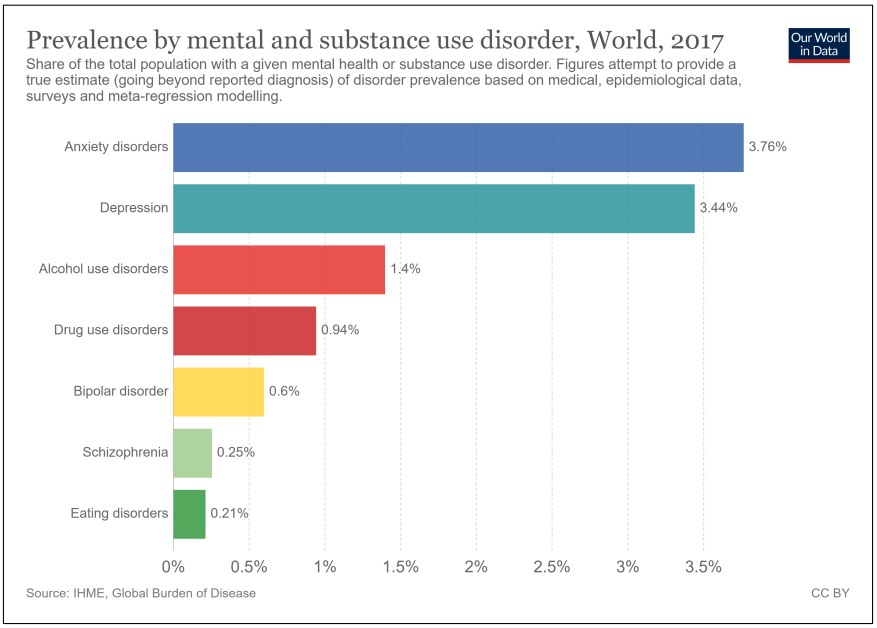

Fig. 1.1: Prevalance of mental ill health: Worldwide. Source: Ritchie & Roser (2020)

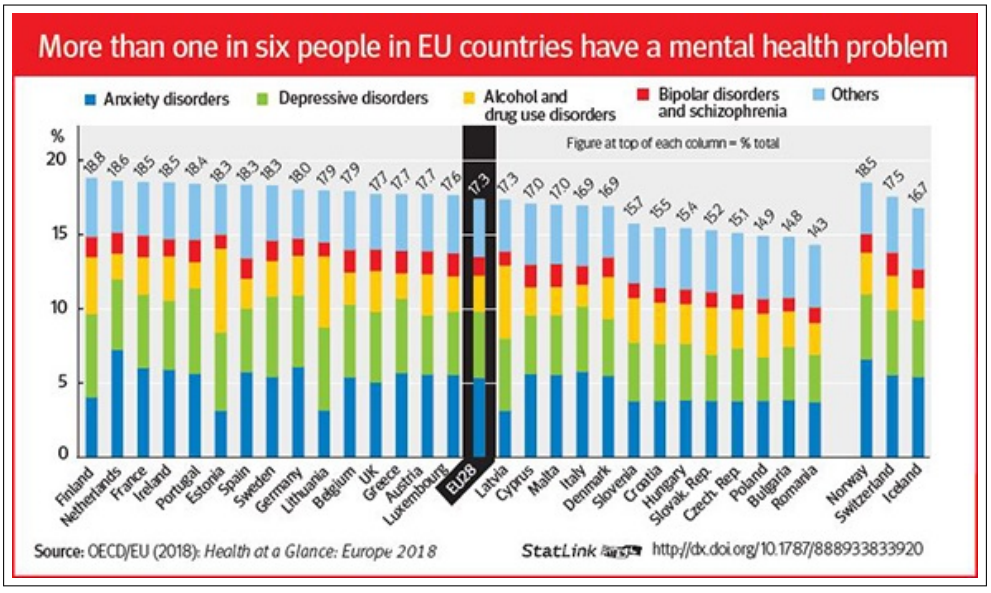

Fig. 1.2: Prevalance of mental ill health: EU map. Source: http://oecdobserver.org

The CBT approach is based upon accepted evidence-based treatment used to treat major mental health distresses (Hofmann et al. 2012). Previous successful studies has

showed that CBT are effective in improving the patient's control of the symptoms, effective state and cope with the disease. This has led to significant improvement for the patients in terms of quality of life and in terms of daily life activities (Cobeanu & David 2018, Matthews et al. 2017).

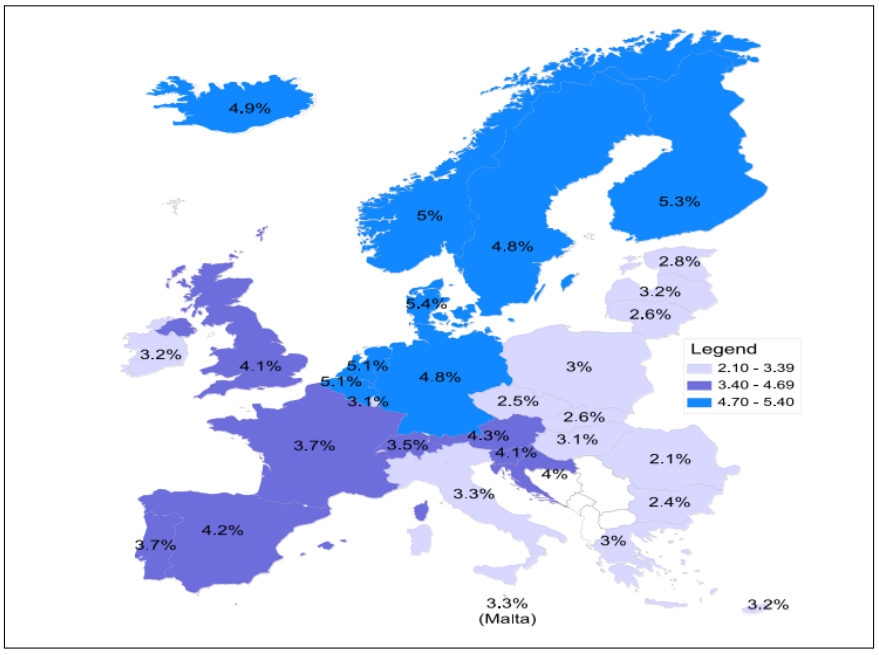

Fig. 1.3: Direct and indirect cost distribution related to mental health problems across EU countries. Source: Health at a Glance: Europe OECD & Union (2018)

Fig. 1.4 illustrates the outline of CBT. Traditional CBT therapy is considered to be resource demanding (Ebert et al. 2018). This has caused a need to develop a new form, internet-based cognitive behavioral therapy (iCBT) which has given online access to therapy for patients using any convenient mobile device or computer. This availability enables users to incorporate therapy into their daily lives where they can schedule their time working with the app accordingly with or without therapist guiding during the process.

There are two types of iCBT, guided iCBT and unguided iCBT. Unguided iCBT provides complete through fully automated CBT programs delivered on a cellphone or PC.This offers patients to get therapy at low cost and with less fear of stigmatization. Also, it provides for evidence-based treatment at a low cost, and for privacy enabled therapy to all low- and middle-income countries where access to psychiatrist

and psychologists might be limited.

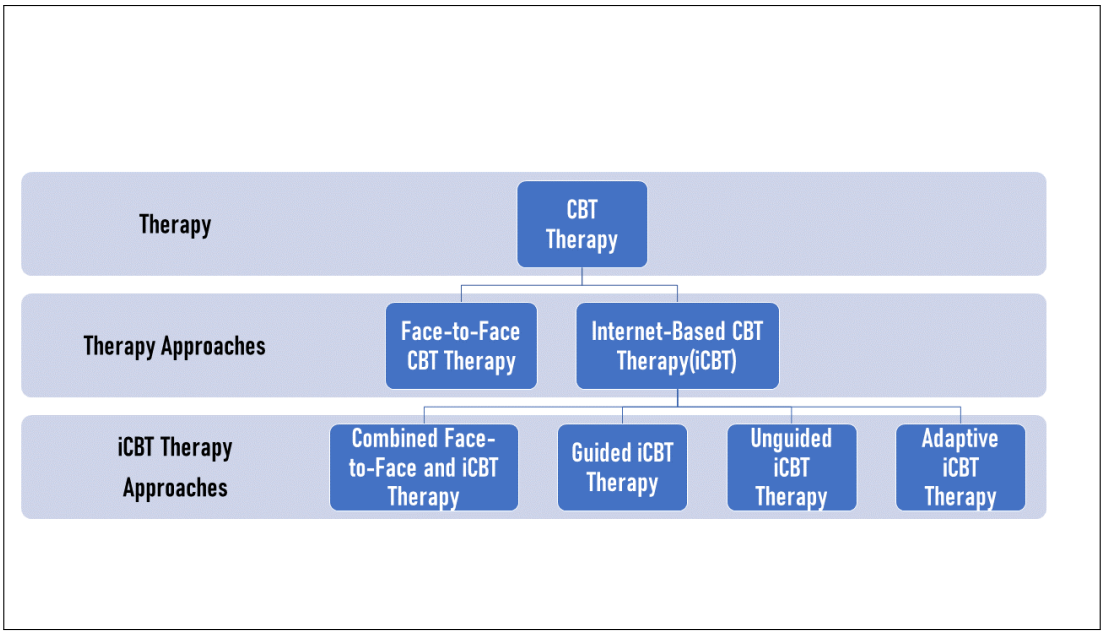

Fig. 1.4: CBT therapy approaches.

A notable limitation of unguided iCBT delivery is that it is not as effective in comparison to guided iCBT and traditional face-to-face CBT (Karyotaki et al. 2017). Another limitation to unguided iCBT is that without the guidance of a therapist unguided cannot deliver instructional CBT material tailored to the individual patient(s). This might lead to dissatisfaction among patients because of unrelated instructional CBT material being offered to diagnose mental, psychological or physical symptoms, and further more, unsuitable CBT activities/tasks or relaxation exercises given for the patients. Furthermore,the capability to provide for additional corrective strategies for coping activities or exercises among patients in these traditional iCBT systems are lacking.

In contrast, adaptive iCBT therapy will continuously diagnose mental health distress symptoms and customize CBT treatment material based on the patient's goals,preferences and progress of treatment. Also, traditional iCBT systems fails to keep track of the patients evolving treatment needs despite of having same CBT material. In contrast, this encourage us to look towards research of how other types of learning systems can be looked at for how to deal with adaptivity in iCBT system.A

possible type of systems to look at are Intelligent Tutoring Systems (ITS). These systems are successful within in education. One such example is SQL-Tutor (Mitrovic 2003).

The main goal of this thesis is to develop flexible domain model for personalized iCBT self-help therapy of COPE application.The software engineering methodology used to build domain specific modelling (DSM) (Bryant et al. 2010).The methodology represent various domain knowledge concepts and its relation and constraints of the system.A domain specific modelling language (DML) as Unified Modelling Language (UML) is used to build domain specific model for an COPE application.

1.2 Motivation

The motivation is to build, design and develop a domain model (or known as domain knowledge) for breast cancer treatment for the COPE application with the following approaches:

1. Application of an adaptive approach for iCBT programs for breast cancer to an existing iCBT domain.
2. While developing this domain model for an adaptive iCBT system, an important question is ; what should one to do to fix difficulties encountered in existing iCBT programs by breast cancer patients to learn CBT coping skills ? To solve this problem, the use of adaptive learning strategies in the current domain model of the system seems to appropriate. This leads us to develop a stable domain model for the COPE system.

This study to build a domain model for such a system was guided by immediate supervisors throughout the whole process leading to reporting this thesis.

1.3 Research goals of thesis

The architecture of the adaptive personalized iCBT therapy COPE application consists of four sub-modules (SLATE 2019), see fig. 1.5

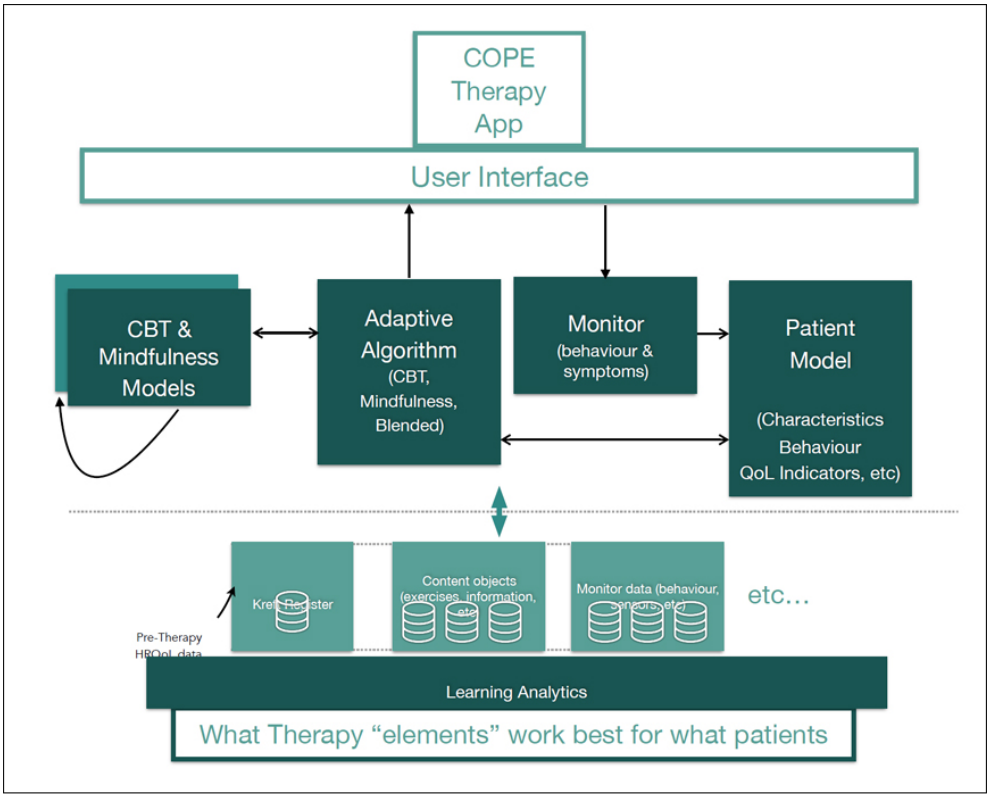

Fig. 1.5: COPE App: A truly adaptive therapy which integrate CBT models and adaptive approach for each individual patient.

- The Domain Model that structures the CBT learning material
- The Patient Model for the patient's data
- The Monitor module for monitoring activities to facilitate individual Patient Models
- The Adaptive algorithm module, which work together with Patient Model and the Domain Model to provide for adaptive therapy.

Thus, for creating the COPE application, we need to first understand (1) who the end users are and (2) what the CBT learning materials is.

The end users of the COPE application are women that suffer from various mental problems after being successfully gone through breast cancer treatment.

The main CBT learning material will consists of CBT treatment modules for mental disorders and coping activities. The domain model, that structures this learning

material is composed of main ontologies is CBT treatment modules.

The main objective of this thesis is designing the conceptual models and developing domain ontology for domain model of the adaptive personalized COPE iCBT therapy application. To our best knowledge,our domain ontology are intervention for breast cancer patients with mental illness.

The main purpose of the conceptual models and domain ontology for COPE domain model are as follows:

1. Gather and analyze all the relevant CBT intervention treatment modules from domain experts.
2. Build CBT intervention for online self-guided therapy for end users.

In order to build domain ontology, we first need to analyze and specify mental health disorders with respect to breast cancer treatment. This means specifying the context of use and requirements of the users of COPE application.

1.3.1 Research Questions

The overall research questions of this thesis are related to how to build a domain model for adaptive iCBT in the COPE application. Specifically, we look towards addressing these following research questions (**RQs**):

RQ1: How to identify an iCBT overall model with modules that facilitates personalized or individualized iCBT therapy?

RQ2: What sources can be re-used from previous literature for creating our domain ontologies of a CBT domain model for personalized iCBT therapy?

RQ3: How to identify treatment contents for each iCBT treatment module in detail from a traditional CBT therapy approach?

RQ4: How can meta-knowledge of treatment modules and sub-modules be organized and structured for personalized iCBT therapy?

RQ5: After identification of meta-knowledge on personalized iCBT therapy, how can various treatment in sub-modules fit with various diagnoses/symptoms/patient goals?

RQ6: In which are various ways can we present the same CBT content with different modalities such as text/video/audio and at which various levels of complexity ?

1.4 Research Methods

In this thesis we aim to address the limitations of the traditional self-guided iCBT approach and follow a design science methodology approach to identify the process that are relevant to the present study. The process of designing an artifact to solve a real problem remains the core of the research with the goal of scaling up iCBT treatment to individual breast cancer patients with mental health issues. In the present thesis, a prototype application domain model has been designed.

1.4.1 Design Science

The Design Science methodology for information systems research focuses on development and performance with clear intention to improve the functional performance of the artifact (Peffers et al. 2007). There are six steps prescription are outlined when applying this methodology. These steps include creating an artifact to solve a relevant problem in practice, whereas in this thesis we used this methodology for designing sub-component of an artifact. The following six activities are defined as:

1. Problem identification and motivation
2. Define the objectives for a solution
3. Design and development
4. Demonstration
5. Evaluation
6. Communication

In Section 1.2, the motivation is described with following problem relevance guidelines defined by (Hevner & Chatterjee 2010). This guidelines state that development of technology based solutions is the core objective of design science research and that the solutions offered are critically important to business problems. Sect. 1.1 discuss the importance and relevance of the problems in traditional iCBT. Furthermore,the next two sections describe the importance of the problem identification process, and

the objectives for the design science solution. The Architecture of the artifact and design and development of domain model sub-component of the artifact are presented in Chapters 3 and 4. The demonstration and the evaluation of domain model are presented in Chapter 6 and Chapter 7. These represent the communication activity, which is elaborated in chapter 8.

1.4.2 Problem Identification

One of the key challenges for personalized self-guided iCBT development in this thesis project is to make involved and motivated delivery of CBT instructions for breast cancer patients. Also, an important part of the iCBT development activity is to have clear therapy outcomes with relevance to CBT practice in a real world context. The developers and designers of an iCBT development must develop to offer correct balance when considering patient's requirements with respect to their therapy needs (and undergoing their previous medical history), their progress and meeting their specified therapy outcomes.

Domain knowledge development through gathering knowledge on mental health distress in women after having gone through breast cancer treatment was initiated through attending presentations of Dr Michael H. Antoni and the director of Kreftregisteret of Norway at Høgskulen på Vestlandet in June 2019. Dr Michael H. Antoni, a professor at university of Miami, presented his research focus on SMART (Stress Management and Relaxation Training) program. The SMART program covers insight about mental health problems that are related to breast cancer patients, and treatment to such problems through a CBT approach for older women (Antoni 2016). The second presentation (by the director of Kreftregisteret of Norway) gave more information about mental health distress problems among breast cancer women and their suffering.

In personalized iCBT therapy system development, domain ontologies are used to build a domain model for the COPE application. A workshop was held at SLATE/UiB to achieve CBT domain model requirements. After this workshop, several meetings were held with supportive domain experts in mental health, psychiatrist, ICT professor and supervisors who had many years of experience on iCBT domain. On the software development part, three other students of software engineering worked in parallel to develop other sub-components of the COPE application.

In addition, specifications on how to adapt an iCBT system for breast cancer patients with different design of instructions were performed using a high-level abstraction. The knowledge modelling for domain concepts for specifying iCBT aspects, adaptive aspects, CBT domain learning aspects and problem-solving accepts were developed by the modelling language. A seamless integration of all previous mentioned knowledge elements with the help of domain conceptual models were represented by modelling language and are provided to be effective and easily understandable by both domain expert and developer. The CBT domain learning aspects, problem-solving and adaptive aspects were merged for final domain knowledge representation of personalized iCBT therapy application.

The main goal of the present thesis is first to create the conceptual models by capturing domain knowledge from domain experts and implement a domain ontology for the CBT domain model of personalized iCBT therapy known as COPE for breast cancer patient survivors.

1.4.3 Objectives for a solution

To solve the identified problems during the process as discussed in section 1.4.2, first we searched for a tool to create conceptual models. Then we performed a literature survey to identify a common approach taken to develop a ontology based domain model as discussed in (Falbo et al. 2002, Tairas et al. 2009). Falbo et al. (2002) show a clear ontology development process.

The steps are as follows :

1. Purpose identification and requirement specification
2. Ontology capture
3. Ontology formalization
4. Integrating existing ontologies
5. Evaluation
6. Documentation.

Steps (1) to (6) cover analysis and development of ontologies using an ontology language. We follow a similar approach to understand the domain and design the

domain model.

A considerable effort was invested in research on understanding the collected information regarding the domain. Coverage of domain knowledge within a large domain made a significant problem for creating a conceptual models to cover the entire domain knowledge for all mental health distress symptoms for breast cancer patients. Hence, we focused on the domain knowledge of four common major mental health distress psychological and physical symptoms (refer to section 2.2 for details) that women suffer after breast cancer treatment.

The cognitive behavioral therapy(CBT) approach opted for treatment of mental health distress that are psychological and physical problems women undergo after breast cancer treatment. The learning material used was based on a CBT therapy course for treatment of mental health distress symptoms and tutored through an Intelligent Tutoring System (ITS) approach. One of the main reasons for selecting an ITS approach for COPE was the fact that some iCBT programs are available to treat mental distress during breast cancer treatment, but these are all non-adaptive and could not be used as a point of comparison. Personalized learning or an adaptive learning using ITS technology in educational has proven to be effective (Moiz et al. 2018, Woolf 2009), could provide for the same within iCBT. Personalized self-guided iCBT therapy will be motivated by the traditional self-guided iCBT challenges and will also benefit by the use of artificial intelligence(of ITS) along the way.

Conceptual models and the domain ontology development process are based on domain knowledge. During the development phase a detailed study of the use of domain modelling language(DML) for designing conceptual models and also use of ontology models was performed. DML and ontology languages, as well as different tools that could be used for this purpose were also evaluated. The pro's and con's of using these methods and tools were noted.

A diagrammatic representation which encapsulated essential features of domain concepts, constraints and their relations were created using domain modelling language. Visualizing an domain knowledge presented through software program (i.e. domain modelling language) approach using a collection of diagrams help domain experts to understand with ease the represented knowledge in domain model,therefore developers uses visual languages to convey information to domain experts. The visual

models usage led to ideas for achieving higher levels of abstraction at the end of the modelling process. The graphic notation and semantic rules represents the different concepts and relationships in the domain model of the application.

1.4.4 Ethical declaration

The present work involve of building a domain model that can support CBT intervention information for the COPE application development, this was done through a literature search for mental illness among breast cancer patients and under guidance of domain experts. Consequently no real patient data was used for building artifacts. The collected journal articles that are used in thesis have been referenced correctly. So, ethical approval was not necessary or required.

1.4.5 Thesis Structure

An outline of thesis is presented here. The most important topics of each chapter are presented briefly.

- **Chapter one** covers an introduction on global mental health, CBT and iCBT therapy in different environments, motivation and problem identification for this thesis, as well as objectives for a solution.
- **Chapter two** presents the scope of the COPE application, breast cancer background and mental side effects after breast cancer treatment. It also covers CBT principles (with advantages and limitations) and iCBT approaches (covering all aspects). It captures the difference between CBT and iCBT treatments and highlight existing iCBT treatments for breast cancer patients. At last, it cover related work to the current thesis.
- **Chapter three** presents the architecture of the application, the role of the CBT domain model (in COPE application) and the knowledge representation within the CBT domain model.
- **Chapter four** contains the purposed domain modelling for the COPE application and the language used to design conceptual models based on knowledge representation in chapter 3.
- **Chapter five** contains the adaptive aspects for the CBT domain model in

the COPE application, design aspects of CBT domain model for the COPE application based on the results from chapter 4.

- **Chapter six** presents the overall implementation details of the conceptual models and detail of the ontology to be used in thesis and development of simple domain ontology model for adaptive personalized iCBT in the COPE application, based on chapter 4 and 5.
- **Chapter seven** presents the evaluation of the designed models. The chapter first presents how domain experts evaluated conceptual models during the development process. Then, it presents the tool and guidelines used to evaluate the domain ontology.
- **Chapter eight** presents findings based on the research questions.
- **Chapter nine** concludes the thesis and discusses further work.

2 Background

In this chapter, the first section gives a short description of the COPE application and follows with an overview that covers research in the area of breast cancer, CBT, and iCBT. Furthermore it covers aspects of adaptive learning and adaptive learning systems known as Intelligent Tutoring Systems (ITS) and recommender systems. Then, the principles of CBT and iCBT and their limitations are described including the difference between CBT and iCBT approaches. Major weaknesses observed in existing traditional iCBT systems are noted from which the research described by this thesis is motivated.

2.1 About COPE

As discussed in Chapter 1 about different environments to provide a CBT in present available technologies, currently we have traditional face-to-face therapy, web based iCBT and mobile-based online systems, and further unique environments that blend many aspects of guided face-to-face therapy and online-based technology and unguided online therapy as shown in fig. 1.4.

In this present project we look to develop personalized (adaptive) iCBT through the COPE application. It provides internet-based self-help (also known as unguided/self-guided iCBT) online therapy, where therapist presence is not needed for personalized/adaptive CBT delivery. Personalized therapy can be regarded as the latest feature of internet-based CBT therapy (iCBT) which utilize technology (such as smartphone). It bring significant changes to patient's experience in online-based therapy, based on their individual requirements, characteristics, preferences, progress path using different levels of interactivity.

A personalized iCBT therapy COPE application can be classified as an ITS or personalized therapy system (Almasri et al. 2019). It can provide facilitates that enables for innovation based on environment for research on internet-based CBT therapy environment that adapt according to patients personal therapy goals, medical background, preferences and progress during therapy, also referred as an evolving patient model. It drifts away from the tunnel view of traditional self-guided iCBT therapy which provides the same therapy for all users/patients (same therapy supposed to fit all) (Danaher et al. 2005). It also utilize artificial intelligence (AI) and

machine learning techniques to offer therapy to patients.

The artifact architecture of COPE (See Fig. 1.5 for details) aid to personalized therapy consists of four components:

- The Domain Model that structures the CBT learning material
- The Patient Model for the patient's data
- The Monitor module for monitoring activities to facilitate individual Patient Models
- The Adaptive algorithm module, which work together with Patient Model and the Domain Model to provide for adaptive therapy.

2.1.1 Scope of COPE Application

Adaptive presentation of CBT learning materials in COPE need to address patients requirements such as therapy pace, preferences on visual perception on presentation done on video and audio as opposed to being presented as text only. The domain knowledge progress are monitored e.g.coping with mental distress symptoms, based on principles of cognitive behavioural therapy. Also, it need to address the various users/patients different levels of understanding CBT principles.

Course sequencing and problem-solving support are main the elements of domain knowledge in COPE (Brusilovsky & Peylo 2003). The course sequencing is based on the patient's needs, goals, medical background and treatment progress. This will aid to adaptive therapy for patients.

Problem-solving support is accounted to provide adaptive guidance to patients to complete CBT activities. To build problem-solving functionality in COPE requires capturing of data from the patient model that defines their learning behaviour of patient.

In the present thesis we focus on a breast cancer CBT domain model that defines the expertise/skills required within an iCBT domain to teach (a CBT therapy course called as a domain model in COPE application).The COPE application domain model will store all domain material that therapists/domain experts recommend for patients suffering from mental psychological and physical distress due to side effects.

These resources will include CBT treatment modules including sessions in the form of videos, audio and their objectives.

Domain model also stores required psycho-education or knowledge required to solve all activities. These include such as how to perform activities (In-session activity) and homework assignments (After-session activities). Also, measuring the progress through self-help questionnaires assigned to patients in the form of activities has to be covered. An activity can be defined as CBT coping skills or relaxation exercises or any other CBT concept in the domain.

2.2 Breast Cancer: background and side effects of treatment

Breast cancer background is the most common type of cancer among women worldwide with 1.7 million new cases diagnosed in 2012 (Triberti et al. 2019). High incidences and mortality rates are estimated in Europe. Incidence statistics in Norway indicated that for women and over 50 cases had risen significantly from 193 in 1995 to 262 per 100,000 women in 1997 (Larsen et al. 2018). Due to more cases,there are also more women that have to deal with important challenges daily, such as coping with mental illness. Some of the common mental illness are (a) stress, (b) anxiety and depression,(c) Cognitive distortions (d) hot flushes and night sweats (e) sleeps problem and (f) fatigue.

Fig. 2.1 show outline of breast cancer statistics worldwide indicating that two million new cases of breast cancer occurred among women. It is observed that developed countries have higher rates than developing countries.

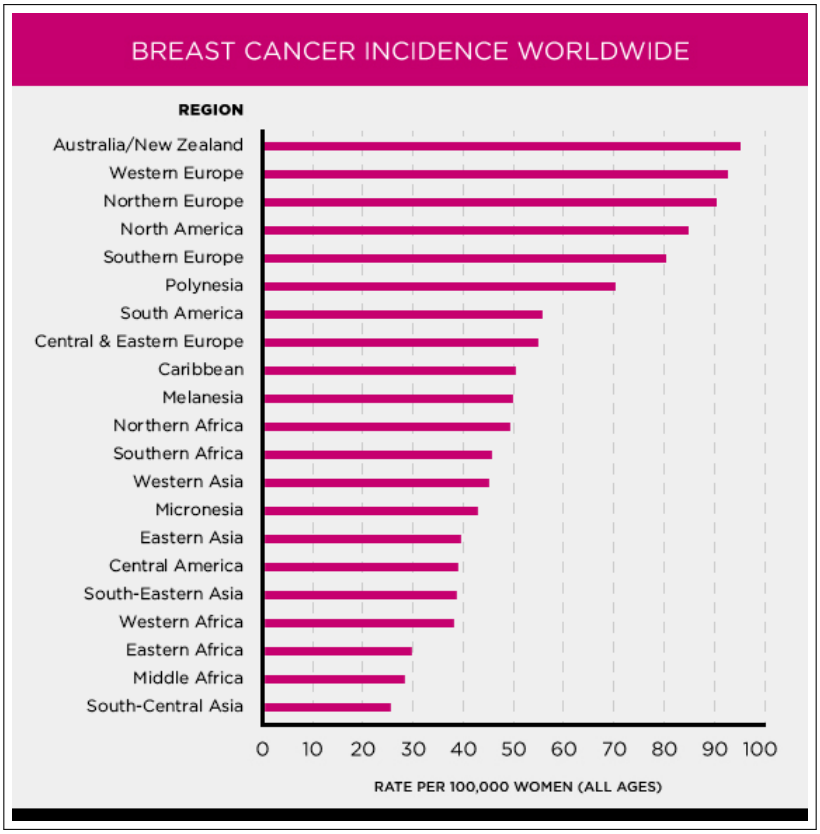

Fig. 2.1: Prevalence of breast cancer worldwide. Source: GLOBOCAN 2012: Estimated cancer incidence, mortality and prevalence worldwide in 2012.

Stress and anxiety can be described as emotional states characterized by feelings of unpleasantness towards cancer and treatment of it. It is an unpleasant subjective experience associated with cancer. Stark et al. (2002) stated that anxiety has two components, physical and psychological. The common physical experiences are hyper-arousal with heart rate acceleration, respiration with or tightness in the chest, tremor, sweating, muscle tension, gastrointestinal changes, sleep disruption and muscle tension. While on the psychological side feeling powerless, worthless, apprehensions, and fearing loss of control in life. Many breast cancer patients or survivors might face uncertainty, worries about cancer treatment after effects, fear about cancer progression and death, guilt, and spiritual questioning. Ashbury et al. (1998) state that 77% of patients within 2 years of treatment recalled experiencing anxiety. The anxiety after cancer diagnosis need understanding of causes. Abnormal anxiety can have long term ill effects on mind and body of patients that can

significantly reduce quality of life (Sheard & Maguire 1999, Sherbourne et al. 1996).

One of psychological influences on mind is cognitive distortions. These distortion are irrational thought patterns. It involve with onset and perpetuation of psycho-social effects that are categorized into mental illness such as depression and anxiety. The breakthrough groundwork to identify distortions was Aaron T. Beck who laid the concept of CBT (Hofmann et al. 2012). This therapy describes personal and professional anecdotes related to cognitive distortions and their elimination through cognitive restructuring. A cognitive restructuring involves keeping record of thought patterns, which can assist in understanding the pathway of tracking dysfunctional automatic thoughts, and devising adaptive alternative responses.

Hot flushes and night sweats occurs during or after treatment and are influenced by reduced sex hormones in the body. Tamoxifen is hormone therapy and it influences hot flushes. The severity of hot flushes varies from person to person. Usually it start with feeling warm in neck or face, which subsequently spreads to other parts of body. The duration of hot flushes varies with some period of minutes to a few months. Usually these are disruptive in nature and make sleep problems during night. The real cause is not well understood and common symptoms of hot flushes are :

- Reddening of the skin,
- Light or heavier sweating,
- Feelings of heart beating in chest (palpitations), and
- Panic or irritability.

Fatigue is lack of energy and feeling tired all the time. It is usually observed as one of the side effects of breast cancer treatment. It is estimated that 9 out of 10 patients experience fatigue in some forms during treatment. Common symptoms includes lack of energy, avoiding social activities, being less focused, trouble in communication and feeling sleepy even after normal sleep hours.

All or any one of these above symptoms reduce Quality of Life (QoL) and sexuality. The diagnosis of breast cancer is always a stressful experience. These aspects together with the emergence of negative experiences in relationships and suffering, guilt and fear of death. Moreover, breast cancer treatment exposure involve changes

in their physical appearance and also in addition the sensation of pain caused by the surgery and limitations in daily functioning have a great impact on family and social areas, including work job. All these changes can affect individuals perception of themselves and their own body image as well. As important for breast cancer patients that their require not only medical attention to the disease, but also dedicated solutions to guarantee long-term care and health management (Triberti et al. 2019).

Common mental health problems that reduces QoLare stress, fatigue, insomnia, hot flashes, and night sweats. QoL can be defined as an important aspect in treatment of mental ill patients and their ability to enjoy normal life activities. an accepted and presently most successful evidence-based treatment is cognitive behavioral therapy (CBT) for these distresses and details of CBT for breast cancer patients are discussed in Section 2.3 (Hofmann et al. 2012). Many previous studies showed that the CBT approach led to significant improvement in patients in terms of quality of life. Breast cancer (in women) is one of severe forms of oncological diseases which affects on QoL. This occurs when breast cells grow without their normal control, which lead to slow formation of tumours in the breast. Some tumors can be aggressive and grow rapidly with years. Due to occurrences of this form, women often experience high levels of anxiety and other forms of mental illness and reducing their QoL (Tang et al. 2017).

One important component of the COPE application is domain knowledge consisting of CBT learning materials, problem solving skills, exercises, tasks, assessments and evaluation. These are used by patients to outcome suffering mental distress due to side-effects breast cancer treatment in their daily life activities. Common major side-effects that are covered under the domain knowledge of the COPE application are shown in fig. 2.2

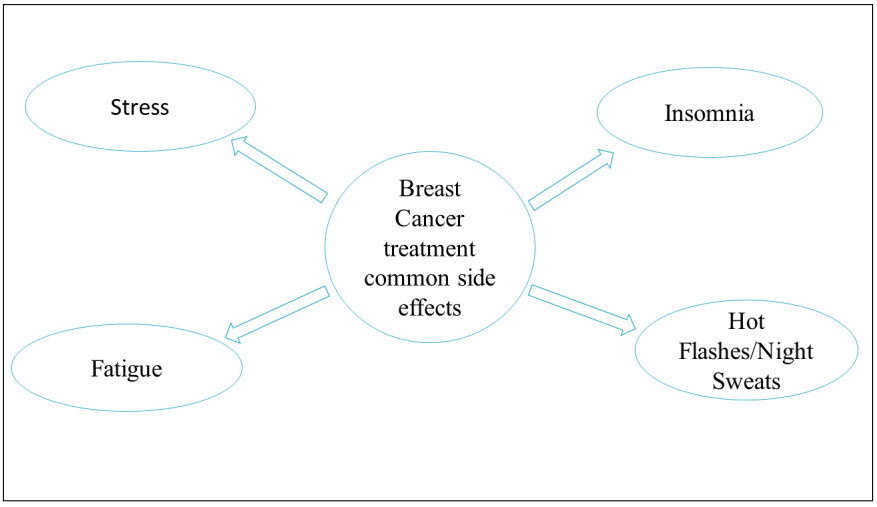

Fig. 2.2: Common side effects of Breast Cancer treatment.

Current international and national cancer guidelines recommends supportive care and assistance for needy patients to get back to normal lives. A variety of psychological interventions have been developed to support cancer-affected patients during and after treatment to reduce unmet supportive care needs (Ringwald et al. 2017). The psychological therapy approach includes understanding that CBT is also an effective approach in reducing mental illness and improving overall QoL (Gudenkauf et al. 2015, McGregor & Antoni 2009, Stagl et al. 2015).

2.3 Cognitive Behavioral Therapy (CBT)

CBT was developed by Dr. A T. Beck in the 1960s (Beck 1997). This treatment or therapy is structured around a cognitive model that use information a processing model and provides an effective approach for a range of psychological illness conditions from minor to severe form. The CBT based on a cognitive model includes people perception, spontaneous thoughts, emotions, situations and behavioral or physiological reactions of an individual. The treatment is specific and tailored according to the individual. The illness treatment covers depression, anxiety disorders, alcohol and drug use problems, marital problems, eating disorders, and other illness of stress, post-traumatic, panic and generalized anxiety disorders (Brewin 2006, Mann & Whitfield 2009).

Many previous studies has shown that the CBT approach has led to significant

improvement in terms of functioning of normal life activities and life quality index for the patients. Looking into other forms of psychological therapies, CBT showed new ray of hope for effective treatment of illness. The other forms of psychological treatment includes psychoanalysis which is based on a Freudian's approach and humanistic therapy which is passive and with little interaction with the patients.

Initially CBT therapy was developed towards treatment of all forms of depression (also from breast cancer) and later extended into other illness such as addiction, anxiety, trauma and psychosis through understanding symptoms. Advances in CBT are based upon both research and clinical practice providing scientific evidence that observe improved changes in patient's behavior. Fig. 2.3 presents the CBT triangle based upon cognitive therapy to understand close links of thoughts, feelings and behavior connected for person behavior. The feelings are influenced by thoughts and behaviors. This approach gives a clear path to address illness and observe improvement of patient well being.

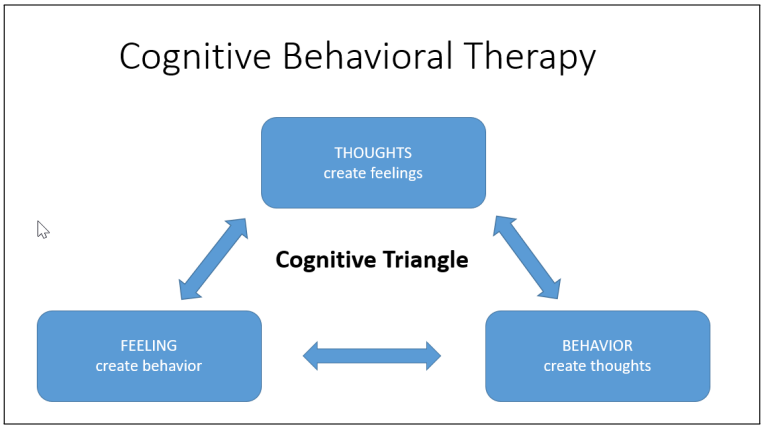

Fig. 2.3: CBT Triangle outline describes all components are connected. (Prentiss Price 2020)

2.3.1 Core CBT principles

The core principles of CBT are based on (Prentiss Price 2020) :

- psychological problems are resulted from faulty thinking in past life events and current life situations.
- understanding repeatable pattern and long term effects of faulty thoughts.

- assisting through cognitive model learning to cope with situations and lead to more effective quality of lives.
- changing thinking patterns and building strategies towards improving people's behavior and self confidence towards solving life problems.
- providing for a new approach by offering "homework" exercises outside of sessions. This enable patients to develop coping skills and also learn to change their own thinking, problematic emotions, and behavior in long term basis.

In recent years it was observed that rational and clear principles based on evidences made CBT popular among therapists. It also made treatment into short-term and structured therapy for individuals (Gaudiano 2008). Therapists are professionals such as psychologists, mental health nurses, psychiatrists, physician who have received cognitive and behavioral therapy training. These therapists treating mental illness patient's based on CBT model state that it helps them to identify, evaluate distorted and dysfunctional thinking among individual patient.

There are various levels of CBT practices delivered according to specific problems to individuals or groups. Also, there are recent development over unguided self-help CBT also referred to as internet-based treatment which differs over face-to-face interaction for therapist and patient. There are many forms of CBT formats offered that are implemented. These formats are made to deliver to different types of people irrespective of race, culture, age, gender and country (Cuijpers et al. 2019).

2.3.2 CBT: Advantages and limitations

CBT has been a successful treatment method to various mental health problems with advantages as listed below Gaudiano (2008):

- It provides for effective treatment to different forms of mental disorders where medication alone are insufficient or inadequate.
- It offers relatively short time periods for treatment as compared to other types of treatment.
- It focus towards re-training individual's thoughts and altering behavior in order to make changes to behavior and allows for feedback on individuals feelings (Mann & Whitfield 2009).

- The highly structured nature can be provided in different formats including for groups, self-help books and computer programs (Gaudiano 2008).
- Useful, practical skills with helpful strategies incorporated to assist individuals to cope better with stress and difficulties even after the treatment is completed.
- It is effective in working with people who have concurrent disorders.
- The primary focus lies on reducing mental disorder symptoms.

While looking into positive aspects of treatment, there are certain limitations that lies within CBT. The disadvantages of CBT are described in the following:

- Expect individual(s) commitment towards each sessions. The therapists assistance and guidance work when individual(s) follow routine/session and cooperate to complete process.
- Extra work between sessions may burden individuals and can lead to a lot of time taken to complete a session.
- Severe mental ill individuals may find learning difficulties in following the structured outline of CBT.
- It engages with emotions and anxieties. It is likely that during the initial phase, patients or individuals may experience anxiousness or feel emotionally uncomfortable.
- It addresses current problems and deal with specific issues. CBT does not cover underlying mental ill causes such as an unhappy relationship or childhood.
- It focuses on changing the CBT triangle (i.e. thoughts, feelings and behaviors) of an individual. It fails to address wider problems of social interaction and a family's influence on an individual mental state.
- It fails to address a person suffering from severe social anxiety that neurological trauma imprint caused in young age. This imprint exacerbated in adulthood because of coping skills to interact with society were not learned in young age.
- Straight forward part of a therapeutic process. The strategies are limited to behavioral changes. It fails to decipher about witnessing, uncovering insights of existential issues.

2.4 Internet based CBT (iCBT)

The emergence of CBT in the 1960s had enormous influence in psychotherapy. The CBT is one of the most researched forms of psychotherapy and many research support group appreciate the CBT efficacy in alleviating mental ill symptoms and also largely mitigate relapsing risk. CBT is suited to target a large range of psychiatric disorders partly due to its flexibility to tailor treatment protocols. Due to the recent rapid growth of internet access, CBT has adapted to being offered as internet-based CBT, which has reshaped psychotherapy. In recent years, CBT has also been adapted to incorporate newly developed interventions and techniques (mindfulness and acceptance-based strategies). Despite this progress, the dominant delivery format of CBT has persisted: face-to-face individual or group therapy.

The development of internet based adaptations of CBT (iCBT), coupled with the exponential growth of internet access. The internet-based psychological treatments has extended CBT approach on interventions. Traditional face-to-face CBT has good results, but access to these treatments are limited. Internet-based inventions enable evidence based treatments to reach to all groups (Andersson et al. 2015). iCBT has been flexible in reshaping towards behavioral and mental healthcare landscape for greater reach to communities (Webb et al. 2017). The WHO estimates that approximately 34 million individuals that are suffering from major depressive disorder (MDD) go untreated in Europe and America each in single year. Major obstacles to treatments were costs, longer waiting time resulting to limited access to psychiatric treatment. Interventions through iCBT has been solution to bridge the gap and provide for facilities to individuals at appropriate time. Different levels of interventions are delivered in iCBT in the form of therapist contact. These levels varies from non-existing to through pre-treatment assessment in addition to support during treatment. Most interventions are CBT and flexible to accommodate in different formats and content. Johansson & Andersson (2012) state that CBT can be transferable to the internet format and provide for both self-help guide and unguided format via internet together with the therapist contact. iCBT also provide individually tailored treatments providing the same content to all patients. A unified tailored approach can be attractive iCBT treatment that may broaden with the help of modern technology through the use of smartphones and AI. The common iCBT programs provides benefits as well as limitations to mental healthcare.

2.4.1 Advantages of iCBT

Internet based interventions with salient features can aid in various ways (Ebert David Daniel et al. 2014, Wallin et al. 2016, Webb et al. 2017):

- Provide easy accessibility from home or anyplace with internet connection. Good feature would increase scalability significantly that boosts functional capacity of the mental health care system. This can provide a possibility to reach mental disorder individuals who have been living in without treatment.
- Accessibility can significantly impact on reducing time elapse for initial screening to a single day session that includes from screening (based on referral), while face-to-face therapy takes order of weeks to initial or first screening session.
- Provide prior appointment to therapist to have face-to-face sessions to be scheduled days or weeks in advance. The patients will get flexibility and feel motivated to engage in with therapeutic content in real time.
- Cost effectiveness of guided and unguided interventions with no human support are affordable and includes flexible therapy to accommodate busy life individuals to make life easier.
- Internet based interventions provide online security and anonymity of users that encourages different personality traits users who are afraid of social stigma will come forward and open about their problems. It will maintain confidentiality of individuals.
- Provide use to work at his own pace, review materials and choose alternatives of treatments available.
- Open and honest conversation are possible than initial face-to-face sessions.
- The programs provide the same content of CBT that is "one size fits all" to every user. It can be as effective as face-to-face CBT. The scalability of program modules will accommodate greater proportion of the eligible individuals to utilize therapeutic resources.
- It can offer multiple languages and latest versions. It can user friendly login and social media sites for greater information about treatment or assignments

given by therapists.

2.4.2 Potential limitations of iCBT

In spite of great flexibility and offering guided and unguided internet based interventions. There are a few limitations related to the use of iCBT. The following are listed accordingly (Ebert et al. 2018, Ly et al. 2014) :

- Not meeting the requirements of a user's expectation could lead to loosing the user's motivation and a premature end to the treatment.
- In deteriorating or no response cases, it can lead to negative attitudes towards psychological interventions.
- Early disappointments have been observed to high expectation participants when they feel lost or not fully understand the structure of the treatment.
- An overall standardized treatment approach sometimes fails to account for an individual's needs for satisfaction or expectation.
- Provide limited ability to identify and assist patients who are prone to self-injury or delivering potential harmful techniques to individuals.
- The reduced health-related self-efficiency should be observed if a participant fail to show or, is not successful in using standalone internet based interventions.

2.5 CBT and iCBT differences

iCBT is a more flexible, online alternative than traditional face-to-face CBT. It allows for low-cost treatment. It might provide for higher participation rate, better compliance, consistency high quality, with providing clinical support for self motivated therapy and better compliance (Atema et al. 2019). It is usually observed that CBT limitations are longer sessions (for e.g. 5-20 sessions on average), sometimes quality are likely compromised, limited geographical availability, may require referrals and recommendation and could lead to longer waiting times.

Internet-based interventions are associated to compliance without therapist support and minimal effects than guided interventions. There are better potential for in-

creasing outreach with low costs with good efficacy of self-managed interventions. Therapeutic work are dynamic as face-to-face therapy and proved to be perceived differently by individuals depending on expectations and outcome (Ly et al. 2014). The evidence-based intervention are limited in traditional intervention due to limited availability, and this can be solved by providing iCBT with psychological interventions. The evidence-based interventions are often free from travel restraints, duration and assisting to provide opportunities to reach individuals who find difficulties in attending or participating traditional face-to-face opportunities (Ebert et al. 2018). There are also benefits to individuals for learning at their own pace, no worries over social stigma, and secure login access for keeping confidentiality for onsite face-to-face options.

The major limitation of iCBT is to access that requires internet for treatment, which is not a issue for many participants. Both iCBT and CBT may achieve success for their similar objective of providing the same treatment, but the commitment and the willingness of the participants are necessary for undergoing treatment. The traditional face-to-face psychotherapy is not attractive form of intervention for all types of people in society. It is generally observed that iCBT with face-to-face therapy is less popular and least recommended for less educated clients with severe condition suffering persons like personality disorders (Andersson et al. 2015).

2.6 iCBT treatments for breast cancer patients

Many breast cancer patients undergoing treatments such as surgery, radiotherapy, chemotherapy, and hormone therapy treatments are shown to have a decrease in health-related quality of life (HRQoL). The most significant side-effect symptoms observed are stress, fatigue, insomnia, hot flashes, and night sweats which negatively affect health of patients. Many research studies have shown that CBT treatment is proven to be effective in reduction of the above mentioned symptoms. However, its limitation on stigma, time constraint that many people avoid, or drop out of therapy, iCBT therapy has shown to have provided relief to overcome those limitations.

Previous studies has shown that iCBT treatments are proven to be effective by both guided and unguided forms of delivery in treating insomnia (Zachariae et al. 2018), reducing hot flashes, night sweats and fatigues symptoms resulting from breast cancer treatments (Abrahams et al. 2017, Vera et al. 2019, Verbeek et al. 2019). The

iCBT programs also shown effectiveness in trans-diagnostic and tailored approaches for treating to an individual breast cancer patients with fatigue, insomnia, HF/NS, stress.

Two types of iCBT approach as referred in Berger et al. (2013), Johansson & Andersson (2012) have evolved into:

- Standardized treatment
- Individual tailored treatment

A standardized iCBT treatment is predefined and stored in the system and used to treat primary specific disorders only. Most iCBT applications are implemented as predefined structured programs with five or more treatment modules which consists of psycho-education, relaxation exercises and some standard set of activities based on psycho-education and specific disorders in mind.

Current iCBT programs are not tailored towards the individual users. Tailoring of iCBT programs typically combines modules from different treatment sets, resulting in different instruction for different users depending on their diagnosis or symptoms. For various types of breast cancer caused mental health disorders, tailoring individual patient specifics has be used in some iCBT programs which directly target breast cancer symptoms such as insomnia (Zachariae et al. 2018), fatigue (Abrahams et al. 2017), HF/NS (Vera et al. 2019). These specific problem tailored iCBT programs can be seen as having larger impact on treatment with positive outcomes than standardized iCBT treatments. Here however, only the contents are tailored to the patients problems, and not towards their initial needs and preferences. Also, the study by Atema et al. (2019) shows that by addressing specific post-cancer problems an effective iCBT program can reduce the costs for healthcare.

To our knowledge and after literature search to date, iCBT programs are offered as structured or diagnosis-specific treatments where patients preferences are not taken into consideration. The approach to adaptive iCBT aims to address the limitations by tailoring individual treatment for breast cancer patients. Stress is a common type mental distress among women after successful breast cancer treatment. However, patients with suffering from stress may have other stress related symptoms and other conditions which is not related to stress but related to different surgical treatments and that they want to address such as insomnia, fatigue, HF/NS.

2.7 Structured data in existing breast cancer iCBT programs

Videoconferenced Stress Management for Women with Breast Cancer (VSMART) is a CBT program for breast cancer treatment for women(Antoni 2016). This program offers group-based sequential treatment therapy which involves interview process, therapist diagnosis and it provides for tablets to the patients. In this program, the patients have access it to many features such as meeting experts, demonstrations, educational videos etc, but the downside of the program is that it is available sequentially through modules and addresses a older aged women only.

Another internet-based iCBT program called Stress Management App Intervention for cancer survivors therapy, is delivered through mobile or PC (Børøsund et al. 2018). In this treatment program the first step is a face-to-face session between the patient and the therapist, were the therapist introduce the app to the patient. Fig. 2.4 shows the first four treatment modules which are sequential (no therapist guided application). The remaining 5–9 modules are optional. This app is delivered in the form of iCBT for treatment-induced menopausal symptoms in breast cancer survivors program and it is guided iCBT starting with a therapist interview followed by the iCBT program which consists sequential of seven modules (Atema et al. 2016).

As we observe in all these different iCBT programs all of them are therapist guided with structured therapy. The current problem in all these traditional iCBT platforms is that they cannot offer customization or personalized therapy for the patient, and that they can only offer sequential/identical or tailored CBT treatment modules to all the patients in a tunnel manner instructional style. The tunnel style is based on a strict step-by-step approach in a predefined order, instead of free access to treatment content such as, activities, exercise, psycho-education (Danaher et al. 2005).

All traditional iCBT therapy utilizes this tunnel style of delivery, and set number of treatment modules that consists the CBT structured CBT content. Patients are also assigned task to do at home on their own in between online sessions. Some guided iCBT programs tailor the feedback and recommendations through email, text messages, pop-up messages and telephone initiated by the guiding therapist. However, the main disadvantages of the tunnel design is that some patients find it to be too time constraining, unfamiliar and inflexible, and patients get frustrated

when they cannot find the right therapy based on their mental health issue. The second main challenge of the traditional iCBT therapy is that, because of tunnel style which does not allow the patients to do CBT activities according to their preferences, treatment needs, or activity based on mental health symptoms, and activity based on symptoms based on other symptoms it might result in patients dropping out from the program due not fulfilling their treatment needs or because it makes them use unfamiliar or not useful treatment modules, activities etc, which at end of the program maybe half of the enrolled patients do not feel that the program is helping them in coping with their mental health issues.

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Fig. 2.4: Overview of StressProffen iCBT treatment modules: Improving QoL. The Reuse diagram was reproduced and taken from (Børøsund et al. 2018)

Module 1 Welcome	▪ Introduction to the online program
	▪ Psycho-education about the effect of breast cancer on menopause, menopausal symptoms and the influence of relaxation.
	▪ In-session assignment: making a schedule for reading the sessions and doing homework
	▪ Homework: keeping a hot flushes and night sweats diary; practicing relaxation techniques
Module 2 Hot flushes	▪ Psycho-education about the physiology of HF/NS and the role of thoughts, feelings and behaviors
	▪ In-session assignment: recognizing patterns of and triggers for hot flushes; cognitive restructuring of unhelpful thoughts
	▪ Homework: as before + monitoring triggers and applying helpful thoughts
Module 3 From stressing to relaxing	▪ Psycho-education about stress, the relationship between stress and hot flushes, cognitive and behavioral stress management techniques, relaxation.
	▪ In-session assignment: identification of stressful events, usual reaction to stress and goal setting to reduce stress
	▪ Homework: as before + implementation of stress goal
Module 4 Improving sleep	▪ Psycho-education about sleep, sleeping problems and how to improve quality of sleep, cognitive and behavioral reactions to sleep problems/night sweats.
	▪ In-session assignment: sleep hygiene questionnaire, goal setting to improve sleep.
	▪ Homework: as before + implementation of sleeping goals
Module 5 My body and sexuality	▪ Psycho-education about sexual problems and weight issues, cognitive and behavioral precipitants and consequences of sexual problems and weight issues.
	▪ In-session assignment: goal setting for sexual problems (if present) and weight issues (if present)
	▪ Homework: as before + implementation of goals
Module 6 Keep progressing	▪ Psycho-education about the (benefits of) using an action plan.
	▪ In-session assignment: identification of helpful cognitive and/or behavioral strategies as discussed/learned throughout each module, goal setting for maintenance plan; identification of possible barriers and how to overcome them.
	▪ Homework: as before + implementation of maintenance plan

Fig. 2.5: Description of program modules. Reproduced diagram taken from (Atema et al. 2016).

In the all three presented traditional iCBT programs, when the therapist introduce patients to the iCBT treatment program, the CBT activities and exercises are integral part of the treatment modules. The activities exist within treatment modules as standardized and are presented in sequential order similar to how the modules are organized, where each module build upon the previous modules and, where the patient gets access to activities only after receiving and reading the weekly feedback from therapists and completing the previous module. Then the patient is given access to the next module. This makes it difficult for the patients to access activities based on their preferences or characteristics, or based on their current psychological symptoms.

Even though treatment is effective in many ways because of inflexibility for accessing particular treatment module activities in traditional iCBT programs leads to limitations. Adapting this structured traditional iCBT data and making personalized

approach for individual patients could be an important and interesting topic for this thesis.

Among the important CBT structured data are the CBT activities in the treatment modules. This data can be used to adapt treatment approaches according to the individual breast cancer patient needs based on the treatment side effects symptoms on specific diagnosis for examples stress, fatigue, insomnia, HF/NS and/or stress related side effects or/and trans-diagnostic related symptoms. Symptom monitoring can provide that data in the COPE application is used to provide personalized therapy based on the current treatment needs of the patient. The adaptive therapy approach gives patient self-controlled, flexible coping activities based on their current mental health issue, with no time constraints on doing the activities or treatment sessions. Also,this adaptive treatment approach can be used to track adherence of the treatment program, increase the treatment outcome and provide for less dropouts from the application.

2.8 Related Work

2.8.1 ICT for adaptive in learning

In recent decades, the adaption concept has been introduced in the field of educational systems research to meet new demands from the students. The design development to integrate information and communication technologies (ICT) at schools and colleges has resulted in more flexible education to deliver with more accessible features irrespective of time and place. Introducing the concept of adaption has been important in research of learning systems due to limitations identified in traditional learning systems. Traditional systems often fail to consider the needs and characteristics of a diverse group of learners, their learning abilities and knowledge and skills, and learning content (Alshammari et al. 2014).

Verdú et al. (2008) showed in their study that adaptive learning systems had greater effectiveness in learners ability in performance and improvement in learning to achieve their goals. It is also observed that with no or less previous knowledge learners showed remarkable improvements through adaptive learning's. These various adaptive methods and techniques proved to be feasible and useful to allow for learners to make progress at their own pace at their convenience compared to tra-

ditional learning systems. It was also shown that in learning the content that was effective to educational learning system was ultimately relied upon learning content delivery.

Traditional iCBT system are similar to that of educational learning system where significant improvements are needed owing to lack of personalized learning. In traditional iCBT systems has described in Section 2.6 showed that systems provided same CBT treatment modules in the standardized structure and content for all diagnosed mental distressed patients. So it is very essential to incorporate adaptive learning platforms to traditional iCBT systems to make CBT therapy treatment online and also distinguish the differences between diagnosed breast cancer treatment symptoms between patients and deliver personalized therapy according to each patient requirements. In present work this is primary focus to incorporate adaptive learning platform in CBT therapy content in COPE application. Adaptive framework is described in Section 3 which enable a data driven approach to personalized CBT treatment content delivery that is called as a domain model.

As mentioned in Section 2, there were no previous work or iCBT literature found in internet-based therapy or personalized applications/system for use of iCBT for specially breast cancer patients.

Multiple adaptive educational systems for personalized learning were identified through searching scientific literature databases. In the present work, adaptive learning methods implemented in education systems provided an idea to build adaptive platform with personalized therapy for breast cancer patients. The following section will describe implementation of ICT adaptive learning methods in education domain and how these methods can be related to the main COPE application.

2.8.2 Adaptive Systems

In recent years, personalized therapy in iCBT domain has become one of most sought technologies. The basic idea of personalized therapy is aiding to meet individual patient's needs during the process. For example, recently it is observed that with growing mental health therapy needed for women treated with breast cancer. This can be found to be difficult to scale based on their individual needs, preferences and progress towards recovery and adaptive technology can assist in iCBT therapy for

meeting individuals requirements. It has been found that there are many adaptive learning technologies successfully implemented in education domain where learners take many different pathways within a learning environment. In last decade, latest advancements in adaptive learning in education were in two methods of intelligent tutoring (which used to simulate one-to-one individual tutoring) and recommender systems (which used to provide adaptive learning to learners based on their individual preferences).

- **Intelligent Tutoring System**

  Intelligent Tutoring System (ITS) was first created in 1970s which was used in education system to teach students geography knowledge (Ma et al. 2014, Woolf 2009). It is based upon computer-based learning system which uses artificial intelligence techniques to adapt to the learner. It provides learners with individualized immediate instruction and feedback without human teacher intervention while using artificial strategies. ITS has evolved into various domains such as medicine, law etc. it assists learners to acquire domain-specific, cognitive, and meta-knowledge and designs significantly differs over traditional computer-based instruction system that follows "one-size-fits all" strategy of delivering content (Ma et al. 2014, Woolf 2009).

  In computer-based instruction employ same strategy of delivering content to a passive learners while in ITS they are able to dynamically customize learning experience to receiving student. It is based on main factors such as pre-existing knowledge, learning style, and progress of student through the content material. In education system, general accepted components are interface, domain model, student model and tutor model (Ma et al. 2014). An interface communicates with learner which is often constrained to domain. Interface determines the moves learner makes in solving problem and seeking information or responding information. A domain model which represents suitable knowledge format such as natural language statements, production rules and knowledge that student is intended to learn. A student model that represents relevant aspects of the student knowledge are determined by the their responses to queries or other interactions with the interface. A tutor model represents instructional strategies that offers a hint when student struggles to grasp a correct response. Ma et al. (2014) study showed that ITS found to be

more effective than other computer-based modes on instructions.

- **Recommender systems**

  Rapid rise of online learning resources are coming up to offer of new method to education courses recently. Learning systems therefore personalized learning became a significant challenge due to popular learning method of e-learning that use recommender systems in e-learning domain. The recommender system in e-learning offers or recommends relevant learning materials to learners and assists in decision making (George & Lal 2019). It retrieves and also filters the learning resources to present it to the learners. The recommnders systems are defined as systems retrieve and filter the data through content and similar profiles are known as recommender systems (Rivera et al. 2018). For e.g. in educational domain, recommender systems aims to predict preferences of learners and offer recommendation related content and tasks that are quite likely to be interesting to them. The recommender systems can be widely seen in retail, music streaming domain.

  In iCBT therapy, recommender systems aspects can be applied to all learning material course. Each therapy course contains as set of concepts and these are related to different learning objects. By using recommender systems aspects, contents of concepts are can be changed according to the learner needs.

3 Method and design

In Chapter 2, we reviewed in the research field of adaptive systems and what it use for. In this chapter first will present architecture of adaptive COPE Application and we discuss the role of domain model and then knowledge representation in domain model. The knowledge representation is about CBT materials and is stored in the COPE system CBT domain model.

3.1 Design Process

The design and building models for the COPE application, regular meeting were held at every 15 days to evaluate the model and to discuss its representations. In these meetings, conceptual model were presented and discussed with supervisors who have experience working on iCBT applications. There were 3 master students of health informatics working on the same project (but working on different components in the COPE application and were also participants to these meetings) in the COPE application.

It also added advantage of conducted meetings and workshops in SLATE/UiB with Professors in mental health, ICT. We also gathered information using related documents analysis journal articles. The design and building model reviews were carried out until it satisfied to design science objectives.

The design and building of the domain model were split up into four stages,

1. **Identification of the domain problem :** As discussed in Section 1.4.2 on problem identification, first goal was to extract knowledge from CBT domain experts about common symptoms women suffer mental distress after breast cancer treatment and understanding other aspects such as working of traditional existing iCBT treatment. Next task was to identify strategies to represent existing knowledge of iCBT domain so that CBT therapy materials can be presented to the breast cancer patients more effectively. In any application there are some form of domain knowledge collected in database of those applications and present research therefore we focused towards on two important aspects, how facts and rules will be represented in domain knowledge (in the adaptive iCBT domain model) and second was assessing of facts and rules when it is requested by user.

2. **Analysing the identified domain problem :** In this step, after extracting knowledge of concepts and heuristics from the experts we analyse and primarily decided to design conceptual models to understand how knowledge can be presented in better way. Then later we decided to transform the models in a formal form to represent knowledge that is to develop the CBT domain model for system from scratch using ontology. The domain specific language is used to represent domain conceptual models. Domain ontologies is used to define the logical structure of the CBT materials of iCBT domain. Then later developed CBT materials ontology can be used as a domain sub-component in developing adaptive personalized iCBT therapy.

   In this stage, various tools are identified and analyzed. Those tools whose features fit the characteristics of the problem are analyzed and decided to include in detail.

3. **Prototype development:** For domain model prototype development we followed ontology development process as mentioned in objective solutions in section 1.4.3.

   (a) **ontology capture** Here we captured relevant CBT domain concepts and its relations by collecting information from domain experts. Those collects knowledge designed as conceptual Models using UMLet tool. The designed conceptual models helps to refine models during development process with guidance of domain experts. Models presenting as graphical representations helped us to better communication with domain experts.

   (b) **ontology formalization** Here we explicitly represented the conceptual models designed using graphical language captured in a formal ontology language using Protégé ontology editor in this study.

   (c) **ontologies integration** Here we not used any existing ontologies, whereas domain ontology built in this study was from starch. Only integration done was of existing CBT therapy materials, context have been reused by relevant publications.

   (d) **ontology evaluation** Here ontology evaluation as been validated with HermiT 1.4.3.456 reasoner and using generic criteria (Fox et al. 2002). It is presented in evaluation in chap 7.

3.2 Architecture of Adaptive COPE Application

COPE app is a mobile based platform that enables a personalized internet-based therapy based on patients personal goals,medical background,progress instead of a tunnel view on therapy. By adapting CBT therapy content and activities,exercises to the patients based on their mental distress symptoms related to breast treatment,the system is able to prepare an model for the women patients which initiates a personalized therapy process in presenting and learning CBT coping content.

The basic system architecture of personalized adaptive therapy based COPE application is composed of four components as shown in Fig. 1.5:

1. **CBT and mindful models:** It is also referred to as domain model to an area of therapy.Domain model provide representations of structured data of evidence based CBT therapy in a specific domain with facts,procedures,or methods that assists therapy to accomplish activities or solve problems. The domain model can be also problem solving domain. Therapy strategies in domain model follow different approaches and patient can access CBT therapy from domain model.

2. **Adaptive algorithm:** It provides CBT contents with therapy needed to attain patients goal. The functionality of this component are :

    - Controls over sequence and selection of CBT therapy material to be presented to the patient.
    - Response mechanisms to reply to patients questions with appropriate answers.
    - Provide psycho-education of when patients need help, in course of solving cognitive problems or practicing for activities, a skill and what type of help to offer.
    - It embraces different approach/adapt therapy strategies to achieve goal and remain responsible for selecting the CBT therapy coping strategies and tactics and choose/determine them regarding the needs of patient which is stored in the patient model.
    - Offer CBT coping skills that been taught, consists facts and principles to

patients based on mental distress symptoms.

3. **Monitor:** This component performs a system monitoring and adapt to necessary with COPE application. It would help to adapt to approach the therapy coping skills used with the patients requirements (as inputs) during the therapy.

4. **Patient model:** The model emphasizes cognitive and behavior states of the patient in relation to their evolution to advancement of CBT treatment. This component models individual breast cancer patients' characteristics, requirements and preferences. The patient model is an overlay on the domain model.

The User interface component as central component communicates and operates interactively to these four components as shown Fig. 1.5. Central health registry or kreftregisteret from cancer registry of Norway can be connected to COPE App conveniently. Kreftregisteret is a central database that manage, the Pre-Therapy HRQoL data of patients. App also connects to outpatient services for uploading the CBT content, activities, and exercises, as well as monitoring services for patient behavior and personalized statistics.

User Interface component act as front-end of the COPE application and integrates all information with different types. This component provides platform to interact with patients through text, video, audio and allows direct interaction with system. It also interfaces between the adaptive iCBT therapy and patient model with functionality is to present the CBT and mindful domains model material in a proper way.

At last learning analytics refers to collection and analysis about patients and their environments for the purpose of understanding and improving therapy outcomes.

The project initiated with "small funding" from kreftregisteret, aiming towards an NFR funded project and initial partners are listed as: HVL (IDR amp; IIKN), SLATE/UiB and kreftregisteret.

3.3 Adaptive iCBT Domain

In the last chapter 2, CBT and iCBT are introduced and ITS technology was discussed from a general point of view. These acted as a foreword to give the idea of the adaptive learning systems in iCBT domain that is dealt here throughout in

thesis.

In this overall project, we work with a domain iCBT (described in Section 3.2) with adaptive personalized iCBT therapy to design and implement an ITS technology. However there are several steps involved for such work and first step would be to build domain model of adaptive iCBT application.

In the present thesis as sub-project, we focus to build domain model for adaptive iCBT application.

3.3.1 Role of CBT domain model in adaptive personalized COPE application

Adaptive COPE application consists CBT and mindfulness models. This thesis, we will be working on only CBT model which we will refer as CBT domain model. Domain model knowledge representation plays an important role in the adaptation of iCBT system because CBT domain model constitutes the knowledge base of presentation of the CBT learning materials, activities/tasks.

3.3.2 Theoretical framework of breast cancer treatment symptoms

In past several decades it had been observed that overall five year survival rate for women diagnosed with breast cancer has been raised. Also, women diagnosed with breast cancer need of a special care after breast cancer treatment. As discussed in Section 2.2 about breast cancer symptoms in women suffer after treatment as shown fig 2.2. Breast cancer survivor ship have been described and it as stressful experience in which women put efforts to balance day-life activities with persistent physical symptoms and psychological distress. The major challenges after treatment is return to the normal life that they led before their breast cancer diagnosis and improve quality of life (Cappiello et al. 2007). The present work focuses only on common physical symptoms and psychological distress among women with their influence with each other or associated to each other shown in fig 3.1. In CBT treatment modules in COPE application consists of physical and psychological symptoms as shown fig 3.2. Further we collect knowledge of mental distress symptoms (caused due to breast treatment to women) and CBT treatment approach and then model it by using domain modelling language which is described in next Chapter 4.

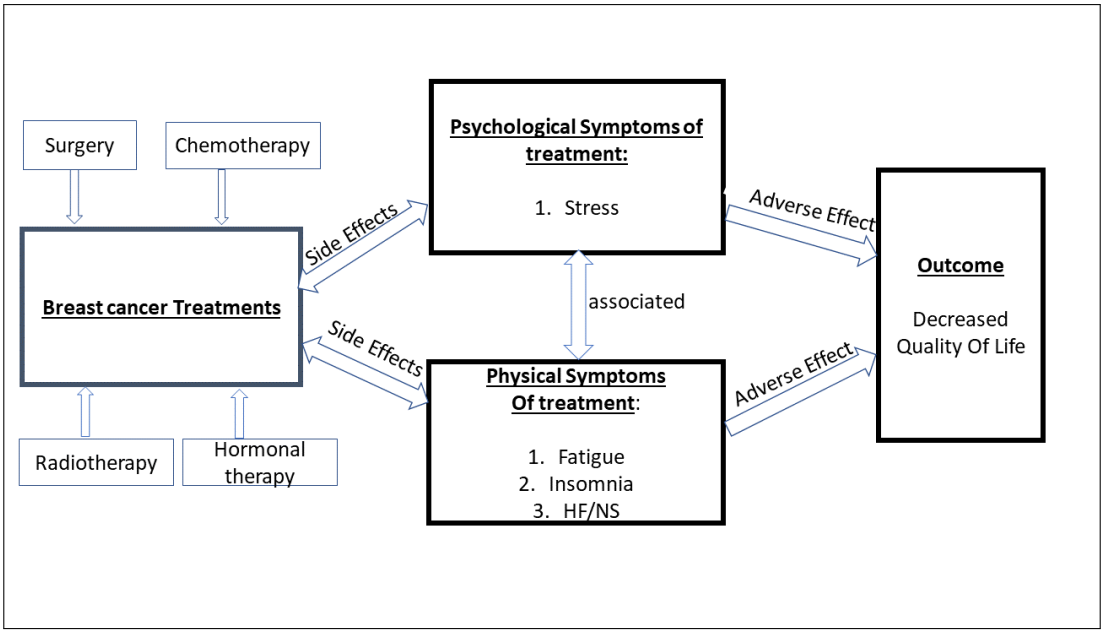

Fig. 3.1: Theoretical framework of breast cancer treatment side effects symptoms

Adaptive ICBT Treatment Modules	
1	Stress
2	Fatigue
3	Insomnia
4	HF/NS

Fig. 3.2: Adaptive iCBT Intervention Modules

3.3.3 Knowledge representation

Domain model provides a representation of the knowledge and further categorized into two different types, declarative and procedural knowledge. In declarative, knowledge is based on concepts, facts and learning objects and are expressed in declarative sentence. While procedural knowledge is information that is needed to

accomplish certain tasks and participation in certain activities that is responsible for knowing how to do that includes rules or constraints, strategies and procedures. For example, the patients with mental distress symptom of varying severity can acquire not only procedural knowledge needed to perform CBT coping skills on COPE application but also the factual/declarative information associated with the activities/task. In this thesis, knowledge are represented in both declarative and procedural (Woolf 2009).

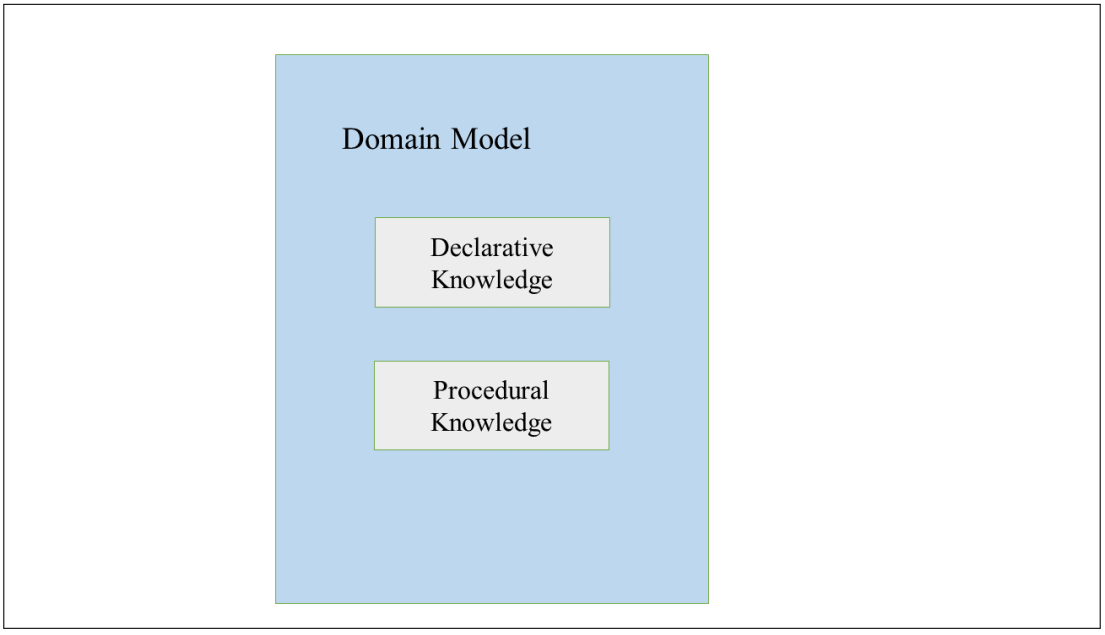

Fig. 3.3: Domain Model with knowledge types

Main purpose of the CBT domain model in COPE Application is to representation of iCBT intervention knowledge structure. All knowledge presented in the CBT domain model does not have supposed to be learned or understand by the patients in an COPE application. However based on diagnosed mental distress symptoms, patient will learn and understand declarative knowledge and perform procedural knowledge.

CBT domain model consists of knowledge types,

1. Declarative knowledge (theoretical knowledge): The CBT domain model consists domain concepts and their relationship in declarative knowledge, which are presentation of CBT self learning materials based on facts. The knowledge

about a domain concepts and relations may assist breast cancer patients to understand about mental distress and their symptoms. Eventually this help to provide theoretical knowledge or information on how to perform CBT coping activities in COPE application. For example, a new domain concept may be relatively unknown or partly known to the novice patient(s) about the mental distress and their common symptoms.In this situation patients are less likely know about coping skills needed for their mental distress. The domain concepts help to assist patients to recognise their problem first and further advised or recommended CBT treatment by application. The domain concepts are organized as CBT treatment modules with each module linked to number of sessions that to be taught about coping activities and relaxation exercises.

As shown in the tables 3.1, 3.2, 3.3, 3.4 as declarative knowledge in CBT Domain Model , four core modules comprise the cognitive/behavioral intervention for individual patient with stress, fatigue, insomnia, and HF/NS. Each module consists one or more session and each session consists: 1) psycho-education ;2) activities/tasks 3) relaxation training. The objective of the proposed treatment approach is to help women patients learn coping strategies for reducing symptoms stress, fatigue, insomnia, and HF/NS, while simultaneously developing skills for managing symptoms of breast treatment side effects on daily lives of women. The treatment is short term, each module consists 3-7 sessions. Also, the arrangement of treatment modules are non-linear, to allow flexibility in the application of the intervention and significance for the specific problem areas of each women patient.

2. Procedural knowledge (Problem-solving knowledge): The domain model consists of problem solving knowledge deals with procedural knowledge. In this knowledge contains of all procedures to a solve a CBT coping activities/tasks based on the declarative knowledge. For example, if breast cancer patient wants to do or work CBT coping activities then a related tutorial or psychoeducation to that activity are present to solve which is based in declarative knowledge. Procedural knowledge also consists pre- and post- assessments to diagnose of mental distress and their symptoms.

Module : Stress	
Session One	Psychoeducation about stress and stress symptoms and in the context of having breast cancer treatment. Information about Deep Breathing relaxation technique which plays important role for self–management of stress. In-session Activity: 1. Q &A on awareness of stress 2. Identify stressful related symptoms that may be After-session Activity: 1. Deep breathing relaxation exercise
Session Two	To help patients identify their relation between thoughts and feelings how stress management work in the context of having breast cancer treatment. After-session Activity: 1. Deep breathing relaxation exercise
Session Three	To help patients how to manage stress and teach adaptive thinking skills for managing various kind of symptoms of stress using CBT techniques. In-session Activity: 1. Create own roadmap to stress 2. Q/A to identify body stress reactions (The appraisal process) After-session Activity: Deep Breathing relaxation exercise

Table 3.1: Stress module

3.3.4 CBT Domain Knowledge is represented as constraints

The knowledge in the domain are represented in the form of constraints which capture facts of the domain concepts. Through relevance condition of the system can determine when it is appropriate to use. There are many approaches to represent domain knowledge, but one popular approach is rule based which represent domain in the form of production rules. In rule-based of represented knowledge required to generate step/by/step solutions while in constraint based express solution should satisfy (Mendjoge et al. 2016). In present work we are using constraints and entire focus will be on the state of the solution in the system that patients arrive at irrespective of the steps taken by the patients to reach the solution. It show SQL-TUTOR is an example that is based on constraints in domain model (Mitrovic 2003).

Module : Fatigue	
Session One	Psychoeducation about the cognitive behavioural therapy of breast cancer treatment -related fatigue and What causes breast cancer-related fatigue? In-session Activity: 1. Identifying the factors which may cause fatigue After-session Activity: 1. Record daily activity diary every day 2. Deep Breathing relaxation exercise
Session Two	Psychoeducation about how to become aware of unhelpful thoughts that may adversely impact on their daily activities. In-session Activity: 1. Identify and record unhelpful thoughts and how to challenge your unhelpful thoughts After-session Activity: 1. Deep breathing relaxation exercise
Session Three	Psychoeducation about how to improve and build up your energy and improve your fatigue and how to Increase physical activity and reduce fatigue and Resting is important to help you cope with fatigue. In-session Activity: 1. Planning activity and rest After-session Activity: 1. Deep breathing relaxation exercise

Table 3.2: Fatigue module

Each constraint in CBT domain model is a rule of the form,
IF < relevance condition > is true
THEN < satisfaction condition > will also be true.

Constraints consists:

- Relevance condition that describes when the constraint is applicable
- Satisfaction condition that provides information and feedback/recommendation message associated with the constraint

This constraints can also be interpreted as when patient violate any constraint during performing activities/task, then system identifies that and suggest patient to understand the concept of the domain and provide help or recommendation regard-

ing to violated constraint.

In the present work, COPE application working on ITS technology that teach breast cancer patients on how to cope with distress related to psychological and physical symptoms by CBT treatment approach. COPE application uses a constraint to represent domain model. Represented constraints can be also used to evaluate the patient's solutions were right to a problem-solving that are similar in the CBT domain model and does not violate any of its modeling rules.

Module : Insomnia	
Session One	Psychoeducation about the cognitive behavioural therapy of breast cancer treatment -related insomnia. In-session Activity: After-session Activity: 1. Daily sleep diary to complete 2. Deep breathing relaxation exercise
Session Two	Psycho-education about sleep hygiene and focusing on general education about sleep and improving sleep hygiene practices (e.g., increasing exercise and avoiding nicotine, caffeine, and alcohol before bedtime). In-session Activity: 1. Practice good sleep hygiene After-session Activity: 1. Deep breathing relaxation exercise
Session Three	1. Psycho-education about Sleep restriction how to shorten the amount of time spent in bed in order to consolidate sleep and give instructions how to do(for e.g.: set bedtime , set wake time) . 2. Psycho-education about stimulus control that patient learn to associate the bedroom with staying awake rather than sleeping and give guidelines about how stimulus control to do (for e.g. Do not take a nap during the day) . In-session Activity: 1. Activity scheduling (personalized sleep scheduling bedtime) After-session Activity: 1. Bedtime Thought Log (The purpose of this log is to provide a space for the patient to record any racing thoughts that are preventing her from falling asleep.) 2. Deep breathing relaxation exercise
Session Four	Psychoeducation about how negative or worrying thoughts can get in the way of sleep. In-session Activity: 1. Challenging thoughts activity After-session Activity: 1. Deep breathing relaxation exercise

Table 3.3: Insomnia module

Module : HF/NS	
Session One	Psychoeducation about effect of breast cancer treatment on menopausal symptoms. In-session Activity: 1. keeping an HF/NS diary daily basis After-session Activity: 1. Deep Breathing relaxation exercise
Session Two	Psycho-education about cognitive behavioural model including physiological, cognitive, behavioural, and emotional role in HF/NS; provided information about the physiology of HF/NS.. In-session Activity: 1.Record patterns and triggers of hot flushes After-session Activity: 1. Deep breathing relaxation exercise
Session Three	Psycho-education the relationship between stress and hot flushes and CBT strategies for the reduction of stress. After-session Activity: 1. Deep breathing relaxation exercise
Session Four	Psycho-education about understanding night sweats and about the influence of night sweats on sleep quality and sleep problems and application of behavioural strategies to night sweats/sleep problems. In-session Activity: 1.Identify way to improve sleep habits After-session Activity: 1. Deep breathing relaxation exercise

Table 3.4: Hot-flashes/Night Sweats (HF/NS) module

4 Modelling

In this chapter, we describe domain modelling which includes software engineering methodology used to achieve representation of domain knowledge as described in chapter 3. A formal representation of domain knowledge in conceptual models are annotated and at final represented as domain ontology.

4.1 Domain Modelling

Domain Modelling is the one of the prerequisite activities for implementing adaptive iCBT COPE application (Iscoe et al. 1991). Here modelling refers to the process of creating domain knowledge models and modelling language is an language with purpose to represent knowledge about domain.

In this thesis, domain ontologies are used represent domain knowledge models. Domain ontologies is a framework for representing domain concepts and the relationship that exist between those concepts in domain knowledge model. One main reason to use ontologies in this paper is it also allows domain experts, software developers and computers can have a common understanding of the concepts and relationships. And this approach also makes it easier to understand the concerns of domain sub-component, consequently, to promote interoperability among the with other sub-components of the COPE architecture. Domain ontologies are successfully used in adaptive e-learning systems (Nafea 2017). Therefore we had implemented knowledge models as domain ontologies.To create domain ontologies there are several standards and tools available which will be discussed in implementation section.

Before implementing the domain ontologies, the knowledge captured from the domain experts is represented in conceptual models. To design conceptual model of domain model in formal way a common modelling language is required. So to present an conceptual models for CBT domain model for an COPE application, UML (Unified Modelling Language) is used as an Ontology modelling (Chan 2004). With this approach any model expressed in UML can be translated from knowledge model to system implementation is supported.

4.2 Unified modelling language

Unified modelling language (UML) is a standardized, graphical, general-purpose modelling language maintained by the Object Management Group (OMG) (Booch et al. 2005). UML is used designed to specify, visualize, and document the artifacts of a software system.It is includes a set of consistent diagrams that be used to capture domain knowledge. In this thesis, we cover UML class diagrams,activity diagrams being used to design conceptual models for self-guided CBT treatment approach for breast cancer patients who suffering from side effects of breast cancer treatment. The notations used to design UML diagrams is explained as:

1. UML package is used as organizing group of classes of domain model.

   The notation used:

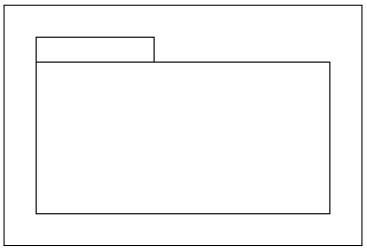

Fig. 4.1: Package Notation

2. UML class diagrams modelled in a declarative way, the static structure of an application domain knowledge in terms of concepts and relations between them.

   The notations for the different types of relationships are as follows:

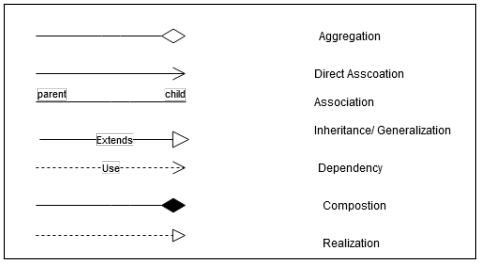

Fig. 4.2: Relationships Notations

3. UML activity diagrams used to represent to relaxation exercises process for

patient in domain model.

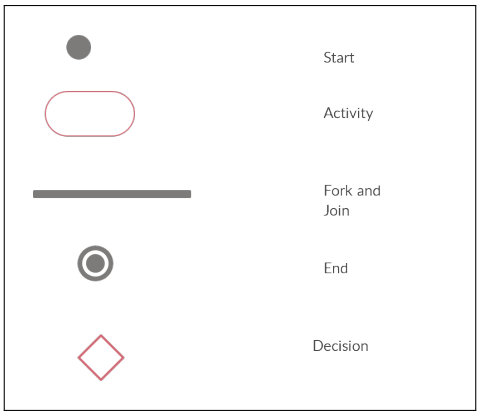

Fig. 4.3: Activity Diagram Notations

4.3 Purposed CBT Domain modelling

Initial CBT domain model shown in fig 4.4 is composed using five main packages based on their role and relationship in domain modelling. It consists of the treatment module packages, module-based sessions package, assessment and diagnosis package, general module package and evaluation package. These packages forms CBT domain specific modelling language foundation model shown in fig 4.4.

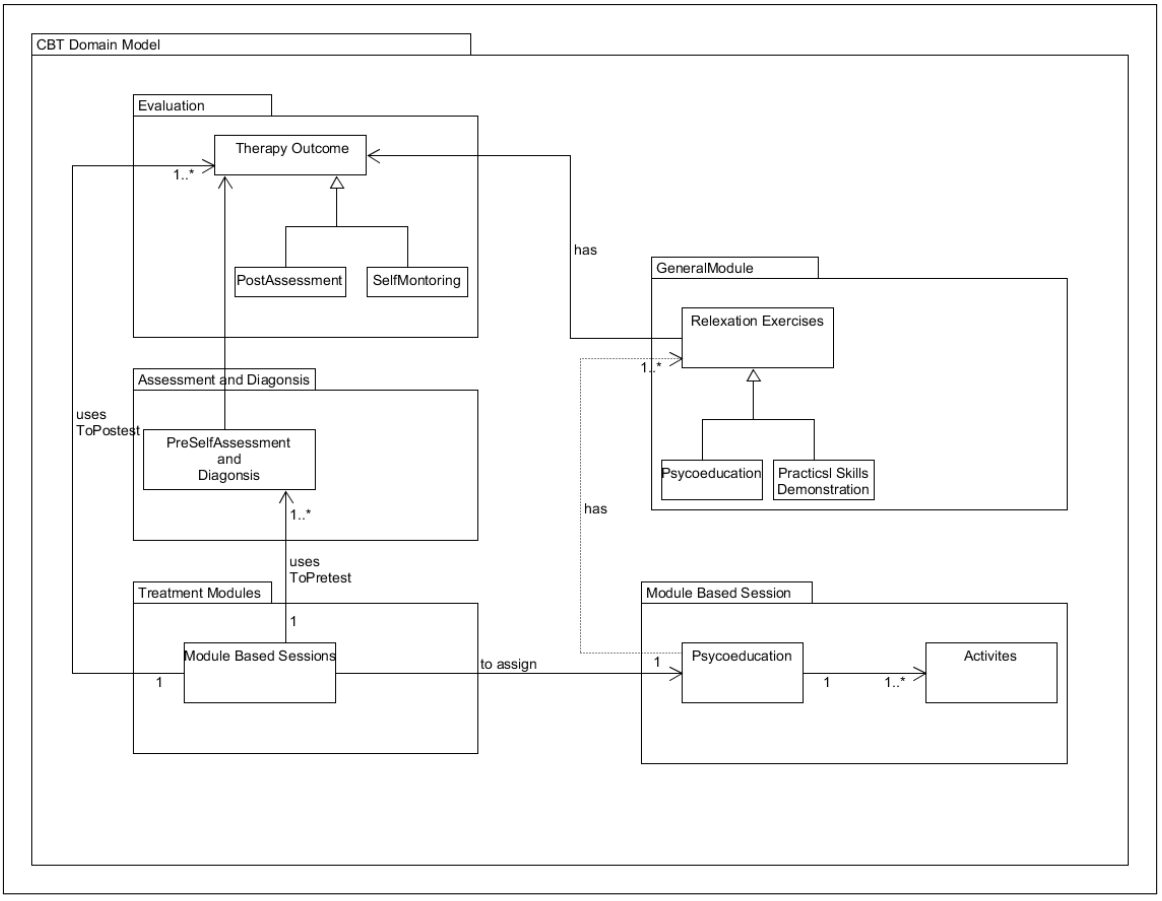

Fig. 4.4: CBT Domain Model

CBT domain model each package are used to model associations and relationship between concepts inside them and each package is dependent on each other. These five packages are represented as domain knowledge in two techniques that are declarative knowledge and procedure knowledge (for details, refer Chapter 3). Here we provide a conceptual model of the domain knowledge collection and relations among them using unified modelling language (UML) notation.

1. Assessment and Diagnosis
2. Treatment modules
3. Module sessions
4. General module
5. Evaluation

4.3.1 CBT Domain knowledge in CBT Domain Model

CBT domain knowledge is a collection of proposals that clarify all the concepts in the vocabulary to solve CBT coping problems (activities). There are two types of domain knowledge components that are declarative and procedural knowledge (discussed in Chapter 3). CBT domain knowledge model shown in fig 4.5 containing information that COPE application teaches only a CBT declarative knowledge where it does not mention of how patients can use domain knowledge to solve a coping problem (activities). CBT procedural knowledge informs procedure to patients to use domain knowledge to solve or to perform given coping problems (activities). The procedural domain knowledge package describes of modelling rules.

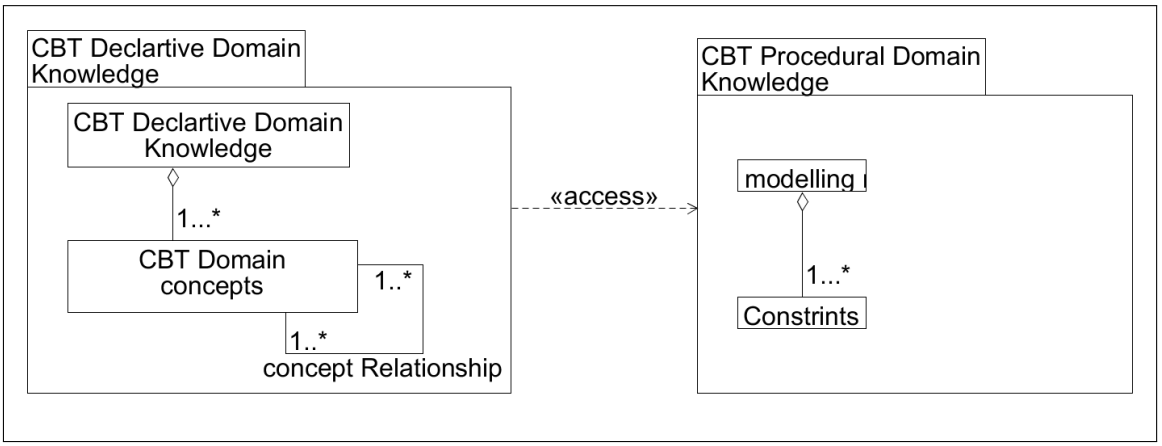

Fig. 4.5: CBT Domain Knowledge Model

The model of CBT declarative and procedural in domain knowledge are as follows:

- **CBT Declarative Domain knowledge :** The model of the declarative domain knowledge includes following CBT materials as shown in fig 4.6 and it show that UML model provides a representation of the declarative knowledge elements (concepts) and relationships among these elements within the context of the CBT domain knowledge. This model is based on some known CBT facts.

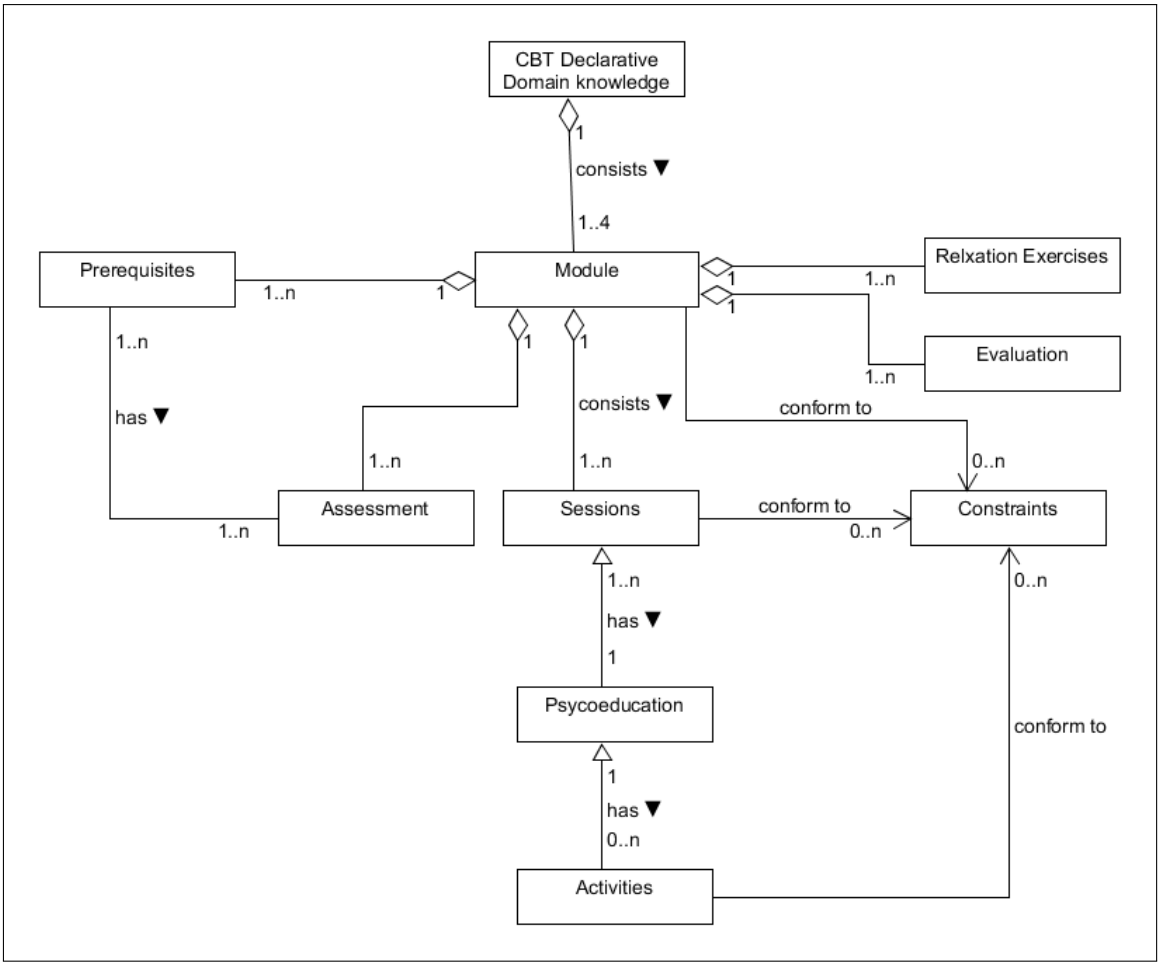

Fig. 4.6: CBT Declarative domain knowledge model consists of Module, Sessions, Assessment and Evaluation.

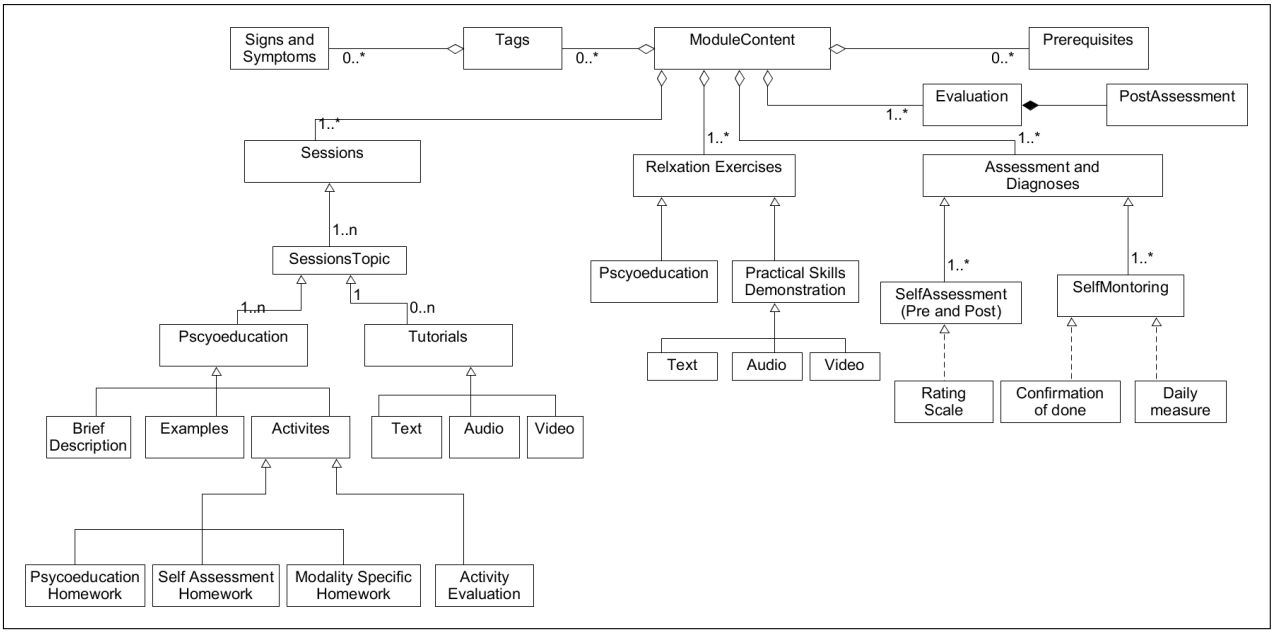

Fig. 4.7: Module Content.

In the proposed declarative domain knowledge in CBT domain model fig 4.6, the following terms are explained as:

1. **Module** presents of four specific mental illness domain knowledge (stress, fatigue, insomnia, and HF/NS) which describes self-therapy or a about coping CBT therapy sessions in COPE application.

2. **Sessions** comprised of knowledge about different concepts required by the patient(s) to successfully complete treatment module. There can be more one or more sessions in each module.

3. **Assessment** provide as prerequisite which are conducted at beginning any treatment module or sessions. It is used to diagnose specific mental illness symptom and its level. It is main also factor used to adapt the module content (sessions) and/or activity to the patient.

4. **Evaluation** is used as post assessment to assess application can be evaluated for treatment effectiveness on specific symptom. The standard post-assessment provide scoring level of symptom which is the progress of patient is evaluated and/or feedback and recommendation of next activity given by the application based on the evaluation result.

5. **Constraint** is used for navigation links related to the represented knowledge. The links constitutes domain knowledge and their order, and relations among them.

- **CBT Procedural Domain knowledge:** Procedural domain knowledge is essential to design CBT therapy coping activities and to define adaption strategies in COPE application. The main aspects in problem-solving is provide teach patients "how to" to perform coping activities (refer to Section 3.3.3 for details).

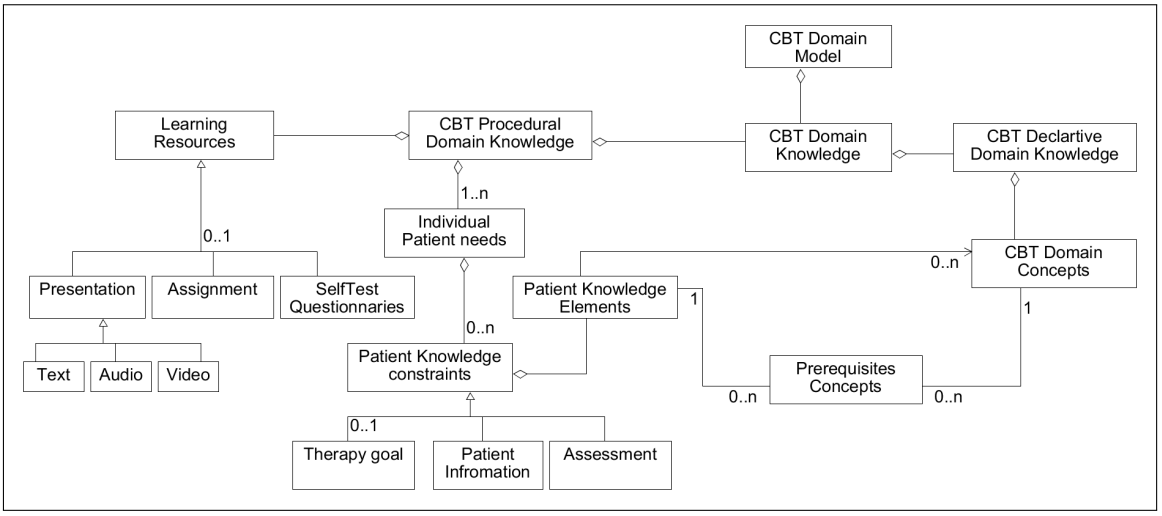

Fig. 4.8: CBT Procedural Domain Knowledge Model

Procedural domain knowledge model includes following therapy methods as shown in fig 4.8. The model defines therapy methods (i.e. modelling rules) about learning methods on its delivery on when it will be learned, and determine if it has been learned in terms of the CBT domain model. The procedural domain knowledge is made up of,

1. Declarative knowledge constraints: The declarative knowledge constraints state sequencing constraints, where domain knowledge of one concept is necessary to understand another concept (for example, the prerequisites of CBT domain main concepts needed to understand before to understand main domain concepts as shown in model, See fig. 5.1).

2. Needs of patient: Patient need allows intelligent tutor to define individual

patients in terms of their therapy goals, patient information, and assess and diagnose mental illness symptoms before starting CBT therapy. The patient knowledge elements includes therapy goals, patient information, assess diagnosed mental illness symptoms in the CBT domain model. This also defined by patient medical history, preferences and progress in CBT domain model concept are monitored.

In the proposed procedural domain knowledge in CBT domain model fig 4.8, it describe CBT domain concepts of declarative knowledge of CBT domain knowledge model is one of the important elements of therapy methods in procedural knowledge.

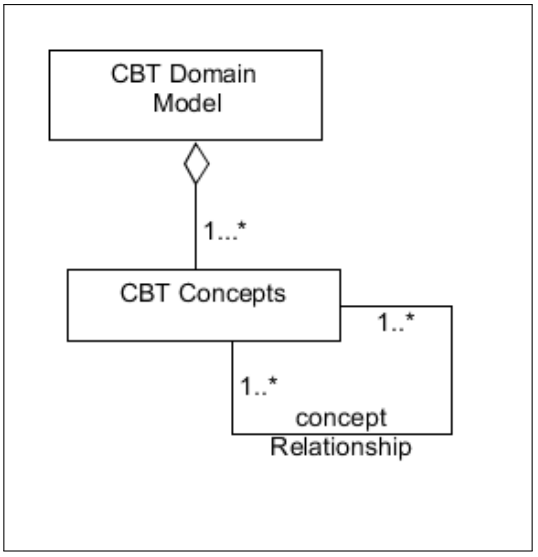

Fig. 4.9: CBT domain concepts

More relationships are defined on the CBT domain concepts, as prerequisites concepts as shown in fig. 4.9 and 4.8. This relationship defines a prerequisite sequencing constraint between two concepts. The pre-requisite concept describes a relationship between a concept and a knowledge element where pre-requisite is satisfied when patient has obtained knowledge defined by the knowledge elements.

Procedural knowledge model defines a individual patient requirements in terms of therapy goals and patient's information and based on assessed and diagnosed mental illness symptoms by patient model. Therapy goals to describe individ-

ual patient current condition and information that describes expected data as requirements or need prior to taking the CBT therapy. Therapy goal and patient information are types of patient knowledge constraints.

CBT procedural knowledge also permit intelligent tutor to define learning resources based on patient preferences. The captured patient preferences by patient model will be used in the CBT therapy that allows to authorize CBT materials in terms of delivery methods to learning resources are adapted or tailored to the patients.

4.3.2 Relaxation exercises in CBT domain model

For mental illness alleviation relaxation exercises played significant role in the long history of treatment of mental illness. These exercises are introduced as an activity in adaptive iCBT therapy COPE application activity. Past studies have proven that relaxation techniques were effective to manage symptoms of side effects of breast cancer. It aid to patient to mitigate symptoms of psychological and physical distress such as stress, fatigue, insomnia, and HF/NS (Demiralp et al. 2010, Yoo et al. 2005).

Inclusion of relaxation exercises in CBT domain model are listed as,

1. Deep Breathing technique : It is also known as abdominal or belly breathing for patient which helps to on their body and mind in a more positive way.
2. Progressive relaxation technique: This technique involves various muscles tightening and relaxation exercise which often combined with guided imagery and deep breathing exercises.
3. Mediation technique: It involves comfortable sitting with more focus on breathing and gather patient mind's attention to the present moment without distraction or drifting into other thoughts or concerns about the past or the future.
4. Guided imagery technique: This technique involve patient(s) to train their focus on wishful or pleasant images to eliminate negative or stressful feelings.

General module in CBT domain model shown in fig. 4.4 consists of relaxation exercises that aims to help the patients relax mentally and physically into everyday

lives. This module also address a way of making patients to get healthy through treating various mental illness symptoms. This general module guides patient in four different relaxation exercises and fig. 4.10 show representation of general Model of relaxation exercise in CBT domain model.

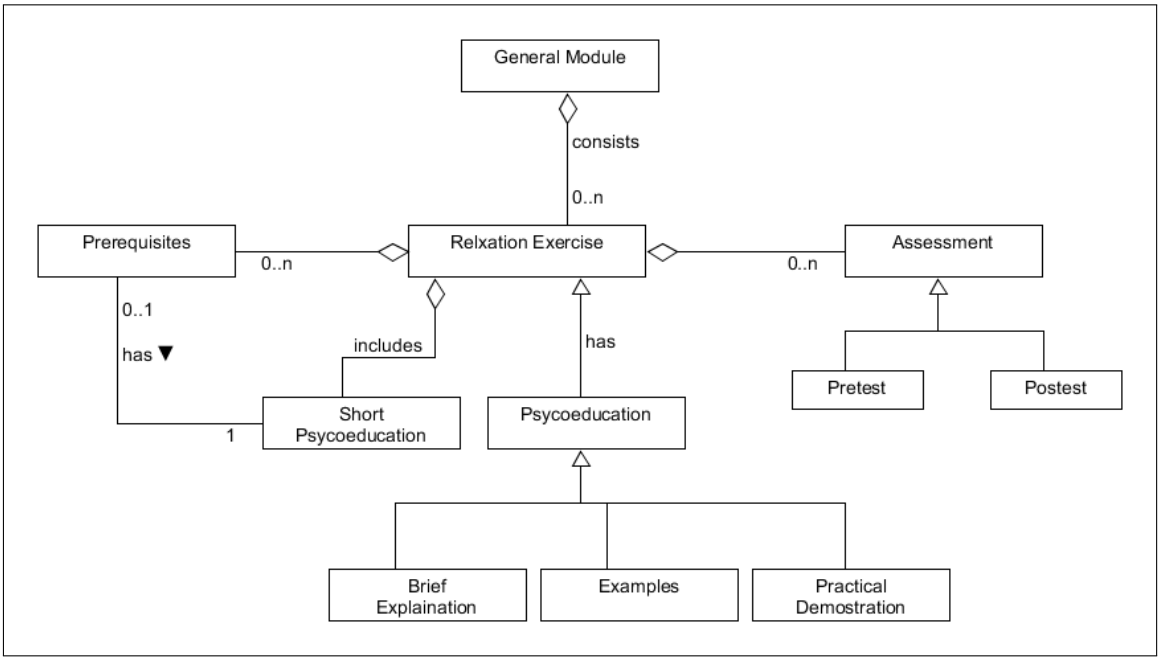

Fig. 4.10: General module in Domain Model

The aim of module in CBT domain model is aid patient(s) to learn and practice according to their own convenient time during iCBT therapy regardless to complete all therapy goals or treatment sessions. Module includes text, audio-visual psycho-education and demonstration of techniques. On completion of exercises at each stage, it provides assessment to know the outcome.

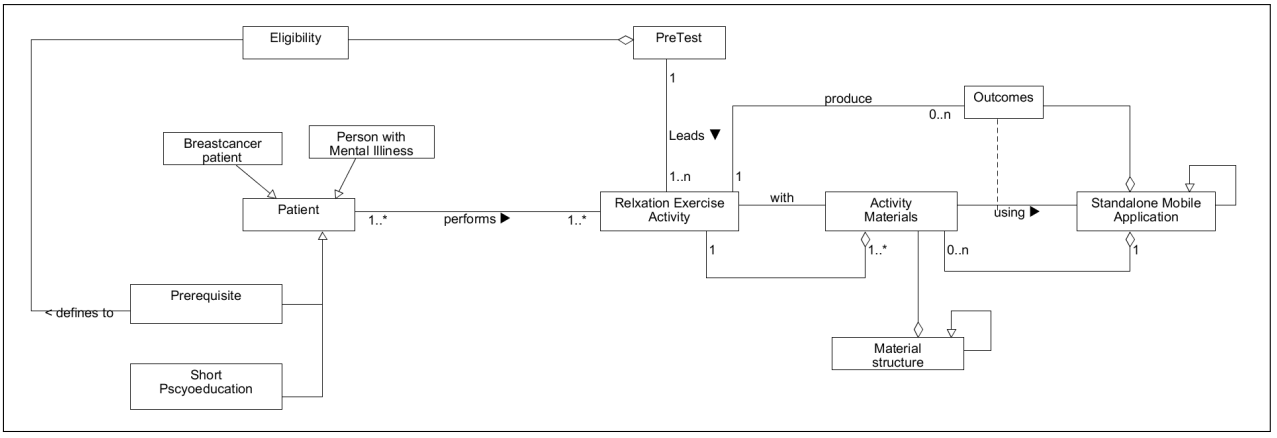

Fig. 4.11: Model for relaxation exercise and learning activity

Fig. 4.11 show outline of patients need to perform relaxation activity in the COPE application. First time learner it will be mandatory to known short psycho-education before doing any other activities.

General module describe different activities that when combined together support a CBT therapy process. The activity diagrams are used to model behavior in a therapy process which are independent of the treatment modules as shown in fig. 4.6. The activity diagrams of relaxation exercises in COPE application are shown in figs. 4.12 and 4.13. The activity diagrams listed as,

1. Progressive Muscle Relaxation (PMR) : This activity shown in fig. 4.12 occur in the COPE application. For eg. it provides an suggestion,"do You have any problems with pulled muscles, broken bones, or other physical issue", if patient have this problem then it recommends to consult the physician before performing exercise.

2. Mediation activity shown in fig. 4.13 occurs in the COPE application and recommends to practice exercise "feeling Stress, Anxiety, Depression and other negative emotions".

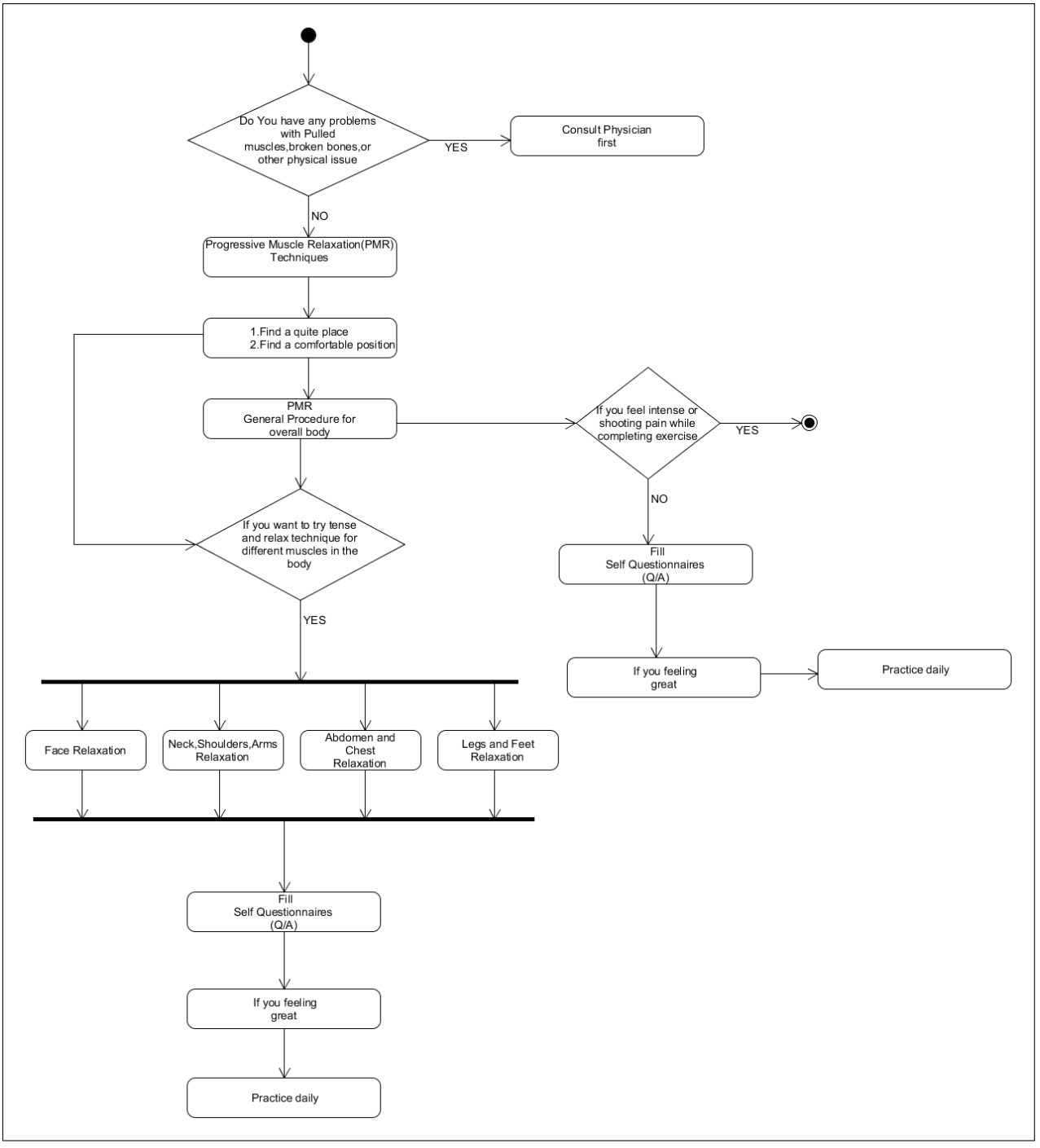

Fig. 4.12: Progressive Muscle Relaxation Activity Diagram

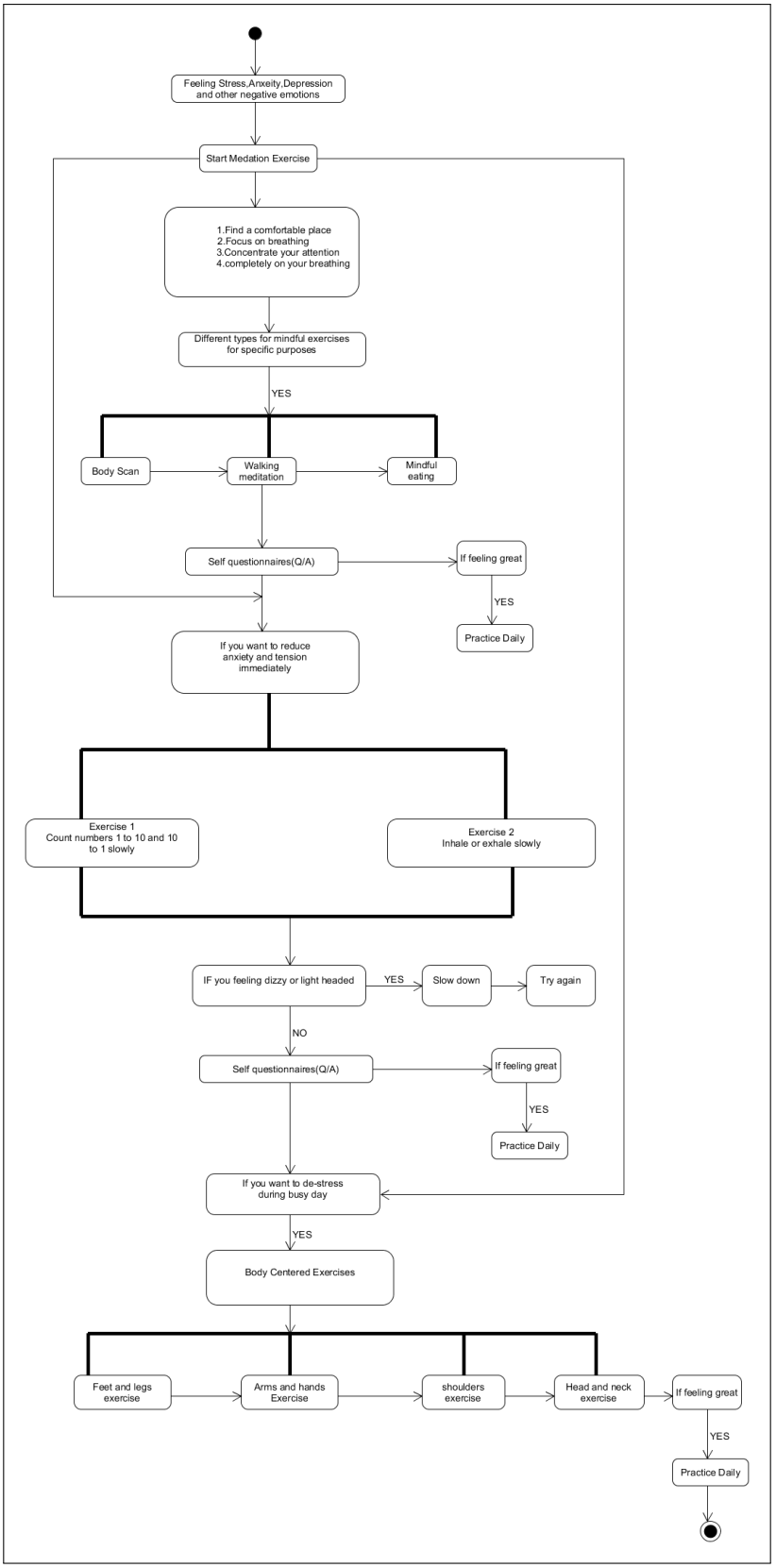

Fig. 4.13: Mediation Activity Diagram

4.4 Adaptive aspects for CBT Domain Model

The aspects of adaptive system are to provide adaptive domain knowledge to different learners based on the individual needs. In adaptive system, domain knowledge representation is widely known to be one of the most significant components of the personalized learning. The domain knowledge representation is comprised of several domain knowledge concepts. Brusilovsky & Vassileva (2002) states that adaptive system able to deliver different domain knowledge concepts to the same learner according to their chosen goals, preferences and knowledge.

4.4.1 Design of CBT Domain Model

With aim of providing the personalized iCBT therapy to patients domain model of the COPE system is designed based on adaptive techniques for domain model organized as three-layered hierarchical levels consisting of learning goal, concepts and educational materials (Brusilovsky & Peylo 2003, Brusilovsky & Vassileva 2002, Kahraman et al. 2010).

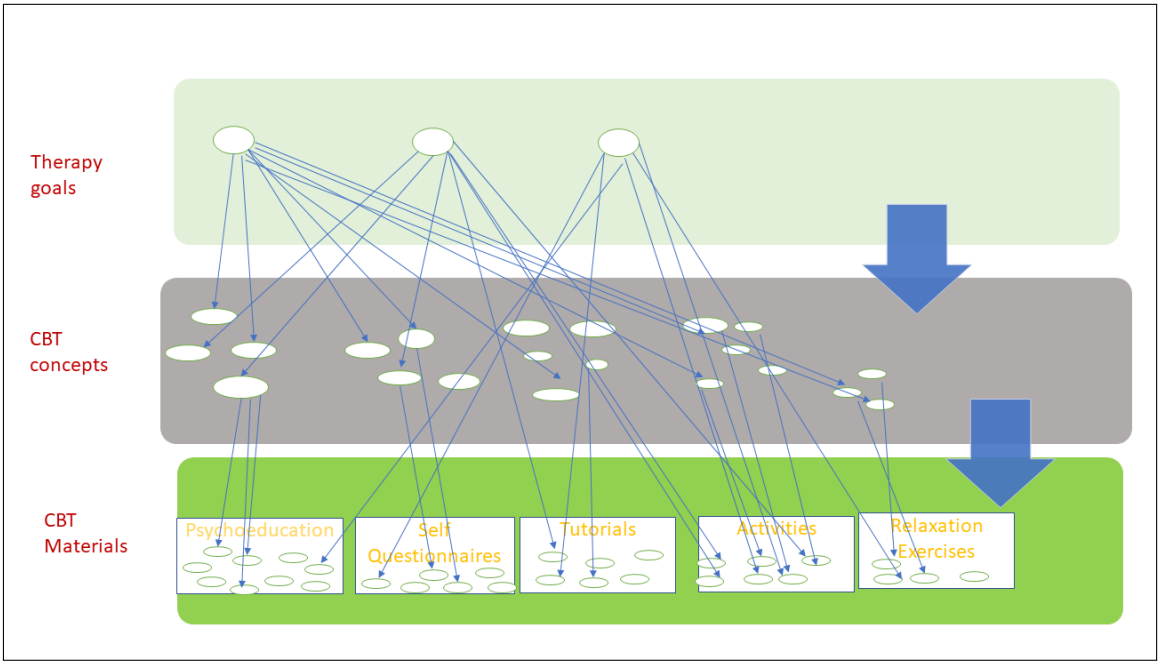

Fig. 4.14: CBT Domain Model Design of COPE application

The layers of the domain model design Fig 4.14 are described as below:

1. **Therapy goal layer:** Intelligent tutor defines a set of meaningful therapy goals based on the patient model. Patients can learn therapy goals of coping CBT activities based on their diagnosed mental illness signs and symptoms, medical history and preferences. All CBT materials necessary for their therapy are provided when therapy goal is selected by the system. For Eg. below Table 5.1 presents therapy goal (first column) "describe how to cope with sleep problem associated with stress" and their therapy goal associated with main concepts (second column) from sessions of treatment modules. The main concepts are associated with pre-requisites concepts (third column) that means there is another concept to be learned before learning a therapy goal.

2. **CBT Domain Concept layer:** The conceptual structure of each therapy goal includes CBT domain concepts that should be delivered according to CBT principles. The CBT domain concepts are important to the completion of a therapy goal which are known as therapy outcome concepts. To fulfill therapy goal, patient should learn all therapy outcome concepts and be successfully assess to all of them. Prerequisites concepts and main concepts are related with each therapy outcome concept completing its presentation as explained in fig 4.9. Prerequisites concepts are important to learn and work with the CBT material of the therapy outcome concept. Main concepts are primitive concepts used in the CBT material of the therapy outcome. In this way, interrelations among the different concepts of the therapy goal are defined. In the proposed CBT concept layer of the domain knowledge are independent elements that can be reused in different therapy goals. The therapy outcome concepts of the therapy goal can also be organized further into layered structure.

3. **CBT material layer:** CBT material of therapy outcome concept includes of four treatment modules of psycho-education which presents the information of the related mental illness symptoms. It also provides related activities, relaxation exercises, self-questionnaires or tool, self-monitoring tools or questionnaires, tutorials, assessments to assess the level of the diagnosed symptom before therapy goal and evaluation that to evaluate a how progress of the therapy going which post condition after completing therapy goal.

In CBT Domain model design shown in fig. 4.14 of COPE application. A therapy goal (first layer) consists of number of CBT coping activities of the domain knowl-

edge, which are recognized and selected by the intelligent tutor based on the patient model. Each therapy goal is associated with a sub-section of CBT domain concepts of the domain knowledge, which are to be learned by the patients to reach therapy goals (that are described in the CBT domain concept layer). The CBT concepts (second layer) design a theoretical structure of the therapy goal and their relationships and each domain concept is associated with a sub-section of CBT material which consisted of domain knowledge. CBT material layer contains overall CBT therapy course content that representations of psycho-education, activities, assessments, relaxation exercises, evaluations etc. In particular, both the structure of the domain concept level and the development of the CBT materials level are guided by the CBT principles facts.

4.5 Adaption Rules

In adaptive algorithm, modelling rules are implemented according to set of constraints to CBT content adaption. Previous explanation on domain knowledge representation in constraints in Chapter 3 and these constraints are defined by domain expert. The proposed set of constraints by CBT domain model will generate adapted CBT content or domain concepts to the patients based on their therapy goals(activities). Therapy goal is provided by system based on patient mental illness symptoms. Also several feedback and recommendations are provided to the patients with respect to the progress in iCBT therapy process.

The CBT domain model constraints suggests to patient on activity to perform and introduce to understand concepts related to it. Content of CBT materials are stored in domain model. An example shown to describe on how constraints are implemented and defined constraints for stress module, see table 3.1.

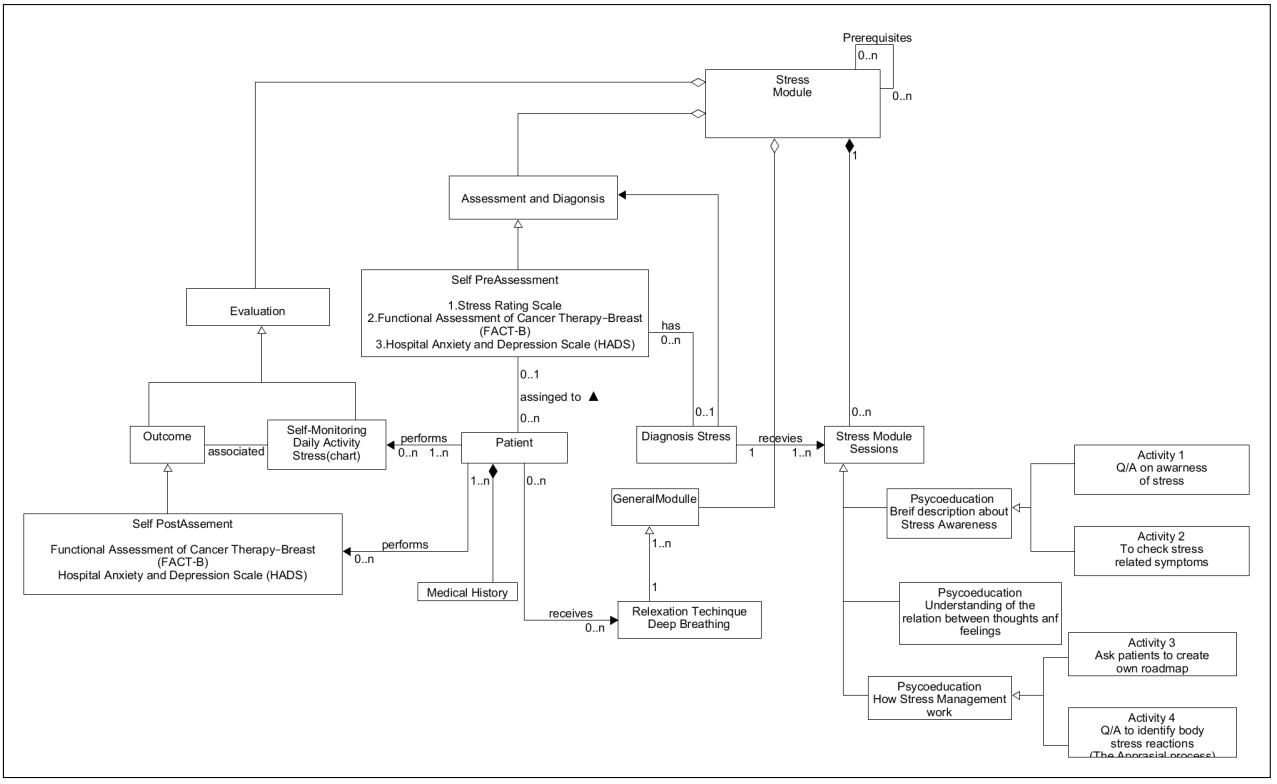

Fig. 4.15: Stress Module

To identify patient as first step is the therapy goal. The patient therapy goal is based upon stress related activities based on his/her treatment needs. In fig. 4.16 shown that patient follows through stress-related coping activities for stress module are generated. In fig. 4.15 show proposed Stress module content containing stress CBT materials and are in the from of text, audio and video. Stress module also includes relaxation exercise with addition of self-questionnaire to perform regular evaluation and assignments that define for all activities. The module session model of stress is shown in fig. 4.16 used to suggest CBT therapy paths.

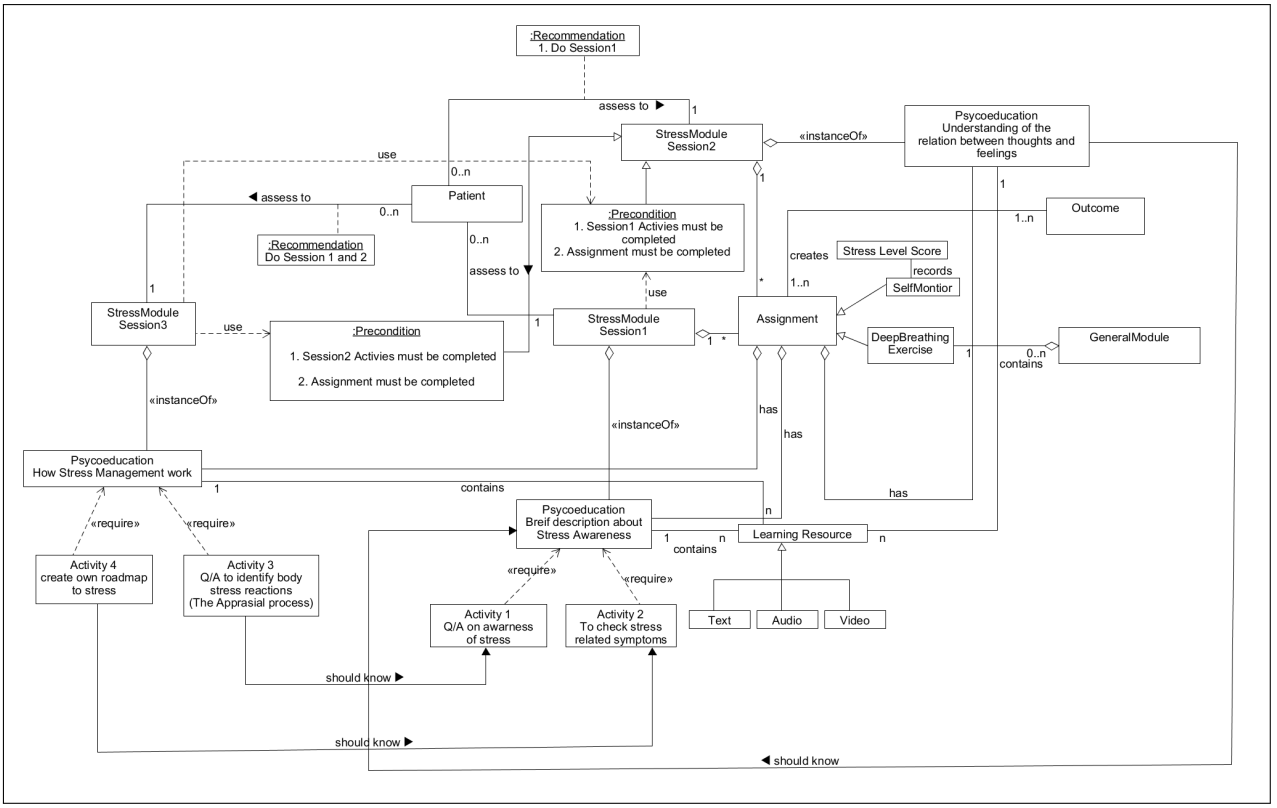

Fig. 4.16: Stress Module Session model

The patient data in the patient model is main input to define constraints for generating stress related activities. Following are the constraints for generating Stress treatment module activities.

1. *IF*
   Patient wants to start activities from stress module
   THEN
   Pre-requisites are :
   (a) Pre-Assessment stress rating scale.
   (b) Pre-Assessment for Anxiety and Depression.
2. *IF*
   Pre-Assessment for the stress rating scale is higher
   AND
   Pre-Assessment for Anxiety and Depression

screened for anxiety depressive symptoms are identified due to negative impact breast cancer treatments.
THEN
Stress psychological distress is diagnosed, and Stress Module is suggested.

3. *IF*
   Patient want to know about stress and its symptoms
   THEN
   Stress Module Activity 1 from Session One is suggested, and Deep breathing relaxation tutorial is recommended.

4. *IF*
   Patient want to know source of stress
   THEN
   Stress Module Activity 2 from Session Two is suggested and Deep breathing relaxation tutorial is recommended

5. *IF*
   Patient goal is perform Activities based on diagnosed symptoms with stress
   AND
   Patient tries for any activities from Stress Module for first time
   THEN
   It is prerequisite to learn psychoeducation related to activities

6. *IF*
   Patient goal is to perform Stress Session Two from Stress Module directly based on patient her preference
   THEN
   It is recommended to learn Stress Session one, but it is not mandatory

7. *IF*
   Patient goal is to perform Activity Three and activity Four from Stress Session Three from Stress Module, directly based on patient her preference
   THEN

   (a) It is prerequisite to learn Stress Session One Activities.

   (b) It is recommended to learn Stress Session Two, but it is not mandatory.

8. *IF*
   Given deep breathing relaxation exercise has failed to help the patient in reduction or improvement for diagnosed symptoms of stress.
   THEN
   Recommend PMR relaxation exercise from related stress from general module.

4.5.1 Activity based on signs and symptoms of stress module

For example in this fig 4.17 shown it is one way presenting how patient perform stress activity in the system based on stress symptoms and how domain model represented its domain concepts and its relations.

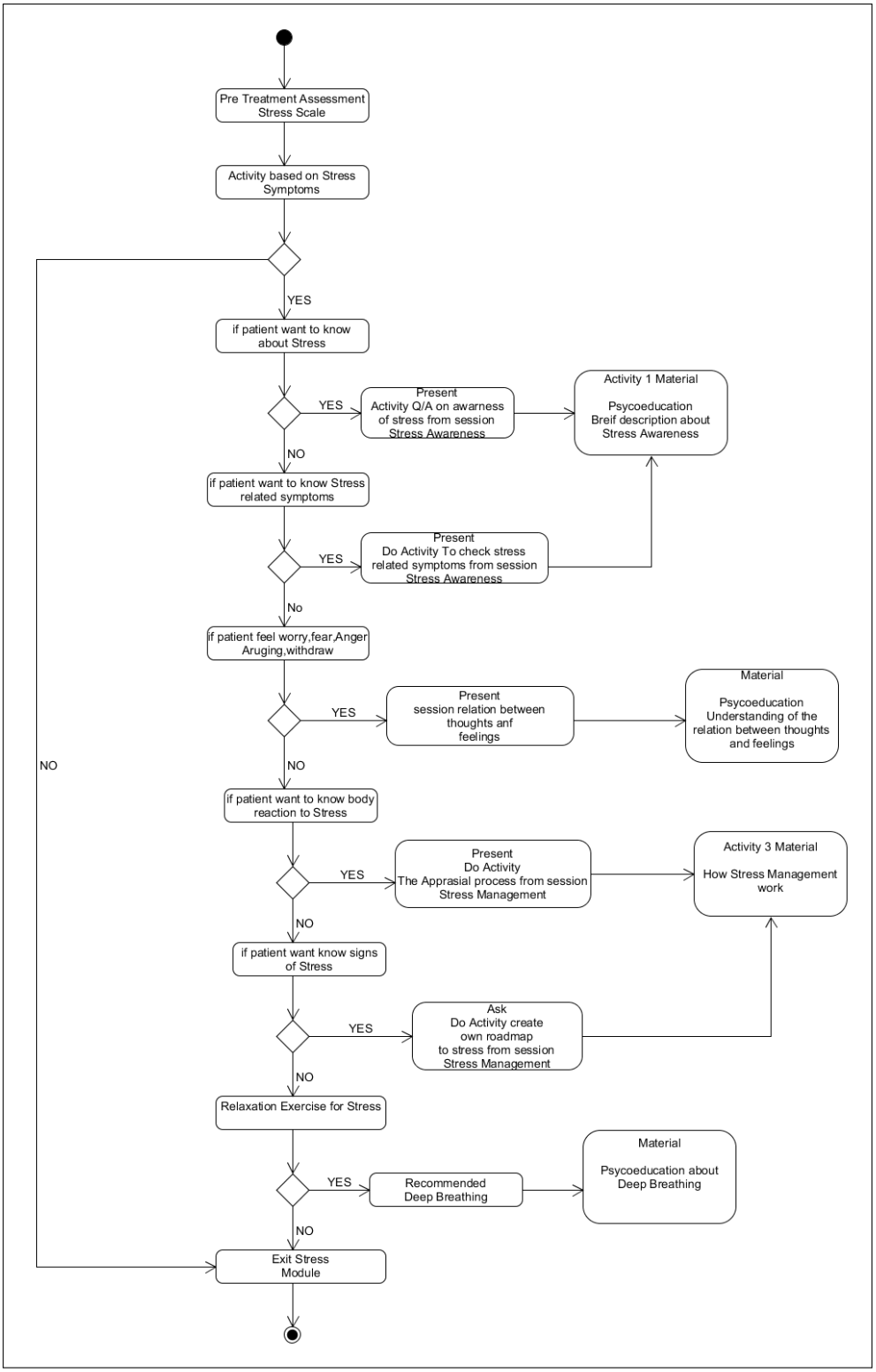

Fig. 4.17: Activity Based On Stress Symptoms

5 Adaptive personalized system

In this chapter, we aimed to design personalized adaptive iCBT COPE application. As discussed in detail in Chapter 3 and 4 about CBT domain model implementation approach that was important part of a iCBT therapy objective which consists CBT learning materials. The important part of application in personalized iCBT therapy process it should adapt to needs of the breast cancer patients dynamically and update itself with CBT learning materials.

In the context of CBT domain modelling, patient model is structured in a such a way that each patient data treated as treatment needs, medical background and preferences from patient model that overlay on CBT domain model and is mapped to a CBT domain concept. The CBT domain concepts retrieved from CBT domain model are shown in fig. 4.14. The patient inputs in patient model provides a concept model, See fig. 5.2 that allow appropriate iCBT therapy process to be created for the patient.

5.1 Personalized iCBT COPE App: CBT Domain Model

In proposed CBT domain model in COPE application, selected CBT domain model consists of four treatment modules as shown in fig. 3.2. For e.g. domain knowledge concepts are displayed in table 5.1 focus limited to one therapy goal based on "patient symptom as sleep problem caused due to stress". To achieve all therapy goals, we identified 8 concepts that must be well understood by the breast cancer patients. Some of the concepts are given in the table 5.1 :

Therapy Goal	Main Concept	Prerequisite concepts
Therapy for stress symptom as Sleep problems	C1: how sleep problems related to stress C2: Sleep hygiene C3: Sleep restriction C4: Stimulus control C1: Deep breathing exercises.	PC1: Psycho-education about stress PC2: Understanding of the relation between thoughts and feelings PC3: How to manage stress

Table 5.1: Domain concepts

Table 5.1 with first column show therapy goal which defines intended therapy outcome of learning CBT materials. The second column provides selected domain concepts related to the therapy goal and last column gives pre-requisite concepts which defines prior knowledge needed to learn before learning domain concepts to completing therapy goal. Fig. 5.1 display representation of domain concepts model

in CBT domain model.

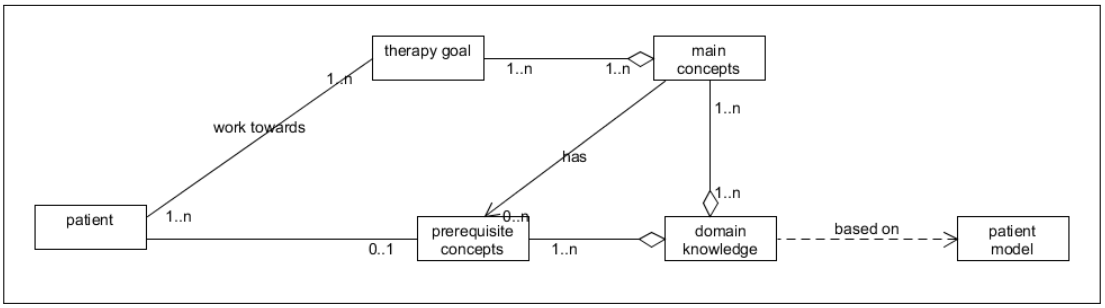

Fig. 5.1: Represents model of domain concepts in CBT domain model

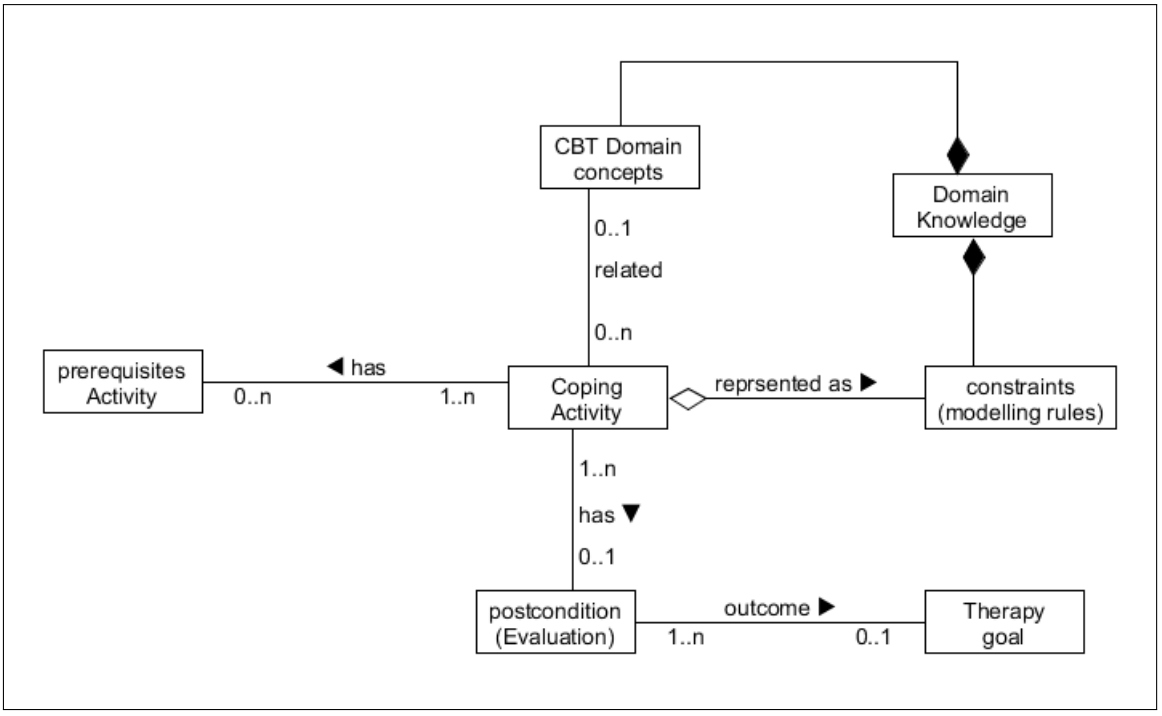

Fig. 5.2: Represents an activity model in CBT Domain Model

In fig 5.2 display representing an activity model in CBT Domain Model in COPE. When patient performs activity in the COPE application, those activities are generated based on the patient model. When activities in COPE application are associated with patient, they are defined simply as coping activities which patient do which as represented as constraints. Then these generated activities as shown in activity model that are associated with related domain concepts which are required to

know prior to performing activity by the patients. The activities has pre-requisites that is activity may relate other activity and post-conditions (evaluation). Therapy goal is associated with activity which is based on patient model which is described as therapy outcome.

5.2 Proposed personalized iCBT: COPE therapy App

In proposed personalized iCBT COPE therapy application (as discussed in Section 3.2), breast cancer patient is a learner and also should perform adaptive sequencing of activities to achieve given therapy goal. However, these activities and order that they perform change with depending on patients and based on their patient model. Therefore, COPE application uses adaptive learning algorithm to infer requirements of a patient (as learner) and modify adaptive algorithm accordingly. The adaptive algorithm responds to varying conditions through adaptive rules (as explained detail in Section 4.5). Our application employ adaptive algorithm that allows patients to select different coping activities and perform with support CBT domain model. The application also uses domain knowledge and constraints-based mechanism for dynamic therapy adaptation to change iCBT therapy process as patients improve or begin to show progress.

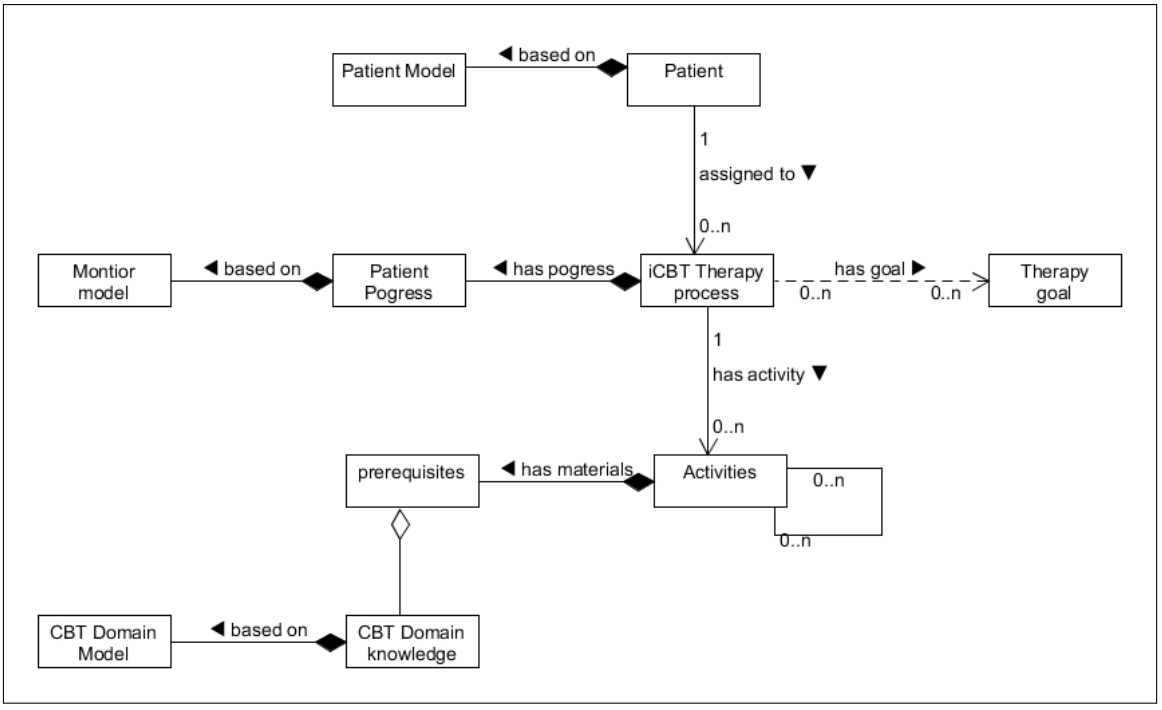

Fig. 5.3: Personalized iCBT COPE therapy process model

Personalized iCBT COPE application therapy process model which models the semantic classes required for definition of adaptive personalized therapy process are shown in fig. 5.3. In iCBT therapy process consists of one or more activities which are assigned to individual patient and activities class consists of set of activities. Therapy goal will achieve by following recommended activities in an iCBT therapy application. It means that, each patient follows a set of activities to achieve a therapy goal. The recommended activities should be achieved by an individual patient for completing iCBT therapy. The activities are suggested based on patient model.

Pre-requisite class as shown in fig. 5.3 defined for each activity. The prerequisite class consists of CBT materials related to activities. To complete an iCBT therapy in COPE application patient must learn or know related CBT domain knowledge. This is related to activity that are recommended as pre-requisites for beginner. The CBT domain knowledge is suggested based on the CBT domain model. In each step of the iCBT therapy in COPE application, activities are updated based on the progress of the patient which are suggested based on monitor model.

5.2.1 Activity Diagram

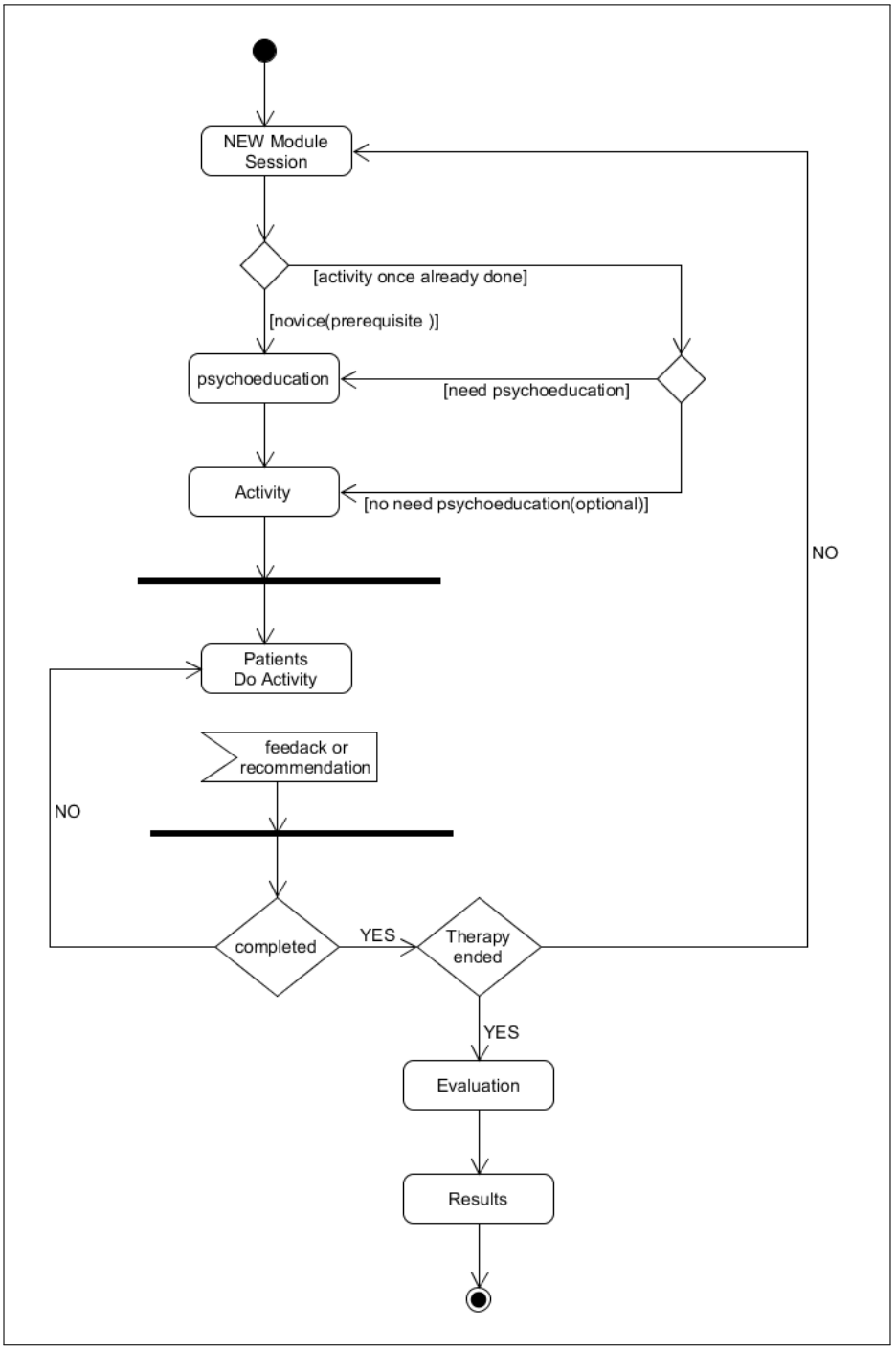

Fig. 5.4: Personalized iCBT COPE Application Activity Diagram

Activity diagram in iCBT personalized COPE application shown in fig. 5.4. Here patients get feedback during activity monitoring and in-turn gain constant regular results on the progress and also next CBT therapy coping activity (Module Session) recommend based on the feedback to support personalized therapy process. After completing each and every recommended activities evaluation is performed to know the overall therapy outcome.

6 Implementation Details

This chapter discuss our research concerning to domain knowledge described in preceding chapters. We proceed with implementation details of domain ontological model of the COPE application. However, scope of thesis is mainly modelling and implementation does little constitute its part.

We choose UML as our ontological modelling language of development for several reasons. First, COPE is based on java programming language environment and UML is object oriented modelling language. So using UML conceptual model for our CBT domain model will make integration smoother.

Cranefield & Purvis (1999) suggested UML as an ontology modelling language. It stated that UML can be used as standard for ontology modelling. So model and capture of domain knowledge that huge world-wide acceptance will enable easy understanding and inter-operatability between ontologies (Kabilan & Johannesson 2004).

First, we describe use-case scenario from the actor's point of view directly influence and employ mostly domain model in the application. In forthcoming section description of tools used during domain modelling are discussed.

6.1 Use-case scenario of domain model: COPE Application by the main actors

During specification and creation of materials for CBT domain model for adaptive application there were two main actors that influence the composition of the domain knowledge: breast cancer patient and domain expert. The desired effects from each and modelling principles are quite different yet both are equally important of effective therapy outcome. Illustration shown in fig 6.1 and fig 6.2 display that input types are based on patient and domain expert involvement.

First thing, we will describe use-case scenario from the domain expert (author) point of view as shown in fig 6.1. The structure of the domain knowledge of the CBT model is created based on the structure of the breast cancer patient treatment modules as shown in fig 4.6. This is for the mental health physical and psychological symptoms (refer fig 3.2). So, CBT domain model implementation had been transformed into use-cases, which are listed into as : CBT materials, treatment modules, module

sessions, resources (text,video,audio), assessments and constraints.

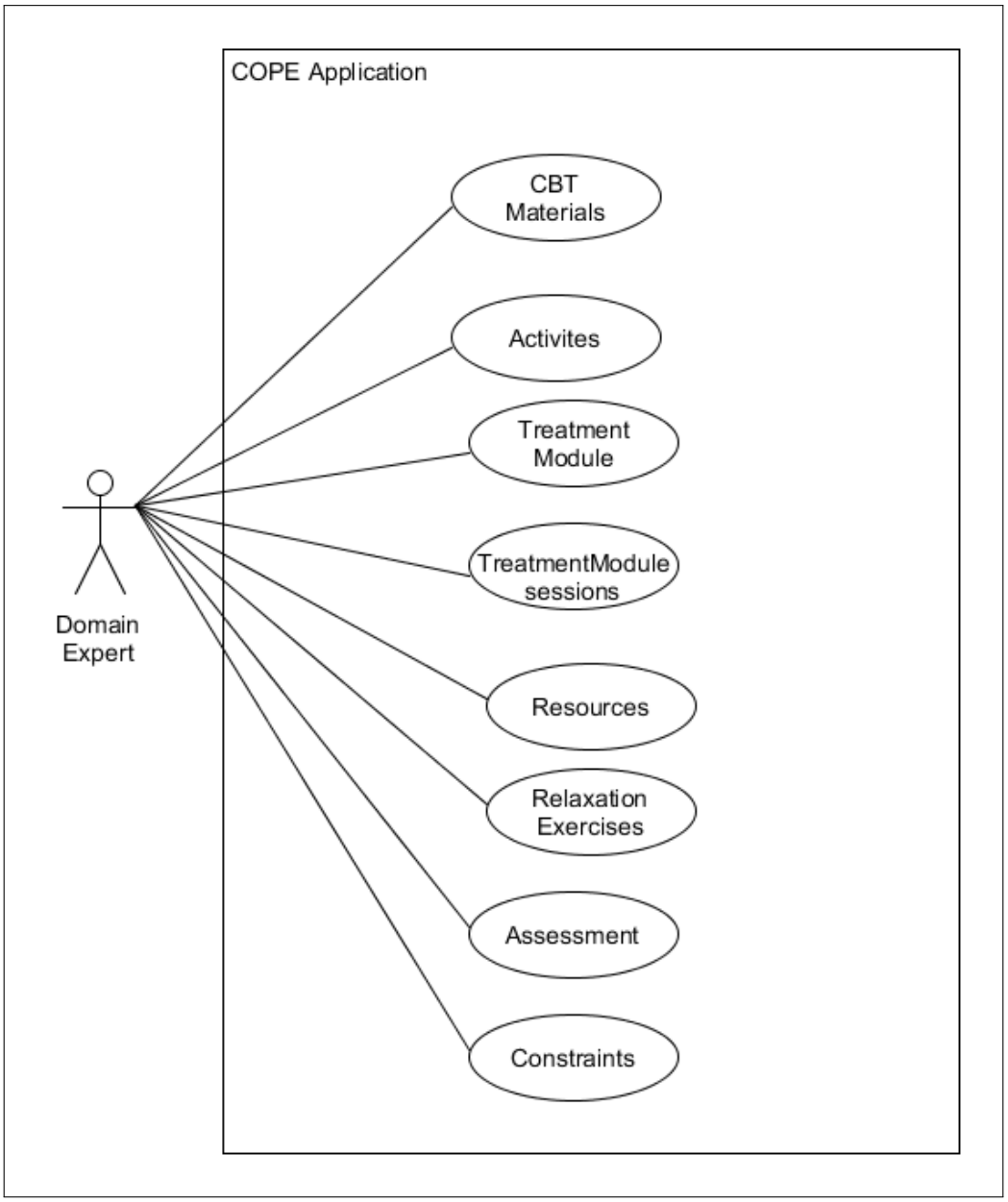

Fig. 6.1: Domain expert : Use-case Diagram

On Second, description of use-case scenario from the breast cancer patient's point of view (fig 6.2), which is primary user of the COPE application. This scenario consists of describing actions and reactions between the application and patient.

Application starts by identifying patients if they are first time users and will be

given a initial screening. Here screening questionnaires are recommended to use to determine patients physical and psychological symptoms, requirements, medical background, preferences etc. After responses from patient, adaptive COPE application will enable to define therapy goals for patients that represent of the main components of the patient model.

When patient already accessed to the application he or she choose a therapy goal for the first time, then COPE application will initiate and takes care of issuing a pre-assessment. The result of this assessment will allow application to initialize patient model by assigning level of symptoms. Depending on the results of the screening and pre-assessment COPE application will proceed to assembling appropriate CBT materials. Also, determine to select activities among these should be added in patient therapy goal that are produced by CBT domain model.

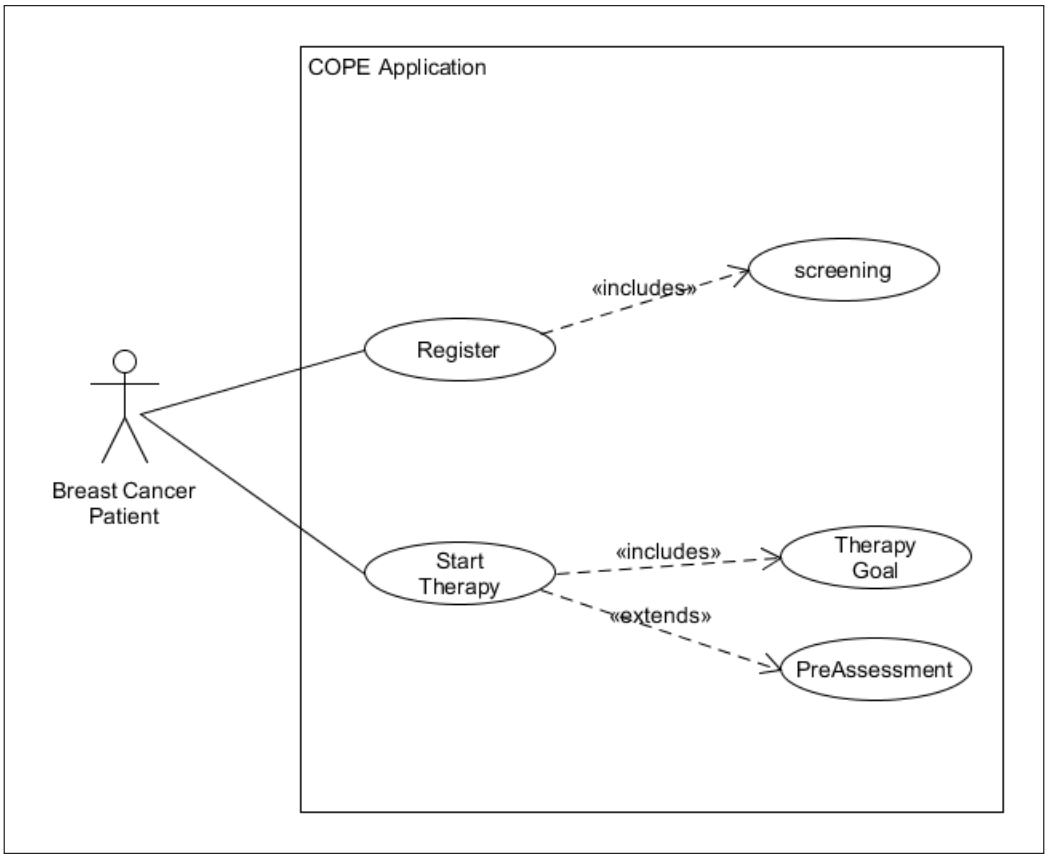

Fig. 6.2: Breast Cancer Patient's Use-Case Diagram

6.2 Tools used during domain modelling

Domain knowledge are currently implemented UML as ontological language. The UML is general-purpose, developmental, modeling language that provide a standard tools or routines to visualize the system-view. Widespread usage of UML with large number of tools are available and these tools are categorized (Martin et al. 2009),

1. UML drawing tools
2. code-centric tools and
3. framework tools.

In this thesis UML drawing tools are used and these aid to focus on fast diagram sketching and offers great flexibility.

6.2.1 UMLet

The UML models were created using UML drawing tool (UMLet) and this can downloaded from www.umlet.com. UMLet is a easier and flyweight java application that can easily be integrated in various development environments (Martin et al. 2009). It is platform-independent application features that allows an innovate user interface and flexible output to different file formats. The user interface provides a platform to draw UML sketches quickly and intuitively. It is based on a simple markup description of UML elements and avoids tedious pop-up dialogs that are commonly found in other UML tools (Auer et al. 2003).

6.2.2 Advantages of using UMLet

1. provides a tool that can aid to easy to distribute and deployed for different software development environments (Auer et al. 2003).
2. provide a fast and intuitive user interface to quickly create UML sketches and diagrams without user with seldom-used UML language features.
3. provide flexible ways to share UML diagrams and to re-use them in different workflows.

6.3 UML creation

UML is a standardized, graphical, general-purpose modelling language (as details described in Chapter 4) describes relationships and inter-relationships that exist within a CBT domain model. UMLet tool actively supports the iCBT content of developer (author) during the creation of the UML through facilitating addition, deletion and modification of CBT domain model concepts.

UMLet allows author to describe relationships between concepts of CBT domain knowledge. It also allows author to create and define customized relationships, hence offering more control to the author during development of materials for CBT domain model construction.

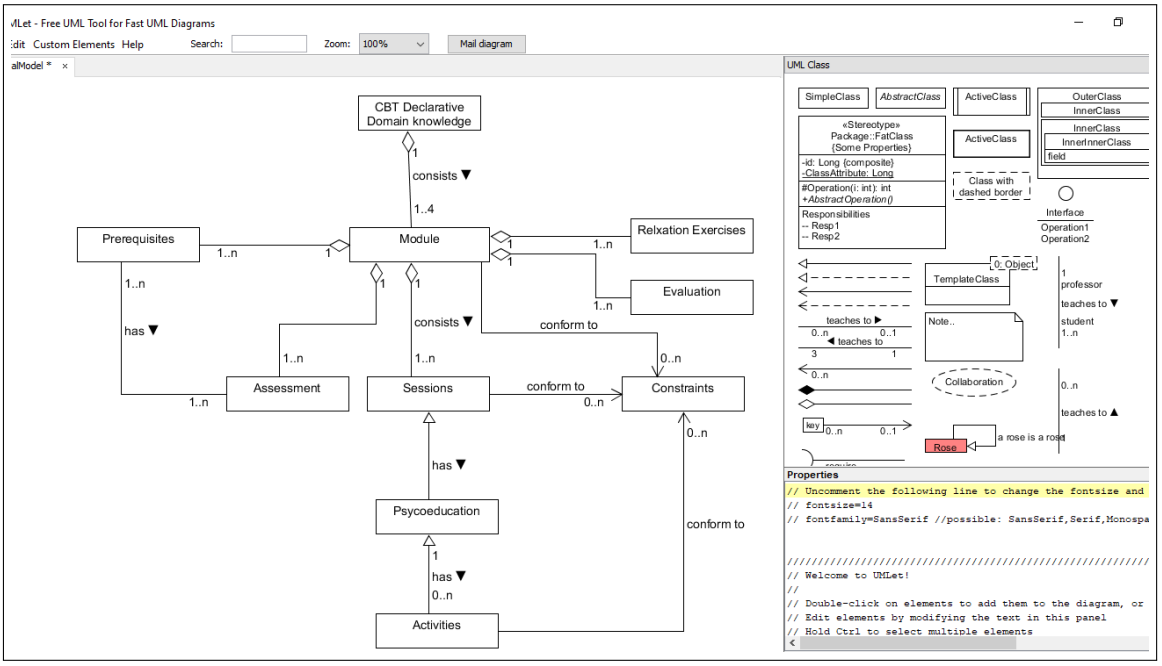

Fig. 6.3: Design of UML Class diagram using UMLet

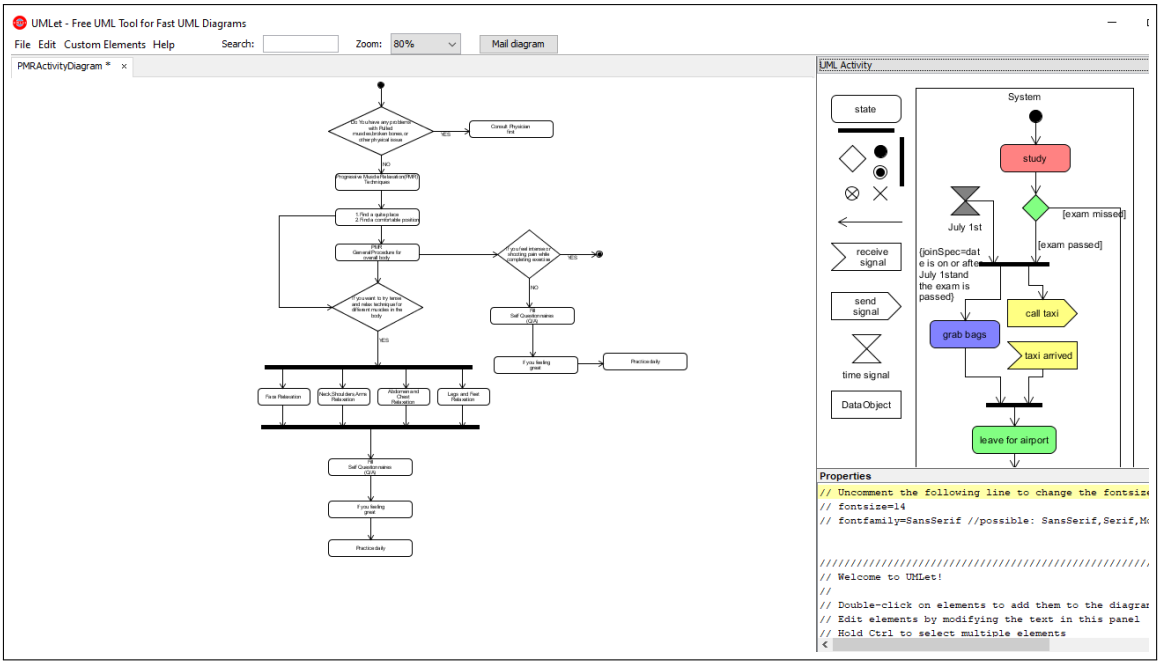

Fig. 6.4: Design of UML Activity diagram using UMLet

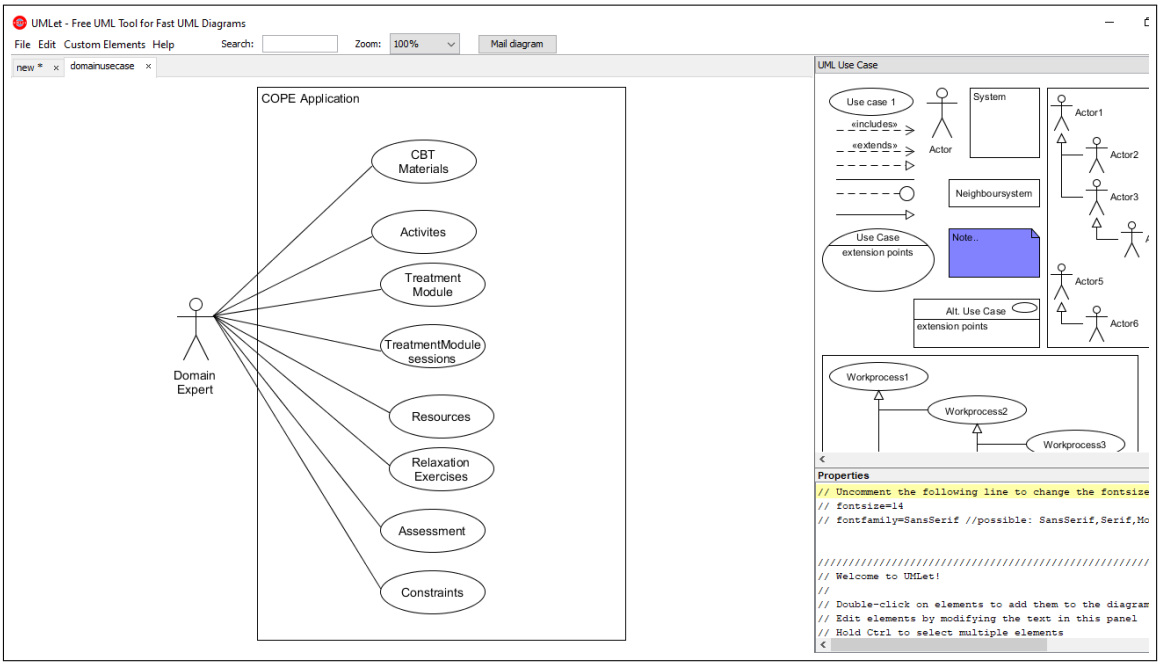

Fig. 6.5: Design of UML Use-case diagram using UMLet

The screenshots shown in all three fig 6.3–6.5 display UML of the UMLet. These illustrates that domain concepts within the UML can be graphically and logically

grouped with associated defined relationships. The left-part of the screen is diagram area where domain concepts are listed and upper right portion is UML element palette where that elements in the palette are graphically identical to the elements displayed in the diagram. The lower right part of the screen is text panel which allows to view and edit a UML element's markup string.Both the element properties on the diagram and on the palette can be edited.

6.4 Ontology-Based Model Implementation

Ontologies provide a modern approach towards the design domain knowledge of domain model component of COPE application. Ontologies are used for domain knowledge representation, as it is a method of modelling the real-world knowledge in information systems. In Artificial intelligence ontology defines as "a formal specification of a conceptualization, that is, an abstract and simplified view of the world that we wish to represent, descried in language that is equipped with formal semantics (Boshnak et al. 2019). In domain knowledge representation, an ontology defines the concepts and its relationships that hold between them. In other words, ontology provide a formal semantics to terms to use them in the machine process-able way. To represent or express ontologies there are various formal languages which are used to share and formalize conceptualizations domain knowledge thus to enable humans (domain experts) and machines to easily understand the meaning of data exchanged.

6.5 Proposed ontology based model

During implementation step, ontology model created based on the outcome of previous step (UML based ontology modelling). At this step, we selected an ontology Protégé tool (http://protege.stanford.edu) in order to model CBT domain knowledge representation and for implementation process OWL (Web Ontology Language) (Malviya et al. 2011). The OWL is used as representation language of the model and is new standard ontology language of the semantic web, defined by W3C.

Protégé is a free, open source ontology editor is used to develop the ontology from Stanford university, which enables in construction of domain ontologies (Malviya et al. 2011). The editor provides a GUI to achieve the same as shown in fig 6.6. The Protégé tool chosen owing to present a user-friendly development environment and

possible to import other existing ontologies.

Fig. 6.6: Stress class hierarchy defined in the Protégé GUI

Protégé comes with visualization packages such as Onto Graph, OWL Viz, these helped us to visualize ontologies with diagrams as shown below. Protégé GUI provides a tree view of ontologies fig 6.7. Although an expandable tree is suitable for many ontologies and terminologies, it can be difficult to visualize those that have multiple types of relationships among the terms. A tree shows the relationships among terms using one relationship (usually the is-a relationship).

6.6 CASE

In this part, we will present how to use OWL in Protégé 5.5.0 tool to describe ontologies due to its flexibility and open source code, that is enabling reason to create these artifacts to use in COPE application. The possibility of transforming UML ontological models (as shown in fig 4.15) into formals specifications has been successfully implemented as shown in fig 6.12. First, we display implemented simple ontology in OWL.

As in our approach, an ontology model which has been developed is comprised of

four treatment modules as shown below in fig 6.7.

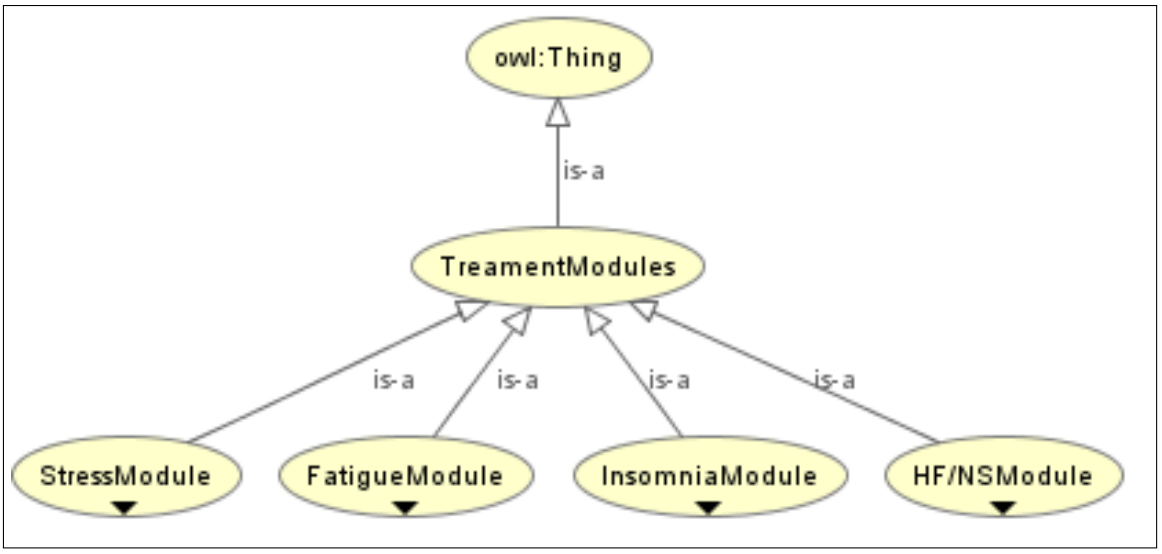

Fig. 6.7: OWL Viz visualization of treatment modules in CBT domain model in Protégé

Each of the main classes is described as follows:

1. **TreatmentModules**: It is main class of the domain ontology
2. **InsomniaModule**: This class contains all of CBT material related sleep problems in **TreatmentModules**.
3. **HF/NSModule** : This class contains all of CBT material related to hot flushes and night sweats in the **TreatmentModules**
4. **StressModule** :This class contains CBT material related stress problems in the **TreatmentModules**.

As in this case only ontology is created for only **StressModule** class of CBT Domain model of COPE application. The sub-classes of **StressModule** are followed as shown in Protégé Onto graph (See fig 6.8) that provides a structure of the sub-classes **StressModule**.

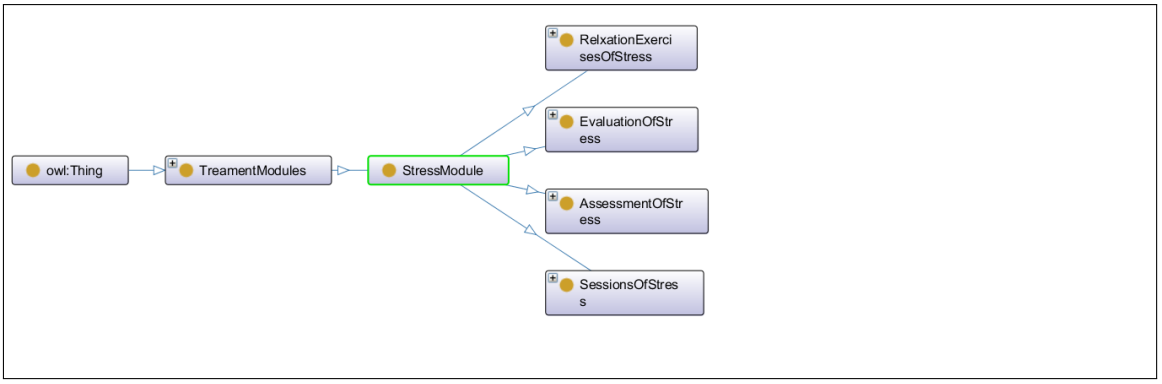

Fig. 6.8: Onto Graph visualization of sub-classes of StressModule in Protégé

It is an ontology to show the relationship between stress treatment module and its contents. Thus,this ontology has one class and four sub-classes. The class is named as "StressModule",and according to iCBT therapy approach, we divide this class into four sub-classes ("AssessmentOfStress","SessionsOfStress", "RelxationExercisesOfStress","EvaluationOfStress"), as shown in fig 6.8.

Description of Sub-classes of StressModule as follows:

1. AssessmentOfStress: it has some sub-class that is PreAssessment,
2. EvaluationOfStress: It has Some sub-classes that is PostAssessment and Self-Monitoring,
3. RelxationExercisesOfStress: It contains Deep-Breathing exercise. Also, further exercises can be added,
4. SessionsOfStress: It contains three sessions,where each session has sub-classes.

Sub-classes of: Assessment and Evaluation : Assessment contain one subclass PreAssessment. It contains assessment questionnaires about the severity of stress and its symptoms. We can use tools but due to less resources of existing iCBT therapy approach used in here. Fig 6.9 show structure of this sub-class.

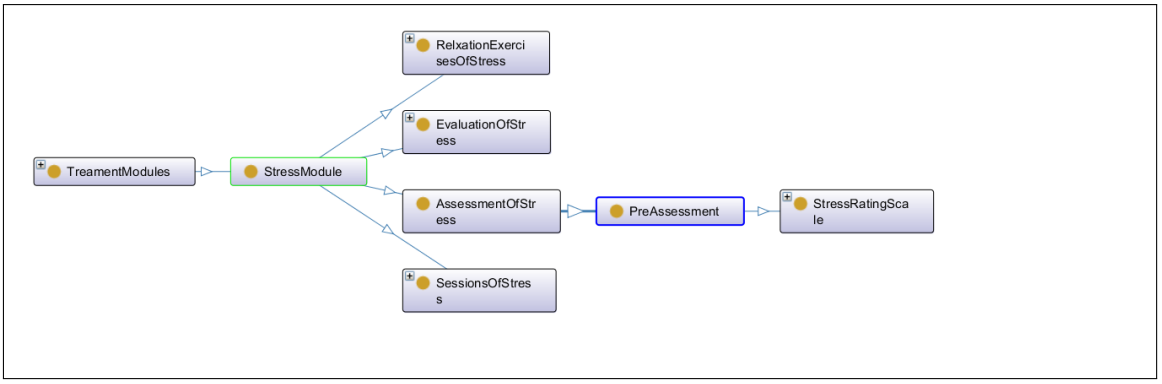

Fig. 6.9: Onto Graph visualization of sub-class Assessment of StressModule in Protégé

The evaluation contains two sub-class, first one contains self-monitoring questionnaires for each SessionsOfStress, based on this adaptive content can be produced to patient. The second sub-class contains PostAssessment which assess severity of the stress disorder and its symptoms after completing the module or of its each sessions. Fig 6.10 shows the structure of the subclass.

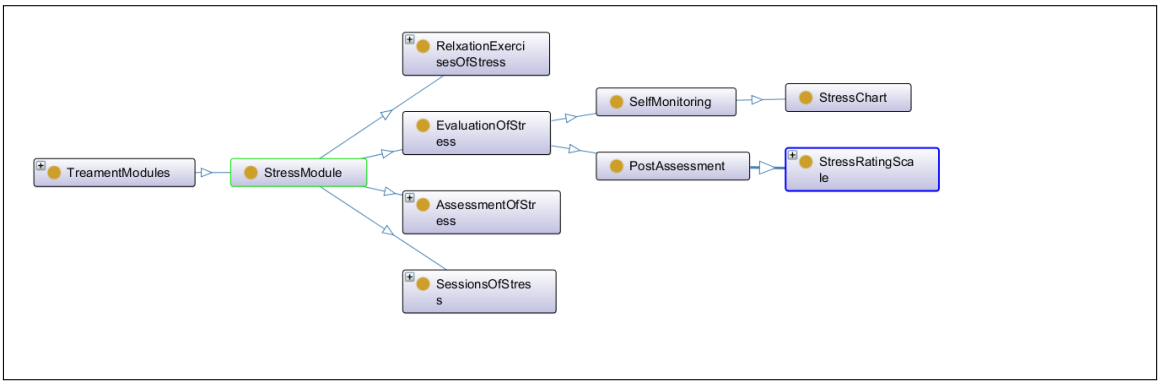

Fig. 6.10: Onto Graph visualization of sub-classes Evaluation of StressModule in Protégé

Sub-classes of: StressOfSessions : This subclass contains of three sessions, but it can be expandable in the future. Each session contains psycho-education about how to cope with diagnosed stress symptoms, activities, and examples how to do the activities. Fig 6.11 show the structure of the subclass.

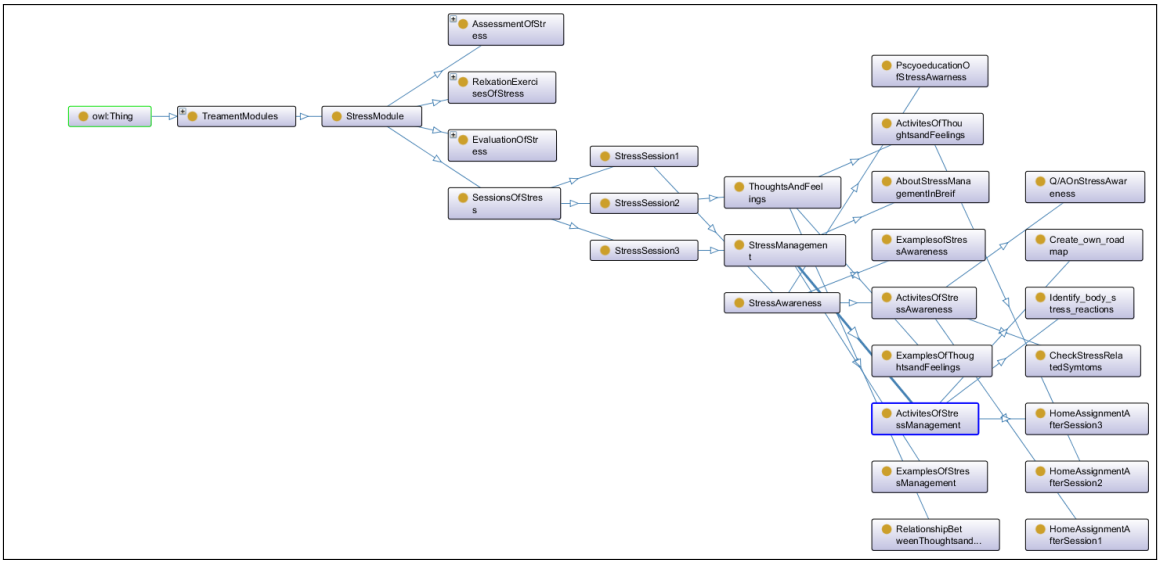

Fig. 6.11: Onto Graph visualization of sub-classes SessionsOfStress of StressModule in Protégé

Visualizing the StressModule with onto Onto Graph : This contains overall structure of the StressModule treatment module in the CBT domain model and fig 6.12 show structure of the stress module class.

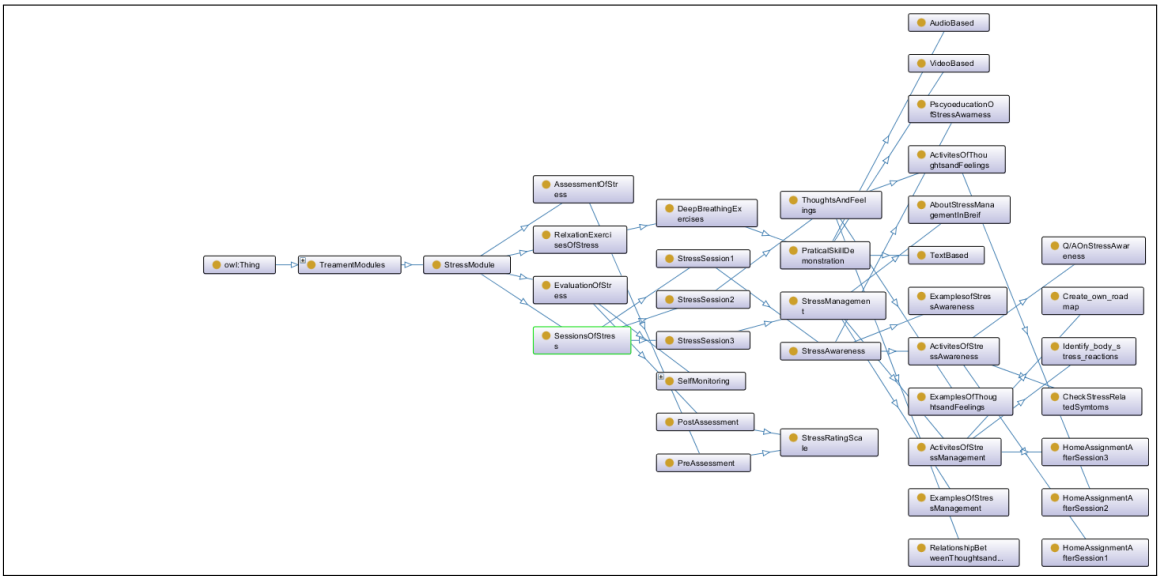

Fig. 6.12: Onto Graph visualization of Class StressModule in Protégé

StressModule Ontology Verification: HermiT 1.4.3.456 Reasoner used to verify

texture and organization of the ontology. This ontology verification enabled during the ontology creation to avoid upcoming faults. In case of class is unsatisfiable a red color will indicate that there is a weakness exists.

7 Evaluation

Proposed CBT domain model includes final step of evaluation as it is important part of design science methodology. The developed domain model of artifact contains overall evaluation of all phases as described in methodology (Falbo et al. 2002). In our case during the knowledge capture before meeting with the domain expert, we had no previous knowledge about CBT resulting that first meeting organized with expert was extremely important. During this phase, we searched research articles related to CBT and iCBT approaches that could be useful in the present work. While reviewing articles of research papers, we faced daunting task of organizing and selecting the relevant treatment modules for mental illness to breast cancer patient. But these issues were clarified by domain expert. In the beginning of the conceptualization phase, we had begin to identify relevant concepts and relations in CBT treatment modules. During knowledge acquisition some points were noted for important concepts, their definitions and even relations between concepts. As in our meetings with expert we agreed that concepts and relations chosen form a conceptual model.

During conceptualization phase, our model was evaluated more that four times by the domain experts. On the first meeting, we explained first conceptual models to domain experts. The domain expert agreed with concepts and their relations with additional concepts that were not covered on those models. The experts gave an overview on CBT principles that are used in the treatment for breast cancer patients which were made to change in the first conceptual models. Also, they identified few CBT treatment modules approach had very less concepts which was modified to add some concepts in detail. In therapy most treatment contents are important for efficient therapy outcome. The domain expert identify few missing concepts and suggested that these concepts such as relaxation exercises should be presented to the breast cancer patients in general way as patients can use them whenever needed. This meant that relaxation exercises are not restricted to any specific treatment module or diagnosed mental disorder or its symptoms.

After taking feedback from domain experts on conceptual models, re-modeling were made. Then after completion, new model was re-evaluated by domain experts and was approved based on coverage of most of the exercises. We reached to finalized

conceptual model that main things were covered to represent in the model. There was team of four people working on the different sub-components in COPE application. These become very useful to this phase because different vision were presented on how treatment modules should be modeled. However there were some expectations to represent all treatment modules as due to limited resources. Therefore only stress treatment module was only approved by domain experts. This was not a problem because other treatment modules can be reviewed and modified in future work. The domain experts sometimes were busy and unable to attend meeting during conceptualization phase, but model was regularly reviewed by our supervisors from the technical point of view.

The main hurdle to this evaluation method that it is continuous process as therefore was sometimes not all problems were immediately identified or addressed. A piece of conceptual model that was supposed to be completed had to be modified at a later stage. Another problem in conceptualization phase was a fact that it was difficult to identify when to halt because of CBT therapy approach where most of the contents are related to one or the other. The higher chances of addition of more specific concepts to the conceptual model and modeling of CBT treatment modules with more details in future are also possible.

After completion of conceptualization phase we design formal UML models to represent the concepts and its relationship in domain knowledge of the CBT domain model by using UMLet tool. This model constantly under the evaluation by supervisors from technical point of view. After these were approved, ontology model was implemented to integrate to the COPE application.

The represented domain knowledge by UML diagrams used into an ontology building tool Protégé 5.5.0 editor. Only implementation of ontology for stress treatment module was performed. As part of our effort to prove ontology competence and usefulness, and to perform some evaluation, verified stress module ontology formed with HermiT 1.4.3.456 Reasoner by sing Protégé tool. And performed as in our case, as set of generic criteria has been used as proposed by (Fox et al. 2002).

These criteria include:

1. **Does ontology contain the minimum number of objects necessary ?**

   In the implemented ontology contains the minimum number of the concepts

of the CBT domain model and its corresponding hierarchy relationships. As the Classes are organized into a hierarchical taxonomy as shown in the fig 6.6. There are many ways to develop class hierarchy which consists of three levels : top-down level approach, bottom-up approach and combination of the both (Noy & Mcguinness 2001). In our approach, we used top-down approach where we start with creating main class as treatment module. Then specialize the treatment modules class by creating sub-classes: StressModule, FatigueModule, InsomniaModule, HF/NSModule. Further categorization of StressModule class, for example: AssessmentOfStress, EvaluationOfStress, RelxationExercisesOfStress and SessionsOfStress were introduced (please refer to fig).

2. **Is ontology easily understandable by the users so that it can be consistently applied and integrated across the application?**

   In the CBT domain ontology simple vocabulary has been introduced. So that it shares a common understanding of the concepts and its relations among users and sub-components in the COPE applications.

CASE STUDY

We now present a case study scenario to evaluate and illustrate adaptive personalized self-guided iCBT treatment modules (refer to Chapter 3).

Usage of COPE application, patients must undergo pre-screening which are provided through application to determine if they meet initial eligibility criteria. Inclusion criteria are listed as (a) breast cancer patients aged 18 plus to 70, (b) Patients who do not have current psychiatric disorders. This information will be stored in the patient model. After initial screening, if patients data are appropriately taken to online therapy program. Then eligible patient(s) will get pre-test to record their as (a) diagnosis/symptoms of either stress, fatigue, insomnia or HF/NS (b) personal goals and (c) preferences.

Patient Model : Pre-defined data

1. **PERSONAL BACKGROUND**: Amy reported that she reside alone in Norway. She have two adult children with one grand-child. These relationships she described were positively "loving and supportive". In terms of other relationships reported that she had few close friends and described herself as "introverted". She is currently working full-time job as human resources representative in private company. She reported of undergone breast cancer treatment 5 years ago and reported as survivor.

2. **ASSESSMENT**: After downloading COPE application, she participated in the initial screening and recorded information as 48 year old Norwegian women with stress disorders.

3. **SYMPTOMS HISTORY**: Using the EORTC-QLQ-C30, She met diagnostic criteria for reduced quality of life after breast cancer treatments (current and past) and further diagnosed as suffering from stress disorder and its symptoms. She reported that experiencing symptoms of trouble sleeping, tense, worry, irritable, tired after breast cancer treatment at the age 45. Over the lifetime she experienced bout of stress symptoms at least everyday that interfered with her daily activities. The symptoms record showed that it worsened since last one year.

4. **MEDICAL HISTORY**: Amy reported of receiving of "talk therapy" and

stress symptoms on few occasions, although therapeutic orientation of the former treatment was indeterminate. She also indicated prescribed anti-stress medication were taken in the past, but medication was discontinued soon after commencement due to undesirable side effects.

5. **PERSONAL GOALS**: Amy personal goal is develop of being worry free for ongoing things and get 7-8 hours of restful sleep each night. Thus this will increase quality of life. She shown of feeling hopeless and less energy to focus on her job. She aim to have feel energetic life throughout the day and can enroll to attend at least 1 hour morning or evening for therapy at least once in a week.

6. **PREFERENCES**: She would prefer information and instruction both in text and video.

Adaptive personalized iCBT therapy:

Given that screening of Amy revealed that she met inclusion criteria for iCBT. She was further interested in self-guided therapy and was given access to "iCBT treatment program". All information collected (about pre-screening, assessment, symptoms, medical history, measures, personal goals, preferences) are provided by patient model (sub-component in COPE Application).

Based on patient model information and adaption algorithm (sub-component in COPE Application) together present adaptive personalized CBT treatment content to her. Also, she reported that stress symptoms were causing trouble in sleeping, remain tense and worried, irritable, tired and she also indicated preferences for how contents to be viewed to her during treatment.

Before releasing CBT treatment content by the application, it assess severity and monitor treatment outcome measures. The measures were rated according to stress rating scale and stress assessments. The perceived Stress Scale is a 10-item self-report tool that assess individual stress levels during the last month with patients rating symptoms on a 0 (Never) to 4 (Very often) scale and Amy scored 6 on the measure suggesting moderately severe stress symptoms. Stress Assessments assess frequency that patient experience common symptoms of stress, these symptoms of

stress Amy is having a negative impact on her life. Amy did not endorse current suicidal on both measure.

Further COPE application adapts to patient (Amy) therapy goals based on patient model of pre-defined data which are listed as,

1. Therapy for stress symptom as sleep problems,
2. Therapy for stress symptom as tense, worry and irritable
3. Therapy for stress symptom as tired,
4. Release of treatment content every week once,
5. Content in the form of text-based and video.

Related CBT treatment content (also known domain concepts in thesis) are adapted by COPE application based on patient model pre-defined data. In system, it is stored as adaptive rules (as constraints).

For eg. Rule 1:

1. IF
   Amy symptom of stress disorder indicated as sleep problem
   $THEN$
   Pre-requisites are :
   (a) Amy must complete at least 5 days of sleep diaries in a seven-day period and
   (b) Measure Pittsburgh Sleep Quality Index (PSQI) for poor sleep quality.

Patient record sleep diaries of seven-days and measure PSQI. Amy scored 6 on the measure PSQI which is a 9-item self-report tool that assess individual Poor sleep quality within the previous during the last month with patients rating symptoms on a 0 (very good) to 3 (very bad) scale.

It consists of 5 interactive main concepts (main treatment sessions) including text and video and it covers the following :

- psycho-education on how sleep problems related to stress,
- Sleeping hygiene,

- Sleeping restriction,
- Deep Breathing relaxation,
- Psycho-education about how to improve and build up your energy and increase physical activity.

If Amy had not completed or missed to complete sessions (pre-requisite treatment sessions) that are related to main treatment sessions then she must complete them before doing the main sessions. The following prerequisite treatment sessions are:

- Psycho-education about stress
- Understanding of relation between thoughts and feelings
- How to manage stress
- Psycho-education about cognitive behavioral therapy of breast cancer treatment-related fatigue and what are causes for breast cancer-related fatigue ?

At the beginning of each session, Amy maintain every week of 5 days record of sleep diaries in a seven-day period. Whenever Amy completed fewer than 5 diaries and unable move forward to the next sessions based on weekly sleep dairies, then quality of sleep is recorded, which further recorded in patient model. At the end of each session, Amy assigned to off-line relaxation exercises. Following the progress, system recommends mindfulness-based stress reduction exercise to her.

When Amy reached 5th main treatment session, then system had precondition to rate fatigue severity by Fatigue symptoms inventory (FSI). FSI composed of 14 items (self-report tool) which assess individual perceived severity, frequency, and interference with daily functioning within previous during last week with patients rating symptoms on a 0 (no fatigue) to 10 (As I could be fatigued) scale. System also asked to record diary can determine daily activities of her.

Amy completed iCBT program in 10 weeks and completed a stress rating scale at the start of each session,she also keeping sleep diary and daily activities dairy,which tracked her stress symptoms.

At the end evaluation of treatment outcome is done based on based on as: (a) Stress rating scale, (b) Sleep diary, and (c) daily activities dairy.

RESULT

The following case study scenario has been simulated on one breast cancer patient with their diagnosis, personal background, symptoms history, medical history,preferences and personal goals using our application and results have been validated. The iCBT intervention involved in this simulation has four treatments modules. Each modules treatment CBT content was annotated with sequences and activities based on the targeted patient data from patient model. The scenario simulate assumes that patient may have five concepts to learn and its prerequisites, respectively. Conducted simulation shows that the adaptive personalized system adequately adapts in delivering personalized CBT treatment content to breast cancer patients.

Sequence diagram illustrate how CBT domain model interact with the system when above use case is executed as shown in the fig 7.1.

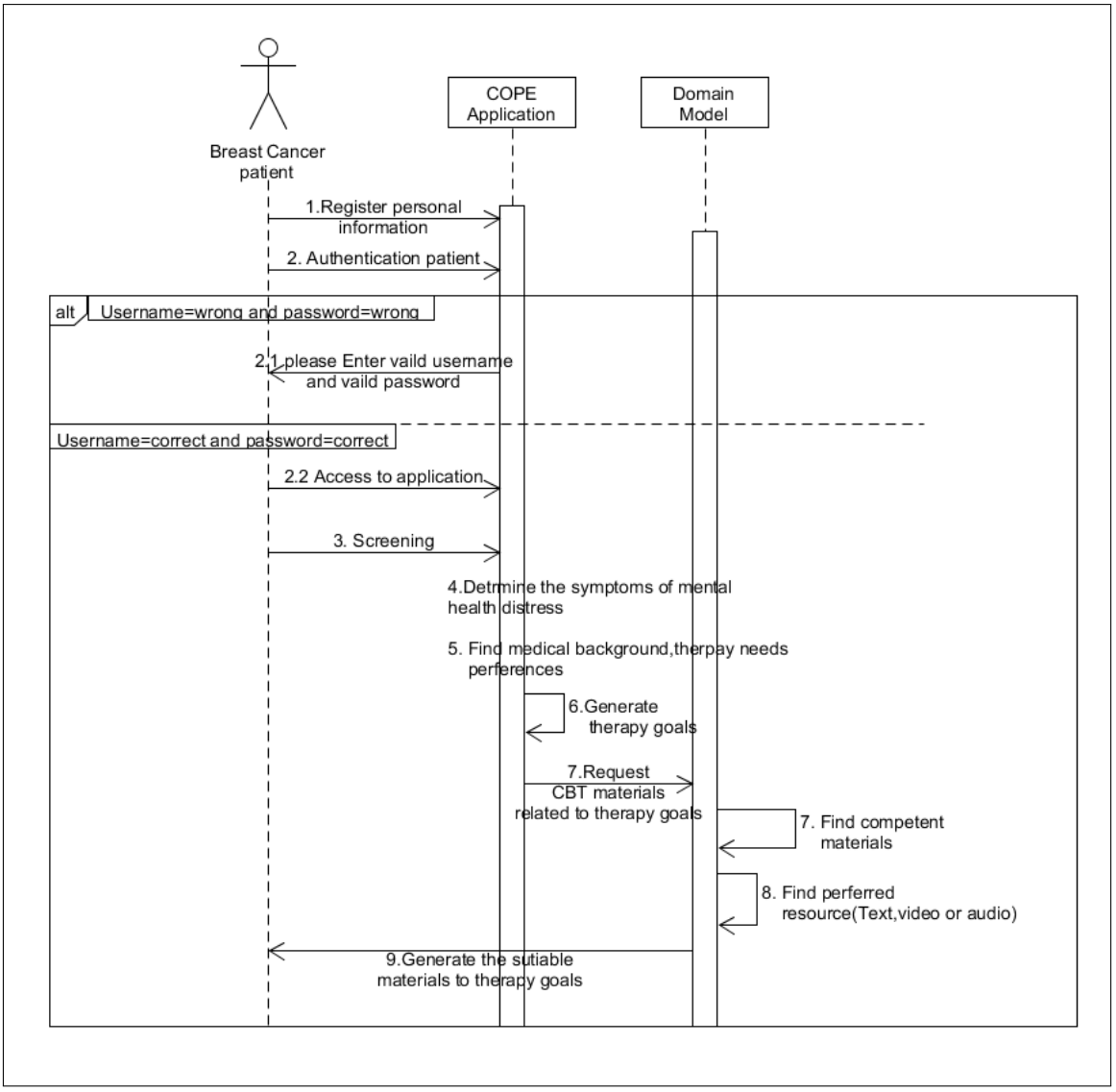

Fig. 7.1: Sequence Diagram

8 Findings and Discussion

Hevner & Chatterjee (2010) describes guidelines for design science research. The presented domain ontology framework specifies how design science should solve problems in the artifact domain, as well as provide research contributions in the form of an addition to the knowledge base. In this chapter presented below are answers to the research questions.

RQ1: **How to identify an iCBT overall model with modules that facilitates personalized or individualized iCBT therapy?**

Our first phase of the study involved an initial meeting with experts with long-standing experience working in the field of mental health particular to breast cancer survivors.And also the literature review were performed which identified a multitude of traditional iCBT systems, all of which were research prototypes. These traditional iCBT systems seem to provide a sound basis for establishing a set of CBT model,and so further we decided to investigate these existing traditional iCBT systems.

Wide variety of descriptions of traditional iCBT systems were available and also academic publications such as journal articles were reviewed for this study. Here our goal was to identify overall traditional iCBT overall model and then identify treatment modules from that existing traditional iCBT systems. Based on this further we to design and develop a CBT domain model for adaptive personalized iCBT therapy application, representing treatment needs to which learning CBT materials has to be prepared. The structured CBT materials will be delivered in adaptive way for patient who are suffering from various mental illness physical and physiological symptoms after breast cancer treatment.

Now existing self-guided traditional iCBT programs are based on CBT principles (explained in Chapter 2) and are delivered via internet. iCBT programs has a sequentially structured treatment modules and clearly defined goals and are scripted(predefined) to most of iCBT programs to provide minimal therapist support or no support at all (fully automated). Also, most of traditional iCBT programs had many features and made up of short-term treatment modules, typically consisting of 6 to 15 modules. But these traditional iCBT programs content and delivery may differ according to the mental disorder being treated.

Most existing self-guided traditional iCBT programs (for breast cancer patient or survivors) lasts up-to to 6-10 weeks. In some iCBT programs, first identified patients will preceded by a diagnostic interview and then receive screening questionnaire by therapists at beginning. So, patient can be matched to the correct treatment and later assigned to iCBT self-therapy or eligibility will be confirmed by various communication tools such as email, telephone followed by baseline assessment. In self-guided iCBT programs, eligible patient will receive weekly one treatment module to complete within one hour. In some systems collect symptom data on weekly basis throughout the treatment and then usually given feedback to patients. It also presents support in the form of reminders or feedback by text messages, email, or telephone those who miss the homework assignment. One important aspect of iCBT treatment is, it has a clear deadline for treatment completion.

In all current traditional iCBT therapy, iCBT treatment modules in this respect are not flexible. Here iCBT program cannot adapt iCBT treatment modules to different patients as modules presented is same for all the patients. As a result, some patients fail to cope with mental illness or dropout in mid way of iCBT therapy or waste their time learning iCBT modules that are irrelevant to their illness.

So to make iCBT modules richer and more flexible so that different patients can get personalized iCBT treatment modules or contents and as well personalized order of presentation of iCBT content in treatment module in adaptive COPE application. We used existing structured iCBT intervention program that can adapt to patients with very different personal background with specific mental illness symptoms, medical history and personal goals (that will be addressed in further research questions).

RQ2: **What sources can be re-used from previous literature for creating our domain ontologies of a CBT domain model for personalized iCBT therapy?**

We also explored whether treatment content of the iCBT programs are publicly available. Also, we wanted to identify on which treatment modules are used in existing traditional iCBT programs. But iCBT treatment content was not publicly available, we relied heavily on written description of the program structure in the research articles. All papers were cited accordingly. To analyze content in treatment

modules of existing traditional iCBT program, we implied for different treatment modules recognized in 4 studies and commonly found in treatment modules. Below providing Table 8.1 show existing traditional iCBT program content to have idea over who is unfamiliar with it. Here we also used some of these program contents to make use in adaptive iCBT therapy research.

RQ3: **How to identify treatment contents for each iCBT treatment module in detail from a traditional CBT therapy approach?**

Most traditional iCBT therapy programs in self-guided iCBT therapy are fully automated, presented by system or some with minimal therapist at the beginning, and all patient receive same content. Most iCBT programs 6-10 treatment modules that often follow a determined structure, **RQ1**.

Traditional iCBT treatment content (Table 8.1) includes CBT therapy concepts as psycho-education about the target at the disorder and a model for recovery at the beginning and ends with recurrence prevention. The contents of traditional iCBT are presented in the form of text to read, audio and videos and other interactive elements.

Most iCBT program treatment modules are arranged in a sequence of modules that progressively build upon the previous modules to encourage coping skills of broken thoughts, emotions, and behaviors. In each module, the content/information is first presented in text to read or audio and sometimes videos to view and activities to complete. In iCBT the activities may have associated features such as test questionnaires and then followed by the homework assignment given which that strengthen coping. This requires that the patient put into practice what has been learned, essentially by conducting a series of self-questionnaires evaluation. For example, homework comprises as relaxation exercises to practice every day.

Most traditional iCBT programs also allow patient to rework previous modules as often as needed, the strength of all online therapy, but do not allow progress to the next module until sufficient time has transpire to have done the homework. Most length of iCBT program has often been the same as in face-to-face CBT. For example, a treatment for insomnia disorder may last 8 weeks, which is a typical length of a face-to-face treatment for that condition. Most programs use a minimal therapist to support the patient in self-guided therapy, with brief interactions by

Research articles	
(Antoni 2016)	10 Modules 1. Introduction 2. Stress Awareness 3. Cognitive distortions 4. Cognitive Restructuring 5. Coping 6. Quality of life 7. Social support 8. Anger management 9. Assertiveness 10. Acceptance and wrap up
(Atema et al. 2019)	6 Modules: 1. Welcome 2. Hot flushes 3. From stressing to relaxing 4. Improving sleep 5. My body and sexuality 6. Keep progressing
(Børøsund et al. 2018)	10 Modules: 1. Welcome 2. What is stress 3. Stress, QoL and planning 4. Thoughts, feelings and selfcare 5. Stress and coping 6. Social support, humor, and meditation 7. Anger management and conflict style awareness 8. Assertiveness and communication 9. Health behaviors and setting goals 10. Summary
(Zachariae et al. 2018)	6 Modules: 1. Introduction 2. Sleep restriction 3. Stimulus control 4. Cognitive restructuring 5. Sleep hygiene 6. Relapse prevention
(Abrahams et al. 2015)	6 Modules: 1. Poor coping with breast cancer and treatment 2. High fear of recurrence 3. Dysfunctional fatigue-related cognition's 4. A deregulated sleep-wake rhythm 5. Deregulated activity pattern 6. Negative social interactions and low social support

Table 8.1: Research Articles

email or phone to encourage and answer obstacles but not to provide new content, much in the way that tutors are used in online learning generally. Most iCBT programs use distress questionnaires or measures at each module to assess patient progress and alert the patient and therapist if additional actions are required.

RQ4: **How can meta-knowledge of treatment modules and sub-modules be organized and structured for personalized iCBT therapy?**

To answer this question, we extend previous literature (**RQ1**, **RQ3**) from traditional CBT) by developing a new stand-alone online iCBT program. The aim of the COPE application to present content in personalized way for individual patient after breast cancer treatment on symptoms of stress, fatigue, insomnia, and HF/NS (fig 3.2).

As in COPE application, CBT Domain model fig 4.4 is an independent component. The knowledge about domain being are represented in the formal way in the form of a conceptual model and later implemented in domain ontology of CBT domain model. Here domain model serves as a basis for structuring CBT treatment modules and its content for adaptive personalized COPE application.

In present study domain model as sub-component of the adaptive personalized iCBT application comprised of 4 treatment modules. Each treatment modules are decomposed into 5 sub-modules (as shown in fig 4.6). The sub-modules are as session, prerequisites, relaxation exercises, assessment and diagnosis, and evaluation. The content of sub-module session (1-6) in treatment module, each session comprises psycho-education about symptoms, activities, homework assignment, relaxation exercises; The evaluation sub-module frequently provide with self-monitoring of the symptoms or diagnosed distress. All provided four treatment modules content represent the practice principles used in the traditional iCBT programs for stress, fatigue, insomnia, and HF/NS. Part of the content of each session in the each treatment module are in the form of text to read, audio or and video. Patients are encouraged to complete sessions based on her diagnosis/symptoms/progress that are provided by system with time-frame selected and if patients could not complete their selected time-frame then system encourages to complete provided session or activity each week by sending reminders. Patient also had access to general sub-module of CBT domain model for additional relaxation exercises other than which recommended by the system based on patient's needs.

In CBT domain model,the domain knowledge are organized into hierarchical taxonomy, which we used top-down approach where we have each module specialize into sub-modules 6.6. As CBT domain model contains a set of domain knowledge concepts along with their relationships (i.e CBT materials), therefore the use of the hierarchy of the domain concepts allows visualizing the logical structure of the CBT treatment modules content, determining the sequence of learning the CBT material, and also allows using control over the treatment outcome of CBT materials learning.

In this thesis, for beginning the domain knowledge concepts are grouped into conceptual models using UML as the basis for identifying the small, self-contained parts of theoretical CBT material which we can also call as domain learning objects. Here learning objects in application are described in xAPI (Experience API) e-learning standard. A learning objects implies a sequence of semantic facts and procedural rules (as constraints) which have logical completeness which result in a more meaningful therapy experience. The learning objects is learned sequentially; from sessions to psycho-education to the activities and then to exercises then to evaluation. It allows relationships between concepts of the learning objects with their place in overall CBT therapy. To sum up, the CBT treatment modules content is structured as a sequence of learning objects learned in a certain order covering the whole CBT material.

RQ5: **After identification of meta-knowledge on personalized iCBT therapy, how can various treatment in sub-modules fit with various diagnoses/symptoms/patient goals?**

iCBT treatment sub-modules (**RQ4**) and its contents are organized and represented by the domain model of COPE application look like a traditional iCBT program structured treatment module (**RQ1, RQ3**). However using adaptive course sequencing technique the treatment sub-modules are generated individually for every patient to fit a certain therapy goal (a domain concept or activity that must be learned). The application considers the information as physical and physiological signs and symptoms of related disorder of the patient from patient model which is measured by various tools and accommodate differences in the individual's way and pace of acquiring the CBT treatment content. The COPE architecture uses a structure of domain concepts (fig. 4.9) which are represented as a set adaption rules (section 4.5) as a road-map to generate a plan of the CBT treatment.

Given a certain therapy goal that the patient want to acquire and a patient model containing the various signs and symptoms of diagnosed illness, and personal-goals for example as patient want to be more activate in day time, preferences as provided materials must be in text or video which are accessed by the screening procedure. Once the information is produced by the patient. The adaption algorithm component searches for a way that fits domain concepts(sub-modules) with the signs and symptoms of diagnosed disorder, personal goals, and preferences with the therapy goal. The patient sees the sequence of the CBT materials related to each domain concept that must be learned. At every point, patient is monitored on her current diagnosed disorder, symptoms by presenting a set monitor tools. A patient model is created for every patient. Here a patient model is created for every individual patient. The patient model is an overlay on the domain design (described in section 4.4.1), that is patient signs and symptoms of diagnosed disorder of each domain concept is represented as score level within a certain interval by pre-assessment , for example patient with health problems as sleep problems is recorded as score level between (0-3) as "Not at all =0, A little=1",Some=2, Serious=3 ". If the patient is not able to achieve the score level for a given domain concept or activity that is needed to advance further with therapy after post-assessment, a new therapy approach is constructed.

RQ6: **In which are various ways can we present the same CBT content with different modalities such as text/video/audio and at which various levels of complexity?**

The system stores several variants (text, video, and audio) of the same CBT content chunk and selects the variants to display based on the patient model. Through this variation in content we can get different ways withing therapy process to present same content.

But in CBT therapy the problems are always arise related some complexity of presenting CBT content to patients depending on the current situation of mental health illness.

Therefore, there are few ways of presenting same CBT content in text, video, and audio at various level of complexity such as:

1. Based on the cognitive, emotional, Behavioral aspects of patients.

For example :

(a) **Cognitive aspects** as anxious thoughts,poor concentration, and difficulty with memory.

(b) **Emotion aspects** as tension, worries, irritability, restless, inability to relax, happiness, sadness etc.

(c) **Behavioral aspects** as tension, crying, sleep problems avoidance of tasks.

(d) **Social aspects** as avoiding others, isolation and seeking out other people.

2. Based on the answers provided by the patient on preferences during screening.

3. Based on the individual patient profile.

9 Conclusion and further work

This thesis presents the CBT domain model of the COPE app for personalized adaptive iCBT therapy. The CBT domain model consists of treatment of breast cancer patients (suffering from mental health disorders). The CBT domain model in COPE app focused on representing treatment modules of mainly four types (Stress, Insomnia, Fatigue and Hot flashes/Night sweats) with their symptoms. Further ontology based CBT domain model built for adaptive personalized iCBT therapy with treatment modules which includes all the concepts and relations.

9.1 Conclusion

Through design science methodology, CBT domain model in COPE app was designed, implemented, and evaluated to solve relevant problems regarding a self-guided iCBT therapy for breast cancer patients. At first, Unified Modeling Language(UML) was used to capture CBT knowledge provided by domain experts as conceptual models. UML is used for knowledge representation because it is easy to understand between domain experts and developers due to its graphical nature. The knowledge captured to represent conceptual models on the proposed approach was evaluated by domain experts. This conceptual models developed became on effective communication between experts and developers for further implementation. Once presented, CBT conceptual models were approved by domain experts, for implementation ontology development process used to organize the domain knowledge formally with knowledge representation language. The ontology editor tool, Protége has been used to build an ontology.

The CBT domain model presents the storage of all CBT concepts and its relations. It also describes how CBT treatment modules and their content is structured. At the implementation process, we created domain ontology to show how CBT concepts were expressed in the domain model. The domain ontology defined the CBT learning materials (treatment modules and its content) used in COPE application. This domain ontology shares a common understanding of domain knowledge between sub-components of the COPE application and among the developer of the application. Here the focus was to describe CBT domain knowledge, not for only human-readable but also to made machine-readable.

The proposed approach in this work opens several perspectives for representing knowledge in iCBT domain in support of personalized therapy. The primary advantage of our domain ontology, it contains a hierarchical content relationship between concepts, and it provides related and useful CBT domain knowledge for adaptive iCBT system. Here the main focus in this thesis is on breast cancer patients but given content may be reused in many other interventions domain for mental health illness, by domain experts or developers.

In the future work adaption rules in ontology to stress module needs to be addressed and other ontologies to other remaining treatment modules (Insomnia, Fatigue, Hot flashes/night sweats) need to be performed with ontology-based adaption rules.

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