Project ID:

24-25J-114

1. Topic (12 words max)

> Ellie's Adventures: A gamified application to enhance Communication, Emotional, Cognitive and Motor skills in children with autism.

2. Research group the project belongs to

> Computing for Inclusive and Equitable Society (CIEC)

3. Research area the project belongs to

> Bio-Medical and Health Informatics (HI)

4. If a continuation of a previous project:

Project ID	
Year	

5. Brief description of the research problem including references (200 – 500 words max) – references not included in word count.

Autism Spectrum Disorder (ASD) is a developmental disability that can cause significant communication, and behavioral challenges [1]. The term "spectrum" refers to the wide range of symptoms, skills, and impairments that people with autism can have [1]. Due to the complexity of ASD, detection and diagnosis has become highly challenging, Communication abilities are essential for growth of children with autism [2]. According to research, these aid in the behavior, learning, as well as interpersonal interactions [2]. Children with ASD experience significant challenges in acquiring communication, emotional regulation, cognitive, and motor skills [3] . Another major problem faced by children and adults with autism is, deficits in emotion recognition and expression [4]. It is mentioned that children with ASD have difficulties in emotional processing [5]. They have different cognitive patterns during emotion recognition compared to typically developing children [5].When cognitive development is considered, children diagnosed with ASD can encounter distinct cognitive development obstacles that might impact their academic performance, social engagement, and overall daily functioning [6]. Children with autism are also facing problems with their fine motor skills. In Individuals with autism, motor skills can affect leading to challenges in fine motor and gross motor abilities [7]. Where fine motor skills involve in coordination of small muscles which includes movements with hands and fingers while gross motor skills involve larger muscle groups for activities like walking, running and jumping. The lack these motor skills also leads the children with ASD in inability to identify and express gestures. Identifying the gesture of autistic children performs a vital role to prevent the meltdown and self-injury [8]. Children with autism also behave differently based on sensory inputs [8], As an example when a child ears a loud noise, or is exposed to a florescent light, they tend to close their ears and feel disturbed by sound. Therefore, it is important to identify the gestures of the child.

There are several therapy methods for the betterment of children with ASD. Traditional therapy methods, while demonstrably effective [9], are often confined to clinical settings and necessitate the presence of trained therapists [10]. This limitation hinders parents and caregivers from providing consistent support within the home environment [11]. To bridge this gap, there exists a critical need for an innovative and user-friendly tablet/mobile application that leverages gamified and interactive activities. This application targets the continuous skill development through engaging, adaptive, and personalized exercises designed to enhance:

- Oral and verbal communication
- Emotional recognition and regulation
- Cognitive processing
- Motor abilities

This approach has the potential to empower parents and caregivers to become more active participants in their child's therapeutic journey, extending the reach of interventions beyond clinical settings and promoting skill development in a more accessible and engaging manner.

References

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[2] Y. Bhargavi, B. D and S. Prince, "AI-based Emotion Therapy Bot for Children with," in *9th International Conference on Advanced Computing and Communication Systems (ICACCS)* , 2023.

[3] M. C. Lai, M. V. Lombardo, B. Chakrabarti and S. & Baron-Cohen, "Localisation and disorganisation in autistic brains," *Molecular Psychiatry,* vol. 19(9), 2014.

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[5] Q. Su, F. Chen, H. Li, N. Yan and L. Wang, "Multimodal Emotion Perception in Children with Autism Spectrum Disorder by Eye Tracking Study," in *2018 IEEE-EMBS Conference on Biomedical Engineering and Sciences (IECBES)*, Sarawak, Malaysia, 2018.

[6] R. I. Does, V.Nivedita, S. V. S. Reddy, D. L. F. Jana, M. Suda and R. R. Manjul, "Robot-Assisted Cognitive Training for Children with Autism Insights and Outcomes," in *7th International Conference on Electronics, Communication and Aerospace Technology (ICECA)*, Coimbatore, India, 2023.

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[9]   B. W. S. K.-K. I. Z. P. &. G. B. F. Reichow, "Early intensive behavioral intervention (EIBI) for young children with autism spectrum disorder: A meta-analysis," *Journal of Autism and Developmental Disorders,* Vols. 42(12),, pp. 2687-2704. .

[10] S. H. R. P. H. J. C. &. J. E. Eldevik, " Parent-mediated interventions for young children with autism spectrum disorder (ASD)," *Cochrane Database of Systematic Reviews.*

[11] J. T. V. C. D. M.-F. B. M. N. &. P.-L. F. Woods, "The impact of parent training on home-based interventions for children with autism spectrum disorder: A critical review," Journal of Autism and Developmental Disorders, vol. 50, no. 11, pp. 3809-3832, 2020.

6. Brief description of the nature of the solution including a conceptual diagram (250 words max)

The suggested solution will be a gamified mobile/ tablet-based application that will address the areas of developing speech and language skills, cognitive and verbal communication skills, emotion recognition and expression through facial exercises, and motor skills and gesture identification. A set of daily activities and games will be implemented to enhance each of these skills, by understanding the child.

Initially, the system will have a screening and identify the child's current level of communication and interaction skills. According to that level, personalized activities and games will be given, and the progress will be evaluated according to a reward-based system.

The system will also keep track of the child's development along with the activities and provide new tasks based on the child's development.

A personalized animated avatar is set to be the main communication agent between the child and the application, and the child will perform each of the activities with the guidance of the avatar. (diagram link: click here)
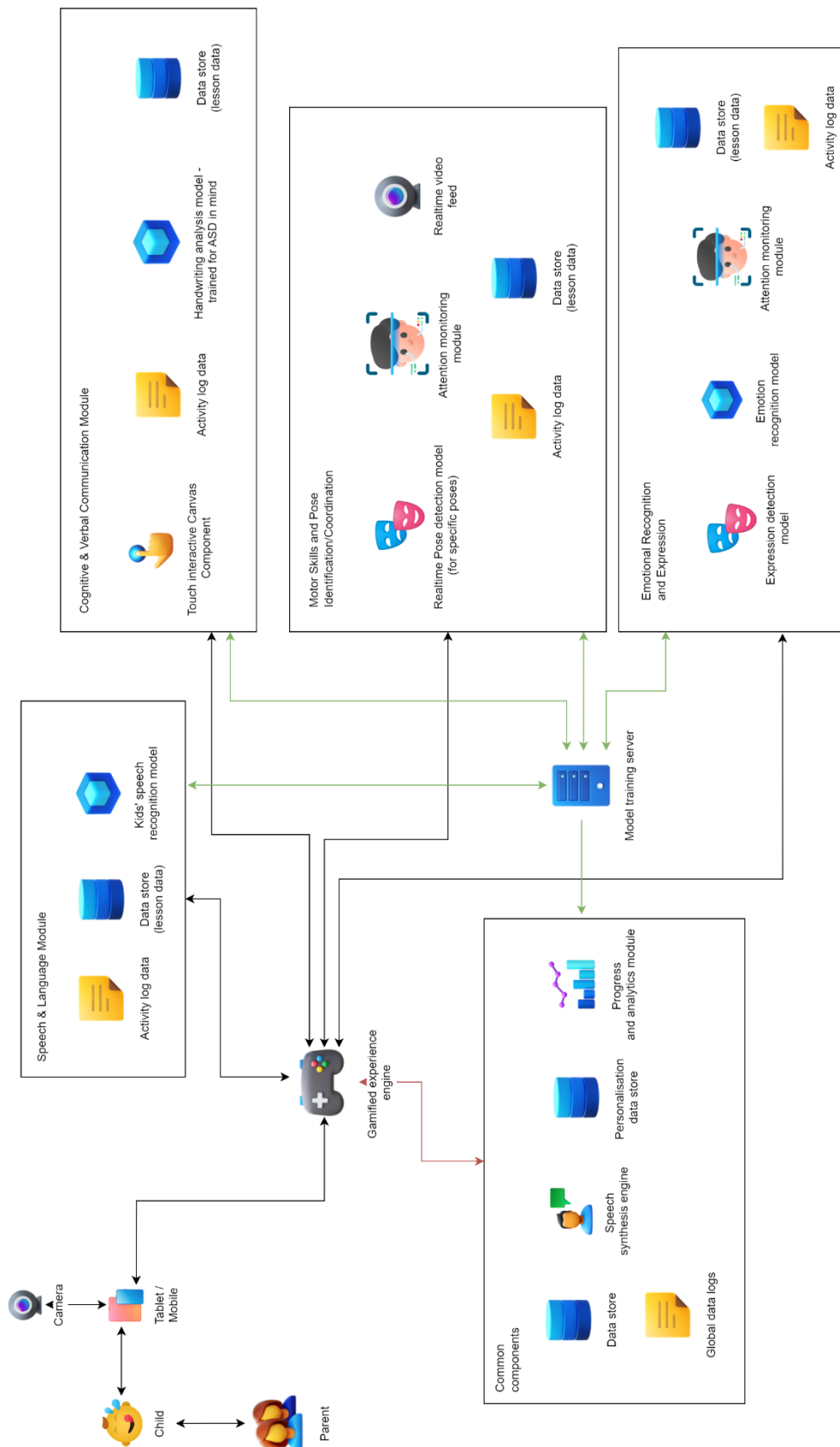
7. Brief description of specialized domain expertise, knowledge, and data requirements (300 words max)

The main domain expertise needed for the development of the application are, the domains of child development and autism spectrum disorder (ASD) where the team understands development milestones in children specifically related to communication, emotional regulation, cognitive process, and motor skills. Professionals with experience in pediatric therapy, child psychology, and autism related interventions are contacted in-order to identify the insights into the topic, challenges and effective strategies for skill development in children with ASD.

Other than this the domain knowledge on speech and language development in children with autism, cognitive and behavioral psychology, and emotional recognition and regulation are focused. Under these domains the knowledge on fundamentals of speech and language development and therapy methods used for speech and language development, and cognitive development theories, behavioral learning strategies for development of the child with learning difficulties, and the techniques used for teaching emotion recognition, and strategies used for improving emotional expression will be studied in detail.

As for the data requirements for the system, several data sets such as, speech datasets, emotion recognition datasets, cognitive and behavioral data, and gesture recognition data will be needed mainly. In addition, usage and interaction data such as the data on how a child with ASD interact with a tablet/ mobile phone, the engagement, task completion rates and guidelines to follow on development are considered.

The key knowledge requirements for the projects includes the knowledge of ethical considerations and privacy, where the team understands the ethical issues related to data collection from children, consent procedures and ensuring data privacy. Then, the knowledge on Development technologies, Principles of gamification and child engagement in educational contexts and reward-based learning. In addition, the knowledge on the principles of designing interfaces and considering the user experience for children with autism is considered to develop the project.

8. Objectives and Novelty

Main Objective
The primary objective of this research is to **develop and evaluate communication and interactive skills for children with autism spectrum disorder.** The application aims to bridge the gap between home and therapeutic settings by providing accessible, engaging, and customizable exercises that can adapt to the unique needs of each child, utilizing advanced speech/verbal cues recognition, facial landmark analysis, and pose landmark recognition technologies.

Member Name	Sub Objective	Tasks	Novelty
Umaira M. M.	Improving Speech and Language Development	1. **Speech Recognition Evaluation** Using supervised machine learning to train speech recognition models on datasets containing children's speech. Evaluate performance in recognizing and providing feedback on pronunciation. • Here pronunciation will be evaluated based on **identifying the lip patterns** when spelling a letter or a word. Libraries like **MediaPipe** face detection library can be used to identify the patterns and to provide feedback based on the pronunciation. **e.g.,** When spelling the letter W or words with W, the lip should be like a rounded hollow. For letter V, a flat lip.	The main therapy method followed for the development of this component is Applied Behavior Analysis (ABA). This method consists of both Positive and negative reinforcement where through each it helps the child to understand the day-to-day contexts and adapt to a normal social setting. The reward-based scoring system here will be built through positive and negative reinforcement

2. **Interactive Flashcards Game**: Design digital flashcards with voice prompts and record children's responses. Implement a reward-based scoring system to assess progress.

- The flashcard game will be an interactive game where the personalized Avatar will be actively communicating with the child and helping the child to respond.
- The child's response will be captured through speech recognition techniques like Natural Language Processing optimized to identify verbal cues (**NLP**).
- The flash cards will of different categories such as **Letters, Numbers, Vegetables, Fruits, Vehicles** and games will developed level by level where the initial levels will be focused on a single category where the latter levels will have mixed categories according to the child's adaptation and development.
- The game consists of different levels where each level will be using flash cards for speech development and the 3D Avatar will be using context-based questions to enhance the language development.

    e.g., The flash cards for an instance will be inside a hidden bag or a box, the Avatar will be asking the kid questions like, "**Where are the**

which can be considered as a novelty.
The component also identifies the words and areas the child is finding difficult to pronounce and suggests more flashcards or words in that to improve in that area ~~through~~through generative AI, which too is a novelty.
And using the collected lip pattern data, suggest more lip exercises according to the new words suggested above to improve pronunciation

cards?",** or **"The cards are INSIDE the box, Let's pick one"** to enhance the child's curiosity.

3. **Customization and Adaptation**: Allow customization of flashcards and exercises based on individual child's need in development.

   - When the flashcards are given to pronounce, Identify the words or areas where the child finds it difficult to pronounce and suggest more flashcards containing words in that area to improve the speech and pronunciation.
   - Technologies like **Generative AI** can be adapted here, where more words will be suggested based on the difficulty.
   - The child's progress will be measured along the process and the reward-based scoring system through positive reinforcement.

   e.g., If the child is finding it difficult to pronounce the word "**Food**", then more words in the similar pattern like "**Mood", "Good"** etc. And a score will be given for each successful pronunciation through the reward-based system.

| Jathurshan M. | Improving Cognitive and Verbal Communication skills | 1. **Writing Exercises**: Develop digital writing exercises that can be performed on a tablet/mobile device. Use **cloud-based Computer Vision** to analyze handwritten letters (characters), patterns or words written by the child.

• Parent can choose the type of exercise for their child as follows:
  1. Option 1: Allow the child to practice with predefined letters or words.
  2. Option 2: Parents can manually add custom letters or words for the child to practice with.

  Once the choice is made, the child can begin practicing accordingly.

• A **Convolutional Neural Network (CNN)** approach will be used to detect letters, words, and patterns. It **predicts the accuracy level** and stores the results on a private cloud.

• **When the level of accuracy is low**, find out which letters or words the child gets wrong the most. Additionally, it **recommends that the child practice more with lower accuracy level letters** and words. This **exercise is repeated** until the child's accuracy level increases to a certain level. | Touch-interactive ABA-based letter and word practice exercises that use dotted lines to guide the child. Once the child traces along the dotted lines, the app compares those lines using a CNN/LSTM to evaluate and provide a competency score. The upcoming exercises are then adjusted to improve the child's difficult areas.

Interactive story making game designed according to which will test the child's cognitive and creative abilities. The game uses generative AI and a cloud deployed CNN to assess the cognitive intelligence score of the variations made by the child. |

- When the child achieves a certain level of accuracy, **show encouraging messages** or reward them based on their accuracy. (Average, Good, Excellent)

2. **Sentence Structure and Grammar Games**: Incorporate interactive games that focus on building sentences, identifying subject-verb agreement, using correct punctuation, and other grammar concepts.

   - Using **NLP models** and **rule-based systems** to identify accurate word prediction and correct grammatical errors.

   - The child is given a prompt to create a story by dragging and dropping blocks. (level-based)

   - The blocks contain objects and actions, and the child will have to order them to match the story given in the prompt. These stories can be dynamically generated using generative AI and an image/object library, for adaptability.

   - There will be multiple possibilities for storylines based on the objects provided, and the competency score will be generated using a CNN model that is trained to process these storylines, according to what best suits the provided prompt.

- **Interactive Vocabulary & Grammar Learning with a Child's Pet (Selective 3D Avatar)**: From level 1 the child can start practicing vocabulary and sentence building. Initially the child must fill in the blanks from selecting the suggestion box. And the child's pet **(Selective 3D Avatar)** feature provides assistance when the child is struggling.
- When the child chooses the wrong answer, the avatar will pop up on the screen to offer help. It guides the child through the correct grammar rule or concept, providing **simple and clear explanations tailored to the child's level**. This feature uses **Generative AI**. The child will be prompted to play the game again to practice more about the incorrectly chosen concept.
- Once the child successfully completes the grammar level by selecting the correct answers consistently, the app can **reward them with points, badges**, or a level completion celebration involving the avatar.

3. **Interactive creativity games:** The child will be provided different shapes of different colors, and initially a picture is shown.

   - The child should arrange the shapes in a way to recreate the given picture.

- For example: The child is provided with a square and a triangle, and it shows a house initially. Now the child has to move these shapes to make the shape of a house.

- Scores will be given how accurately the child recreates the given picture.

Helapalla K. O. P. S.	Facial Cues and Expressions (FCEs) Recognition Improvement	These exercises based on **Applied Behavioral Analysis (ABA)** will be presented in a gamified way, that advances with the child's competency, with the usage of a **customizable 3D avatar** (using **Unity 3D**)
		
		1. **Understanding the child's competency and planning the exercises:**
		    • Prior to starting exercises the child will be taken through a common exercise to determine the current abilities.
		    • The data from these exercises will be used to evaluate the child's competency and it will generate a <u>multi-point score</u> that is system-specific which will be used to determine the types and levels of exercises given to the child in latter stages.
		2. **Adaptive games that train identification of FCEs:**
		    • A **3D cartoon avatar** will be shown on the side of the app to accompany the child throughout the training exercises, and it can portray all kinds of facial cues required for the exercises.
		    • The games would look like below,
		        i. Asking the child to select the matching faces with emotions
		        ii. Using the avatar's expressions and asking the child to match the expressions
		        iii. Game to test related cognitive skills at different social settings
			Detecting how far the child has gone in each exercise in portraying the facial cue and expression, using Facial landmarks.
			
			Using a 3D avatar that mimics the child's facial cues in real-time during the exercise and using encouraging voice messages.
			
			Providing therapy-recommended & ABA exercises based on child's current ability and deciding what exercises are suitable next, considering factors like lip movements, etc.
			
			Usage of storylines that is aware of the context of other components in the app, and adapting them continuously using **Generative AI** to make it interesting for the child.

- The results acquired throughout the exercises will be used to pick and adapt the next exercise based on the child's competency.
- Use of child-friendly sounds and voices to encourage the child to keep going.

3. **Games that train expression FCEs:**
   - The app will use the device camera to monitor the facial cues in each exercise.
   - Using **3-dimensional facial landmarks and facial blendshapes** to detect the child's expression of different facial cues. The app will use a model like **Google's MediaPipe face landmarking model**. Further this will be utilized to lookout for:
     - i. Lip movements
     - ii. Facial muscle movements (forehead, etc.)
     - iii. Eye movements
     - iv. Mouth movements
     - v. Head movements,

   - To determine this, an **Artificial Neural Network (ANN) or a CNN** will be trained.
   - Rewards will be assigned based on how competently the child completes each task.
   - The expressions will be mirrored by the avatar (ex: a 3D monkey face) It will make friendly gestures like *"open your mouth a little wider"*, *"smile a little more!"* based on the situation.

		• These expressions will be generated on the fly **using generative-AI** for a realistic experience. • In some exercises, the avatar **will show how to do the face in an animated sequence**, and the child is given a small time to complete it while the camera records it. And the recorded clip will be processed and sent to the server to fully to calculate the score. **4. Attention retention and context aware features:** • Whenever the child is inattentive for a certain period during an exercise, the avatar will pop up on the screen and **make a friendly gesture with a voice to get the child back on track**. • The context of the identification exercises will be considered when providing the next exercise. Meaning, the **areas that the child lacks competency will be tackled more** in the next and upcoming exercises.	
Mallawaara chchi T. D. R.	Improving Motor skills and Gesture Identification	1. **Animated Exercises**: The idea is to create animations showing personalized avatars performing exercises and to use the device's camera to detect and analyze the child's movements, ensuring they mimic the avatar correctly to assess their gross motor skills. • Avatar Customization – Allow children to customize a preferred character from a variety of features (**Unity 3D**).	Follows Applied Behavior Analysis (ABA) using Interactive avatar guided exercises in a gamified approach which identifies the current ability level of the child in the first screening test and suggests activities according to that.

- Exercise Library – Develop a set of exercises like jumping jack, squats, arm circles.
- Pose Detection – Utilize technologies like **OpenPose** or **PoseNet (Pose Landmarking** models) to capture and analyze the key points of the child's body to track pose landmarks and analyze the child's movements in real-time.
- Feedback System – Provide feedback and encouragement to the child after **pose detection** based on their performance.

Ex:
A child selects a superhero avatar. The avatar performs a jumping jack. The device's camera tracks the child's movements and provides feedback like **"Good job"**, **"Lift your arm higher"** if needed.

2. **Fine Motor Skills Evaluation**:
Develop tools to analyze handwriting and other fine motor skills through photo uploads or on-screen exercises. Can be used technologies like **TensorFlow** or **OpenCV** for real time image processing and analysis to identify patterns using device's camera or photo uploads.

Different color spaces can be used with **color segmentation algorithms** along with a separately

In the fine motor skills evaluation, it is planned to identify patterns of how the child performs the given tasks.

In gesture identification game, it is planned to use Generative AI to identify the ability of the child and suggest more complex tasks according to that.

Games involving real world objects using computer vision and custom trained **CNNs**.

trained **CNN** to identify objects placed in patterns, etc., (according to the exercise)

Ex: Use exercises like placing LEGO blocks into specific patterns or assembling them into simple shapes to assess fine motor skills.

3. **Gesture-Based Games**:
Design games that involve gesture guessing games which can be used to improve their recognition skills. Can be introduced multiple levels that increase the complexity as the child progresses.

Generative AI can be used here to **suggest more complex gestures**. A reward-based scoring system will be implemented for **positive reinforcement**. Limited countdown and limited hints will be implemented as **negative reinforcement** features.

Possible features that can be included:

- Timed Challenges
- Level of difficulty
- Hints and assistance
- Feedback system
- Progress tracking and rewarding

Ex: Games like Simon Says, with the use of the 3D avatar

9. Supervisor checklist

a) Does the chosen research topic possess a comprehensive scope suitable for a final-year project?

Yes		No	

b) Does the proposed topic exhibit novelty?

Yes		No	

c) Do you believe they have the capability to successfully execute the proposed project?

Yes		No	

d) Do the proposed sub-objectives reflect the students' areas of specialization?

Yes		No	

e) Supervisor's Evaluation and Recommendation for the Research topic:

10. Supervisor details

	Title	First Name	Last Name	Signature
Supervisor				
Co-Supervisor				
External Supervisor				
Summary of external supervisor's (if any) experience and expertise				

This part is to be filled by the Topic Screening Panel members.

Acceptable: Mark/Select as necessary

Topic Assessment Accepted	
Topic Assessment Accepted with minor changes (should be followed up by the supervisor)*	
Topic Assessment to be Resubmitted with major changes*	
Topic Assessment Rejected. Topic must be changed	

* Detailed comments given below

Comments

The Review Panel Details

Member's Name	Signature

***Important**:

1. According to the comments given by the panel, make the necessary modifications and get the approval by the **Supervisor** or the **Same Panel**.

2. If the project topic is rejected, identify a new topic, and follow the same procedure until the topic is approved by the assessment panel.