Disability-Aware Adaptive and Personalised Learning for Students with Multiple Disabilities

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Introduction

Although a good number of students go through educational institutions with relative ease and enjoy the learning process, this may not be the case for some students who need to make significant efforts to achieve the same results. For students who experience some form of stress during learning, which may be brought about by disabilities such as mental health difficulties, support is usually needed to alleviate the situation. Support workers recruited by the Student Support Service could be very helpful in enabling such students to study with less stress. Support could be in the form of mentoring or accompanying students in classes to help calm any anxieties they may have. Other forms of disability such as visual impairment and hearing impairment just to name these two, will require special adjustments in the form of assistive technologies or a change in mindset in the way learning materials and environments are designed in order to meet the needs of these students. This is a necessity, given the increasing number of students with disabilities accessing educational institutions. The efforts being made by educational institutions to accommodate the needs of some students with disabilities should be lauded, particularly the adjustment of the physical environment to improve access to lecture halls. Nevertheless, much still has to be done by these institutions to promote digital accessibility (Steyaert, 2005). A lot of the existing online learning environments are not accessible to students with disabilities as these environments are not disability-aware (Nganji and Brayshaw, 2014).

Research into the design and development of learning environments for the benefit of all learners, including those with disabilities has not spread its tentacles far enough and has fallen short of providing solutions on how learning environments can respond to the needs of students with multiple disabilities. Often, such learning environments have focused on meeting the needs of learners with a specific disability (Sampson and Zervas, 2011), such as visual impairment or dyslexia. The needs of learners with multiple disabilities therefore are often neglected. The overall aim of this article therefore is to advocate the need for considering learners with multiple disabilities when designing and developing learning environments. Rather than designing a learning environment for learners without disability and then retrofitting for those with disability, this article argues that their needs should be consider from the onset and then proposes ways of allowing a learning environment to fetch specific information, in a suitable format based on the learner's disabilities. Thus by applying some combinatorial mechanical concepts during various

phases of the development cycle particularly during needs analysis, the result would be a learning environment that meets the needs of learners with multiple disabilities. This article is organized as follows: the following section reviews literature on the learning environments that have been designed to meet the needs of students with disabilities. This review will help to situate the work and also present its originality and hence contribution. It will also help future researchers by providing a foundation upon which they can build. Some disabilities and how they affect learning are then discussed. Although there are many disabilities that exist, there would not be enough space to analyse and present them in a single article. Thus, those that are common in educational institutions and those that affect people the most will be presented. In discussing these disabilities, the most appropriate formats of learning materials for these disabilities will also be presented. The article will then move on to use combinatorial mechanic concepts to show how specific learning materials from a repository of learning materials can be presented to learners with multiple disabilities. This is done by considering two cases: one with a student presenting with two distinct disabilities and the other with a student presenting with three distinct disabilities. This article will then conclude with some recommendations on how the concepts discussed herein can be applied to design and develop fully inclusive learning environments for the benefit of all learners with disabilities.

Personalised learning environments for students with disabilities

Personalisation of a learning environment allows for a personal learning experience as it allows the learner to access content that meets ~~his~~ their needs. In a traditional classroom setting, such personalisation is not possible. Thus, the personal learning environment is a radical shift from traditional learning, providing learners with content adapted to meet their needs (Childress and Benson, 2014). Personalisation could be very beneficial for students with disabilities as it presents them with learning materials in formats that are suitable for them and also compatible with any special educational technology they may be using. When a learning environment is personalised, it becomes easy for a learner to find specific learning materials.

Existing learning environments are not designed to accommodate the needs of learners with disabilities. This is evident from the fact that there are still accessibility barriers with current learning environments. This often results from the designers and developers not considering the

needs of learners with disabilities (Nganji and Nggada, 2011) and the difficulties of designing for people with complex situations of disability such as those presenting with multiple disabilities. A few existing learning environments designed for people with disabilities show how much focus is placed on single disabilities. For instance, the learning environment implemented by Tzouveli et al., (2008) and Schmidt and Schneider (2007) was solely for helping pupils with dyslexia. Also, Drigas et al., (2006) worked on meeting the needs of students with sight disabilities. Although only these two examples have been cited, there are numerous articles focusing on a single disability. This article will therefore bridge the gap by showing how learning environments can respond to the needs of learners with multiple disabilities by presenting them with learning content in formats suitable for their needs and compatible with any assistive technology they may employ for such access.

Impacts of disability on a learner

The complex nature of some disabilities demand that enough attention be given in order to provide an appropriate solution. This section will discuss three common disabilities and how they affect the individual. It will also consider the assistive technologies that are available to them.

Visual impairment

Visual impairment represents a range of disabilities affecting vision such as partial sight, low vision, colour blindness, totally blind and legally blind. Whilst people with low vision could use screen magnifiers to read information on a screen, low vision affects every day functioning and cannot be corrected with glasses or contact lenses (Kalia et al., 2008). The cause of visual impairment such as blindness varies and could be due to cataracts, glaucoma, macular degeneration, tropical parasitic diseases such as onchocerciasis, etc. Current e-learning is designed for people with vision, thus those with visual impairment might struggle to access the learning environment especially when accessibility considerations are not put in place or an adaptive and personalised environment designed.

To assist learners with visual impairment in accessing information in an online learning environment, various assistive technologies exist. Such technologies include screen magnifiers which help magnify content on the screen, screen readers which are text-to-speech software that read content to the user, and Refreshable Braille Display Devices which provide information to the user by stimulating the sense of touch. Although such technologies facilitate access, some such as screen readers could be useless if accessibility considerations are not followed, thus leading to incompatibility between the learning environment and the assistive technology. Basic accessibility considerations such as alternative texts for images especially providing comprehensive descriptions of the image (Nganji et al., 2013) and following other accessibility guidelines would be very helpful in facilitating access to learning content for assistive technology users.

In an e-learning environment, the format of the learning materials would also determine if the learner with visual impairment can access them. An individual who is totally blind for instance will not be able to access the content of a video without transcripts. Appropriate formats of learning materials for people with visual impairment include Braille, audio and text. With an audio learning material, a learner who is completely blind but can hear can still listen to the audio. They can equally employ a screen reader to read the text format of the learning resource, since screen readers work by converting text into audio. This article will use legal blindness when referring to visual impairment in later sections.

Hearing impairment

Hearing impairment could result from ageing, exposure to loud noises, viral infections, meningitis, etc. and results in loss of hearing to one or both ears either partially or completely. People with hearing impairment could make use of assistive technologies such as hearing loop to magnify sound. ~~Such~~ Other devices ~~have been~~such as ~~A~~augmentative and alternative communication devices improve an individual's communication and ability to participate in interactions (Hagan and Thompson, 2014). People with hearing impairment can best interact with content that exploits their sense of sight such as videos with captions or transcripts as well as text-based learning materials.

Dyslexia

Dyslexia has been identified as the most common disability amongst higher education students (Dunn, 2003, Snowling, 2001), it is neurological in origin and manifests in "poor spelling and decoding skills" (IDA, 2011, Hulme and Snowling, 2016). Students with dyslexia could make use of the range of assistive technologies available to support them in their learning. Such technologies amongst others include homophone tools that help with improving reading and writing (Lange et al., 2009) and diagramming tools such as Inspiration (McKenzie, 2003) which help with organisation. Rather than having these as stand-alone tools, such technologies could be integrated directly into the learning environment for personalised learning. In order to do this, designers and developers of such systems have to consider doing this from the conception of development rather than retrofitting it after the learning environment has been implemented.

Given that Students with dyslexia struggle with the huge amount of reading and writing in a higher education context (Hughes et al., 2011) these students could benefit from a personalised learning environment which considers their disabilities and learning needs and hence adapts to these needs. An e-learning environment could intelligently present a learner with a different learning interface which contains the tools and materials they may need, based on their disability type, its severity and hence the learning needs associated with the disability (or disabilities). A student with dyslexia for instance upon logging into a learning environment could be presented with a user interface which has integrated software to assist with reading such as text-to-speech software and software that helps with word recognition and thus facilitates reading.

The format in which learning materials are presented to students also determines if they would be able to access and understand the information in order to improve their learning. Students with dyslexia have a wide range of learning material formats depending on the degree of dyslexia and could benefit from materials presented in audio, video, text formats or a combination of these.

Recommending specific learning materials using basic combination rules

The preceding sections discussed the fact that disabilities affect people in differing ways. The degree of disability could range from mild, moderate to severe which is the extreme form. For visual impairment for instance, a moderate form could be low vision where the individual can still

use screen magnifiers to view information on a screen or in print. The severe form would be total blindness where the individual cannot see anything at all even with an assistive technology. Some individuals could also have multiple disabilities, which is a combination of at least two distinctly different disabilities, such as hearing impairment and dyslexia. Designers and developers of learning environments need to consider these scenarios when implementing learning systems and not only focus on meeting the needs of individuals with a single disability. Adaptive personalisation of learning environments or digital systems in general to meet the needs of people with multiple disabilities is an under researched area that merits attention, given that individuals do not necessarily have only one disability but may have two or more and their needs should be considered.

One way of achieving new learning is simply being told. How to deal with a set of multiple disabilities will be known and suitable knowledge acquisition methods can be used to make this knowledge explicit. Therefore using standard knowledge engineering techniques this knowledge can be modelled as a set of rules. When we come across combinations then we can look to use this rule set and see if there is a set of explicit axioms to take this into account. However if the representations are modelled well enough then this can be done automatically by logical combination.

Logic Based Rule Induction (Mak and Blanning, 2003) is a way of folding existing rules into new rule sets. It is a machine learning technique that allows us to safely combine existing rules into new rules. It has been proposed as a general caching method of combing rules to present a general learning mechanism in rule base systems (Laird et al., 1986). This method of generalisation learning can be linked to concept learning (Michalski, 1983) in that it takes examples and logically combines them using their inherent logic to provide safe new rules which is imperative given the applied domain of this paper.

Considering the above context, rule combination methods are used to combine multiple disabilities. Combinatorial mechanic concepts (e.g. complement) and set operations (e.g. intersection, union, difference), are used to apply these concepts to determine the effects of disability that are common to individuals with multiple disabilities as well as those that are unique for specific disabilities. Similarly, one could determine which format of learning materials could be recommended to the learners based on their disability type and their preferences of the format

of learning materials. Such information could be inferred from their profiles. Although the importance of having a learning environment that incorporates assistive technologies has been discussed above, the focus here is to show how the appropriate formats of learning materials could be presented to learners and hence assistive technologies will not be discussed.

The case of visual impairment and hearing impairment

An individual with both visual impairment and hearing impairment will present with symptoms of both disabilities. Some of these symptoms and how they affect the learner were already discussed above. To be able to understand how appropriate formats of learning materials can be offered to an individual with visual impairment and hearing impairment, consider the following assumptions:

Let U be the universal set of all disabilities in the individual

V is the set of disabilities pertaining to visual impairment.

Thus, V= {V1, V2, V3} where V1, V2, V3 represent the symptoms of visual impairment. A combination of those symptoms or disabilities results in visual impairment.

H is the disability known as hearing impairment and H= {H1, H2, H3}, where H1, H2 and H3 represent the symptoms associated with hearing impairment. The combination of those symptoms results in hearing impairment. The above disabilities can be represented in a Venn diagram as shown in Figure 1 where the individual will thus have the symptoms associated with both disabilities and could be expressed as a union as shown in (1).

$$V \cup D = \{V1, V2, V3, H1, H2, H3\} \qquad (1)$$

The above equation shows that the individual presents with symptoms associated with both visual impairment and hearing impairment. Equation (1) can also be expressed in a Venn diagram as shown in Figure 1.

Fig. 1. Venn diagram representing the disabilities of an individual with visual impairment (V) and hearing impairment (H)

It is important to note that the signs of visual impairment are completely different from those of hearing impairment. That implies therefore that in Figure 1, the sets V and H are independent sets as expressed in (2).

$$V \cap H = \emptyset \qquad (2)$$

As both disabilities do not have any symptoms in common, it follows that the individual will present with the symptoms of each disability as shown in (1). It is thus important to consider how each disability affects the learner separately and then to design the learning environment such that it meets his needs. When designing for an individual with both visual impairment and with hearing impairment, it is important to first consult with the individual to determine their needs. The use of personas will also be helpful as described in Nganji and Nggada (2011). The symptoms associated with each of the disabilities could then be analysed. This can be done in consultation with various individuals including but not limited to the learner for whom the learning environment is to be designed, disability experts and educators.

Fig. 2. Determining symptoms for a learner with visual impairment and with hearing impairment

It is understood that for some projects, budget constraints may not allow for inclusion of several consultants. In that case, it is always important to seek the opinion of the learner for whom the learning environment would be designed. This way, the resultant learning environment will meet their needs. The disability-aware method for designing learning environments if followed, will ensure that the learning environment meets the needs of the learner. The process of analysing the various symptoms of the learner's disabilities is presented in Figure 2.

Having analysed the various disabilities of the learner and how it affects learning in order to present the individual with the appropriate learning materials, the learning resources need to be modelled with meaningful technologies such as semantic web ontologies. Modelling with semantic technologies allows for a better means of communicating with the learning environment and querying it to produce the desired results. Modelling information about the learner facilitates searching and recommending the correct format of learning materials for the individual. This

paper will not dwell on how the learner and various concepts are modelled with semantic web technology as this has been considered in other research (Nganji and Brayshaw, 2015).

Recommending the correct learning materials could be done through algorithms that can still employ set theories to filter out the correct information to the learner, depending on the disability type and the available formats of learning materials in the repository.

To understand how the appropriate learning resources could be recommended, consider R_i to represent all the learning resources in a repository.

R_H= Learning resources suitable for hearing impairment

R_v= Learning resources suitable for visual impairment

The learning resources that can be recommended for this individual with both visual impairment and hearing impairment would be a combination of the learning resources that are suitable for an individual with visual impairment and those that are suitable for an individual with hearing impairment. This is because it was shown earlier that the symptoms associated with both disabilities are independent of each other (2). Thus in designing learning materials for such a learner, it is important to understand all the possible formats of learning resources that could be useful for the individual, considering both disabilities. This can be represented in a Venn diagram as shown in Figure 3.

Fig. 3. Venn diagram representing the learning resources compatible with visual impairment (R_v) and hearing impairment (R_H)

As could be seen from Figure 3, an individual with visual impairment could make use of his sense of touch to read information presented in Braille format. The learner can also make use of his sense of sound to listen to an audio version of the learning material and can use a screen reader such as JAWS, NVDA, etc. to read the information in the text. However, in this case, the learner has hearing impairment and will thus not be able to make use of the sense of sound. Similarly, for the hearing impairment that affects the individual, he can make use of audio resources with

captions, text and video with captions. Since the individual may not see or hear the video and audio, it is important to exploit the sense of touch in order to design for this individual.

Unlike for the symptoms of both disabilities where in (2) there was nothing in common, for the learning resource format, there appears to be some resources that are common for each disability as expressed in (3).

$$R_v \cap R_{dys} = \{audio, text\} \qquad (3)$$

Although text-based resources are common for both disabilities, such resources can only be read either by someone who sees the text or by a machine and can be understood by someone who hears. In this case, the learner can neither see nor hear. It therefore makes more sense for such text-based resource to be converted into Braille format where the learner can use the sense of touch to understand the information that is presented. This reveals an interesting requirement for designing learning environments: users should be given some control over the information that is stored in their profile and should be able to modify their needs and preferences. The learner in this case should be able to state that they prefer learning materials in Braille format, rather than the system recommending text-based materials which might be useless. Also, the learners should be able to update their disability type, to allow the system to recommend specific learning resources.

Figure 4 diagrammatically presents the process of retrieving specific learning resources that are suitable for a specific learner. To summarise what has been presented above, when designing learning environments, it is important to put the learner's needs first and this should involve the learner in the process. Learners should not only be consulted to test the system at the end of the design, but should be involved throughout the process including during needs assessment/requirements gathering to ensure that the end product adequately meets their needs. By so doing, designers and developers of such systems will be avoiding expensive retrofits.

Fig. 4. Retrieving learning resources compatible with visual impairment and hearing impairment.

The case of visual impairment, dyslexia and hearing impairment

It is understood that designing for people with multiple disabilities is difficult, but this is achievable when resources are put together and such project prioritised. This section will look at how a learning environment can be designed to recommend specific learning resources to an individual presenting with multiple disabilities. The complexities of such cases should not discourage those who wish to design inclusively as this is achievable. The same principles used in the case of a learner with two disabilities will be applied to show how specific learning resources could be recommended to a learner with three or more disabilities.

Let U be the universal set of all disabilities in the individual

V is the set of disabilities pertaining to visual impairment.

Thus, V= {V1, V2, V3} where V1, V2, V3 represent the symptoms of visual impairment. A combination of those symptoms results in visual impairment.

D is the disability known as dyslexia and D= {D1, D2, D3} where D1, D2 and D3 represent the symptoms associated with dyslexia. The combination of those symptoms results in dyslexia.

H is the set of disabilities pertaining to hearing impairment.

Thus, H= {H, H2, H3} where H1, H2 and H3 represent the symptoms of hearing impairment. A combination of those symptoms results in hearing impairment.

The above disabilities can be represented in a Venn diagram as shown in Figure 5 where the individual will thus have the symptoms associated with visual impairments, dyslexia and hearing impairments and could be expressed as a union as shown in (4).

$$V \cup D \cup H = \{V1, V2, V3, D1, D2, D3, H1, H2, H3\} \quad (4)$$

The above equation shows that the individual presents with symptoms associated with all three disability types. Equation (4) can also be expressed in a Venn diagram as shown in Figure 5.

Fig. 5. Venn diagram representing the disabilities of an individual with visual impairment (V), dyslexia (D) and hearing impairment (H).

The three disabilities are independent of each other, thus there is no symptom common to all three disabilities as expressed in (5).

$$V \cap D \cap H = \emptyset \qquad (5)$$

Also, visual impairment and hearing impairment are independent of each other as expressed in (6).

$$V \cap H = \emptyset \qquad (6)$$

The above learner will have the symptoms that are associated with all three disabilities: dyslexia, hearing impairment and visual impairment. For designers and developers of learning environments, this knowledge is important as it will enable them to better design the learning environment. They will still need to consult with the learners in order to produce an environment that meets their needs. In addition to talking to the learners, great insight can also be obtained from educators and disability experts. The pedagogical component of the system is of vital importance and good principles of design can be obtained from educators and instructional/educational designers/developers. The process of analysing the individual disabilities to determine true needs is summarized in Figure 6.

Fig. 6. Determining symptoms for an individual with visual impairment, dyslexia and hearing impairment

Having analysed the disabilities of the learner, their needs could also be analysed and then a decision made on the appropriate format of learning materials or means of interaction. Again,

consider how the correct format of learning materials can be recommended for this individual from a repository of learning materials by considering the following:

R_i represents all the learning resources in a repository.

R_{dys}= Learning resources suitable for dyslexia

R_v= Learning resources suitable for visual impairment

R_H= Learning resources suitable for hearing impairment

The learning materials available for this individual are represented in Figure 7.

Fig. 7. Venn diagram representing the learning resources compatible with visual impairment (R_v), dyslexia (R_{dys}) and hearing impairment (R_H).

Unlike the case of the symptoms of the disability that were independent, the format of the learning resources are not independent sets as expressed in (7), (8), (9) and (10).

$$R_v \cap R_{dys} = \{audio, text\} \quad (7)$$

Thus, as already expressed earlier, audio and text formats of learning materials will be suitable for the visual impairment and the dyslexia of the individual (7) while audio, video and text will all be suitable for both dyslexia and hearing impairment. However, because of hearing impairment, the audio and video must be captioned (8).

$$R_{dys} \cap R_H = \{audio+captions, video+captions, text\} \quad (8)$$

$$R_v \cap R_H = \{audio+captions, text\} \quad (9)$$

$$R_v \cap R_H \cap R_{dys} = \{audio+captions, text\} \quad (10)$$

Unlike the case with two disabilities discussed above where all the learning materials that were suitable for each disability type were considered, the case here is different as most of those

learning materials suitable for each disability type will not be useful. This is because this individual cannot make use of the sense of sight and sound due to the presence of visual impairment and hearing impairment which means he can neither see nor hear. The only available sense that could be exploited is that of touch, hence, reasoning could be done on the ontologies that model this learner and the ontologies modelling the learning materials to determine that the appropriate format of learning materials will be that which exploits the sense of touch. Given that hearing impairment and visual impairment are the two main disabilities which could determine what format of learning material could be suitable for this learner, it could be determined that Braille is the most suitable format for this individual as expressed in (11) and (12) because it makes use of the sense of touch which is still available after the individual cannot use his sense of sight and sound.

$$R_v - R_H = \{x \in U: x \in R_v \text{ and } x \notin R_H\} = R_v \cap R_H' \qquad (11)$$

To obtain the suitable format of learning material for this individual with visual impairment, dyslexia and hearing impairment, the relative complement or set difference of sets R_v and R_H, denoted $R_v - R_H$, which is the set of all formats of learning materials that are suitable for visual impairments that are not normally the formats that would be recommended for a learner with hearing impairment in their study, need to be computed.

$$R_v \cap R_H' = \{Braille\} \qquad (12)$$

Although this learner can neither see nor hear, he can make use of the sense of touch to read information with Braille. For such an individual, it is important to develop tactile technology that will enable interaction in a web-based learning environment. Just like in the other case study for a learner with two disabilities, when analysing the learning materials that are suitable for this individual with three different disabilities, it is important to carefully analyse different possibilities. The difference here is that sound judgment needs to be made as to whether the learning material format is suitable for the learner. This can be successfully achieved by working in collaboration with the learner and with various experts. The process through which such decision is made is summarised in Figure 8.

Fig. 8. Retrieving learning resources compatible with visual impairment, dyslexia and hearing impairment.

Considerations for improving learning environments for students with disabilities

In this paper, ideas have been presented in order to improve the design and development of learning environments for the benefits of all students, particularly those with multiple disabilities. The following specific recommendations will ensure that designers and developers of learning environments can meet the needs of these students.

1. Consult with potential learners and gather requirements from them (Nganji and Nggada, 2011, Nganji, 2012). User centered consideration is always a starting point.
2. Consider giving the learner the ability to adapt the learning environment to meet his needs. Technology enhanced learning is a great enabler but it needs to be linked with personalisation and personal needs.
3. Consider building in various assistive technologies in the learning environment such that learners could activate them when needed. Consider this at the outset of the Software Engineering Process and not just as an add-on at the end. Assistive Technologies are not just additional Apps that are provided in the *Utils Folder* but are core, first order priorities that constitute first order design considerations.
4. Allow the learner to be able to adjust some interface elements such as text and background colour and size. This is important for some learners with dyslexia. Small elements can also be vital elements and should not be overlooked.
5. Ensure that learning materials that are uploaded into the virtual learning environment in various formats are accessible to learners. A recent study (Nganji, 2015) has found accessibility flaws with journal articles that are published in the portable document format. This could present access challenges to some students with disabilities, thus the need to incorporate accessibility throughout the design process.

Conclusion

Most learning environments are not designed to meet the needs of learners with multiple disabilities due to the challenges encountered when trying to do so. This paper has shown that it is possible to design for multiple disabilities and has suggested an approach which requires analysing the needs of the learner, the learning materials and then matching specific learning resources to individuals through ontological modelling and adaptive personalisation. Thus, by using basic machine learning concepts, learning environments could be collaboratively designed to deliver to the real needs of the learner. The resultant system is thus a good learning environment and an assistive tool in the education of all learners regardless of their abilities or disabilities.

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Figures

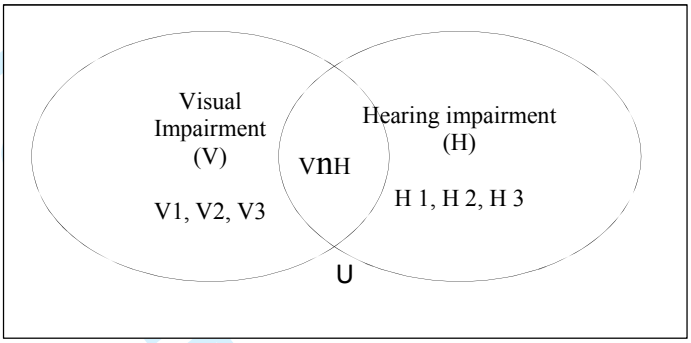


Fig. 1. Venn diagram representing the disabilities of an individual with visual impairment (V) and hearing impairment (H)

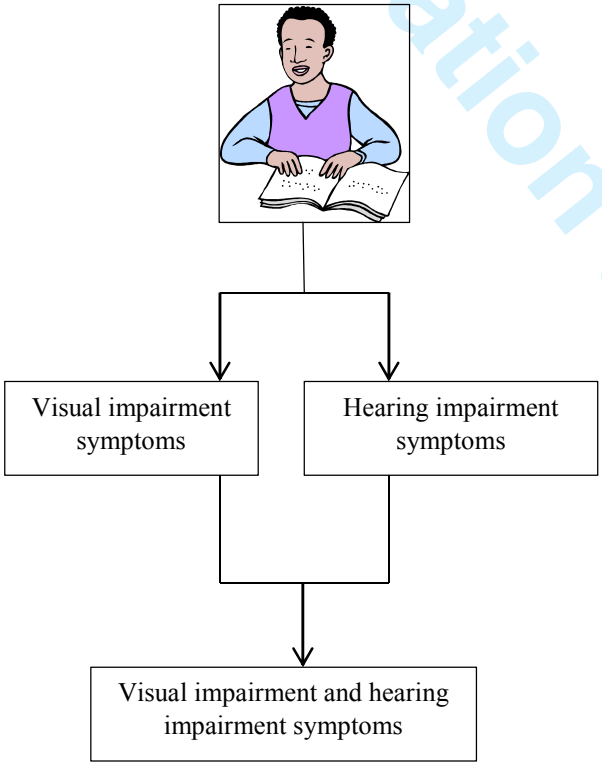


Fig. 2. Determining symptoms for a learner with visual impairment and hearing impairment

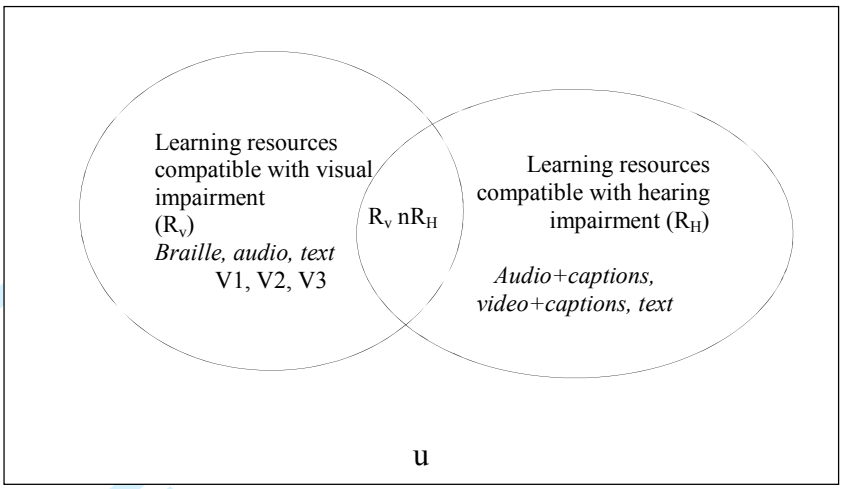


Fig. 3. Venn diagram representing the learning resources compatible with visual impairment (R_v) and hearing impairment (R_H)

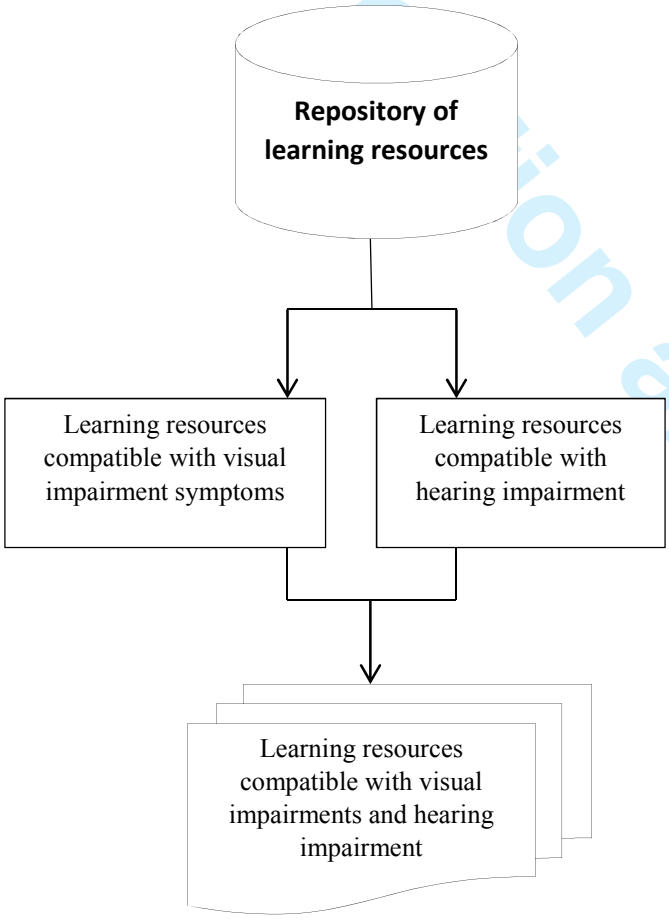


Fig. 4. Retrieving learning resources compatible with visual impairment and hearing impairment.

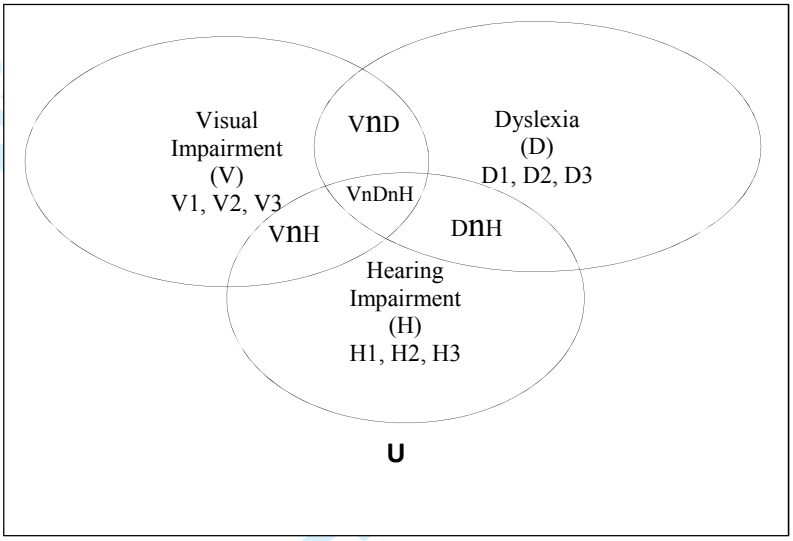


Fig. 5. Venn diagram representing the disabilities of an individual with visual impairment (V), dyslexia (D) and hearing impairment (H).

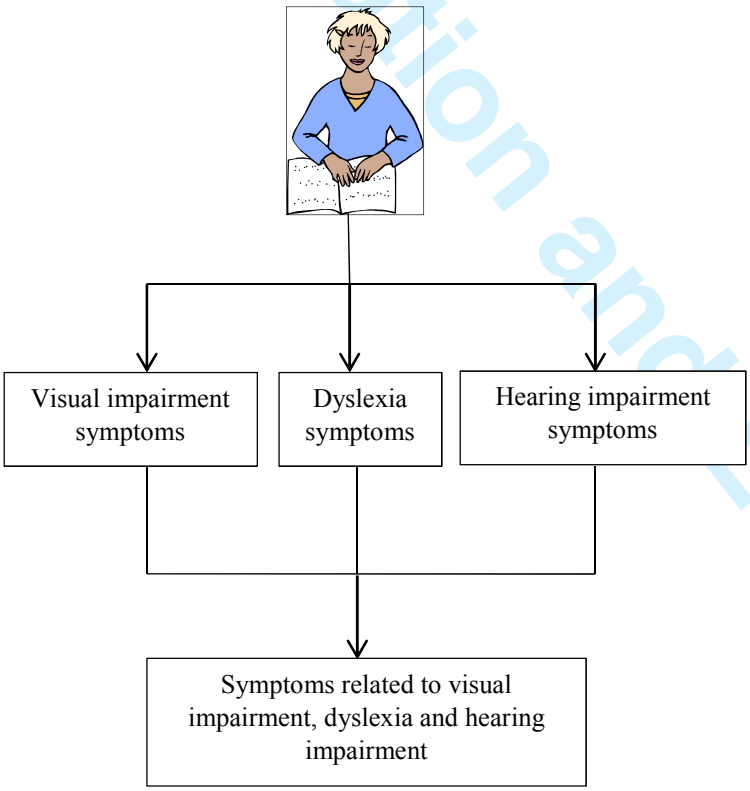


Fig. 6. Determining symptoms for an individual with visual impairment, dyslexia and hearing impairment

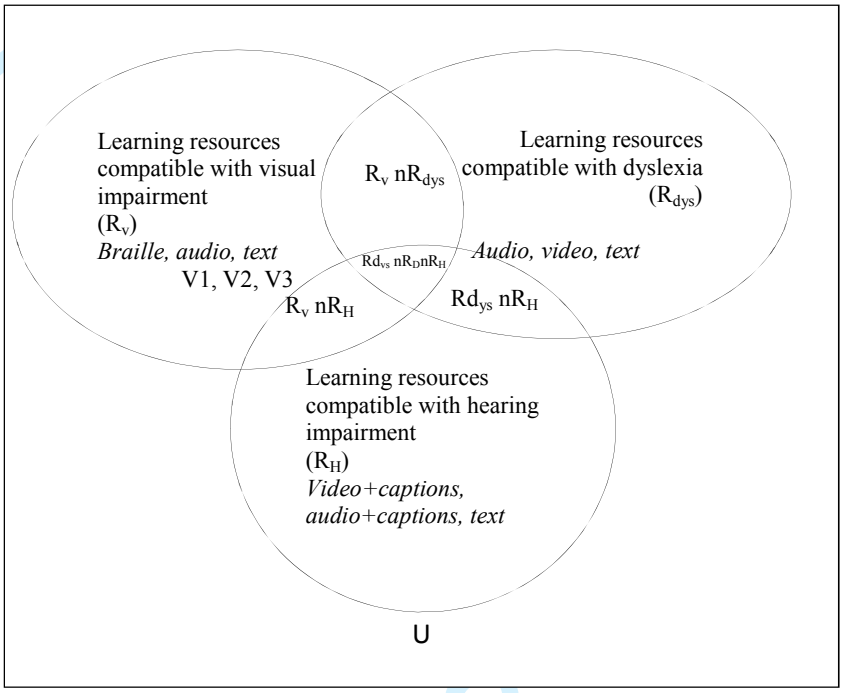


Fig. 7. Venn diagram representing the learning resources compatible with visual impairment (R_v), dyslexia (R_{dys}) and hearing impairment (R_H).

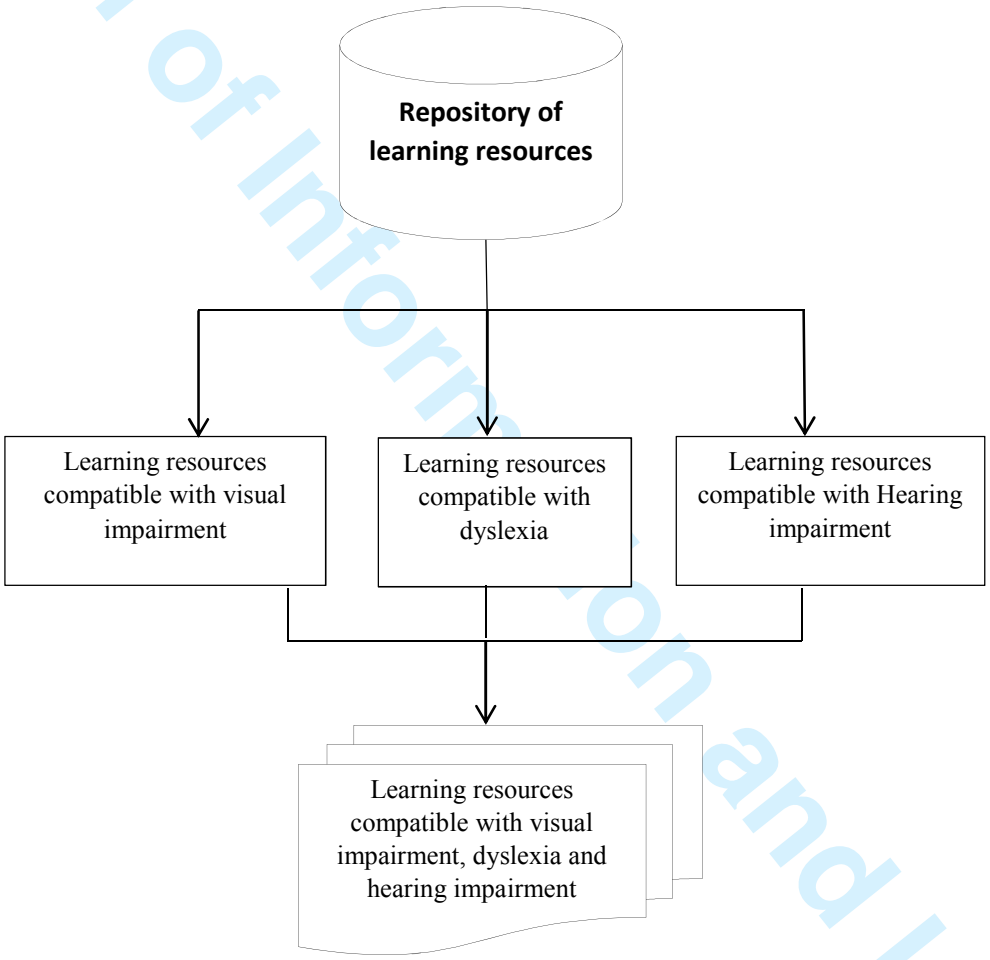


Fig. 8. Retrieving learning resources compatible with visual impairment, dyslexia and hearing impairment.

Figures

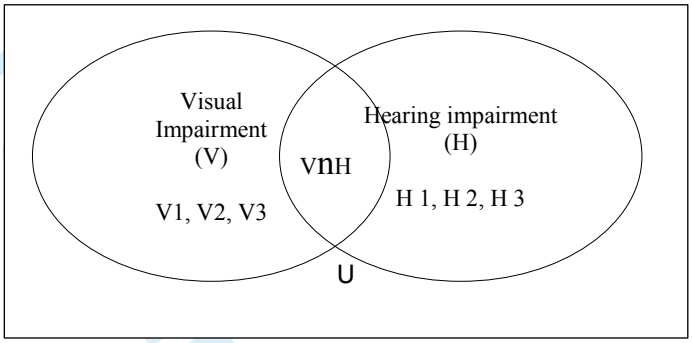


Fig. 1. Venn diagram representing the disabilities of an individual with visual impairment (V) and hearing impairment (H)

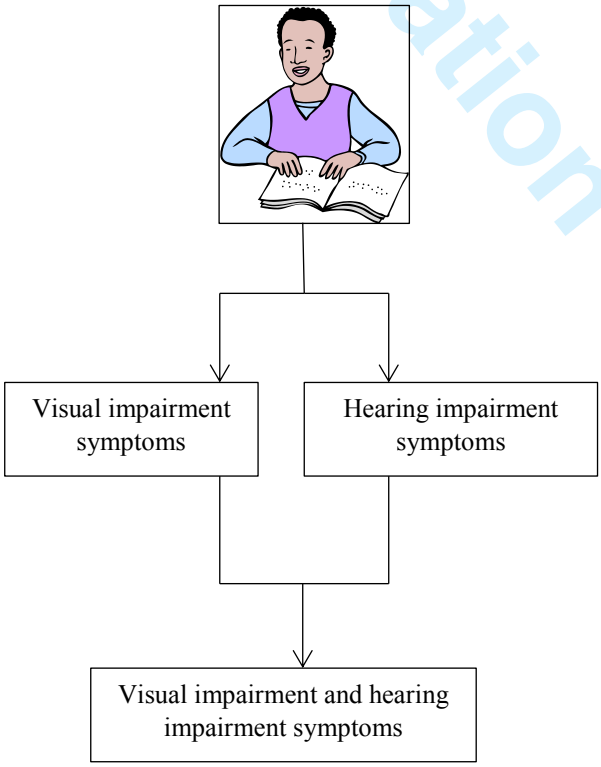


Fig. 2. Determining symptoms for a learner with visual impairment and hearing impairment

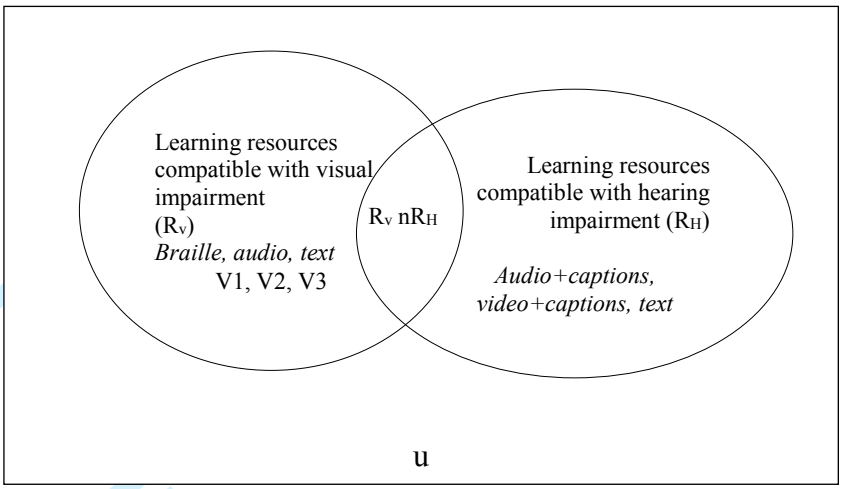


Fig. 3. Venn diagram representing the learning resources compatible with visual impairment (R_v) and hearing impairment (R_H)

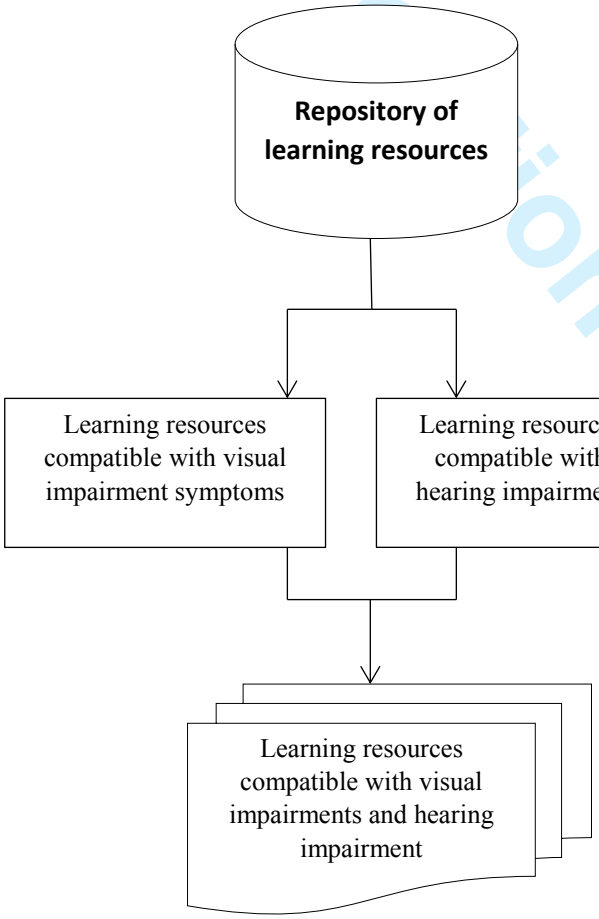
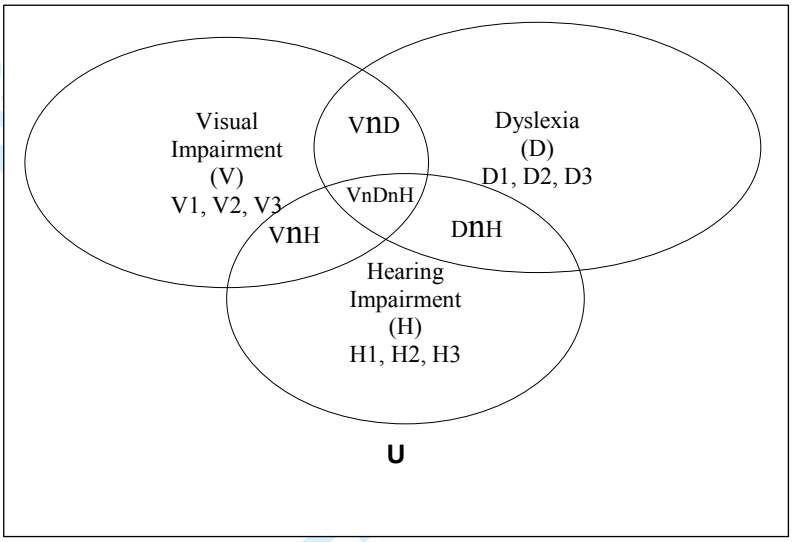


Fig. 4. Retrieving learning resources compatible with visual impairment and hearing impairment.



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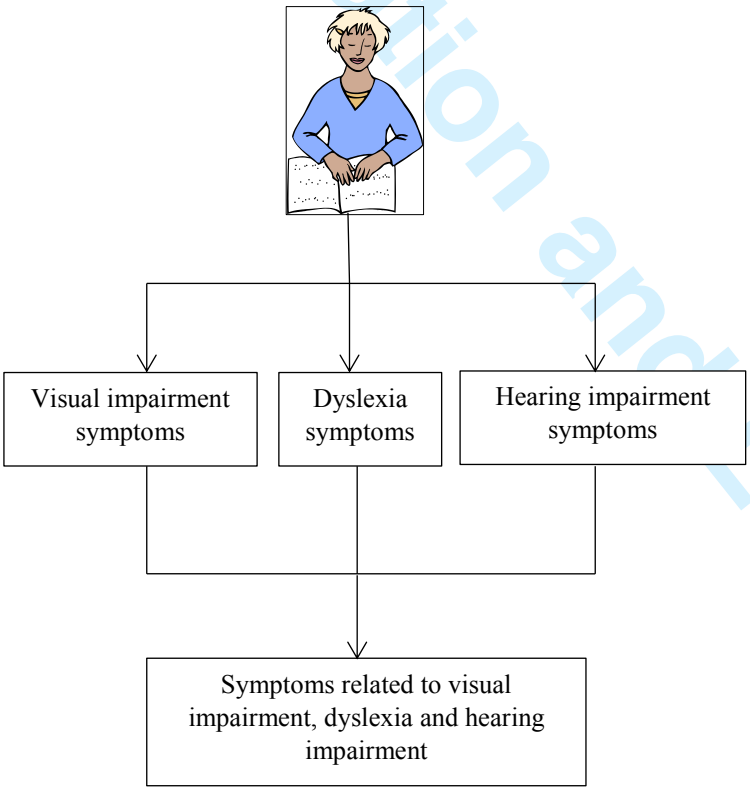

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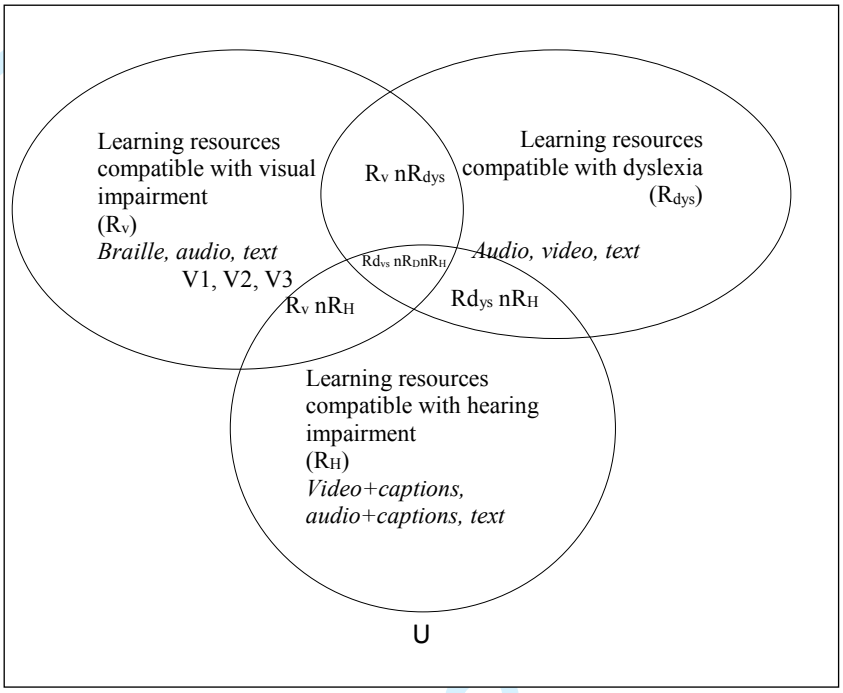

Fig. 7. Venn diagram representing the learning resources compatible with visual impairment (R_v), dyslexia (R_{dys}) and hearing impairment (R_H).

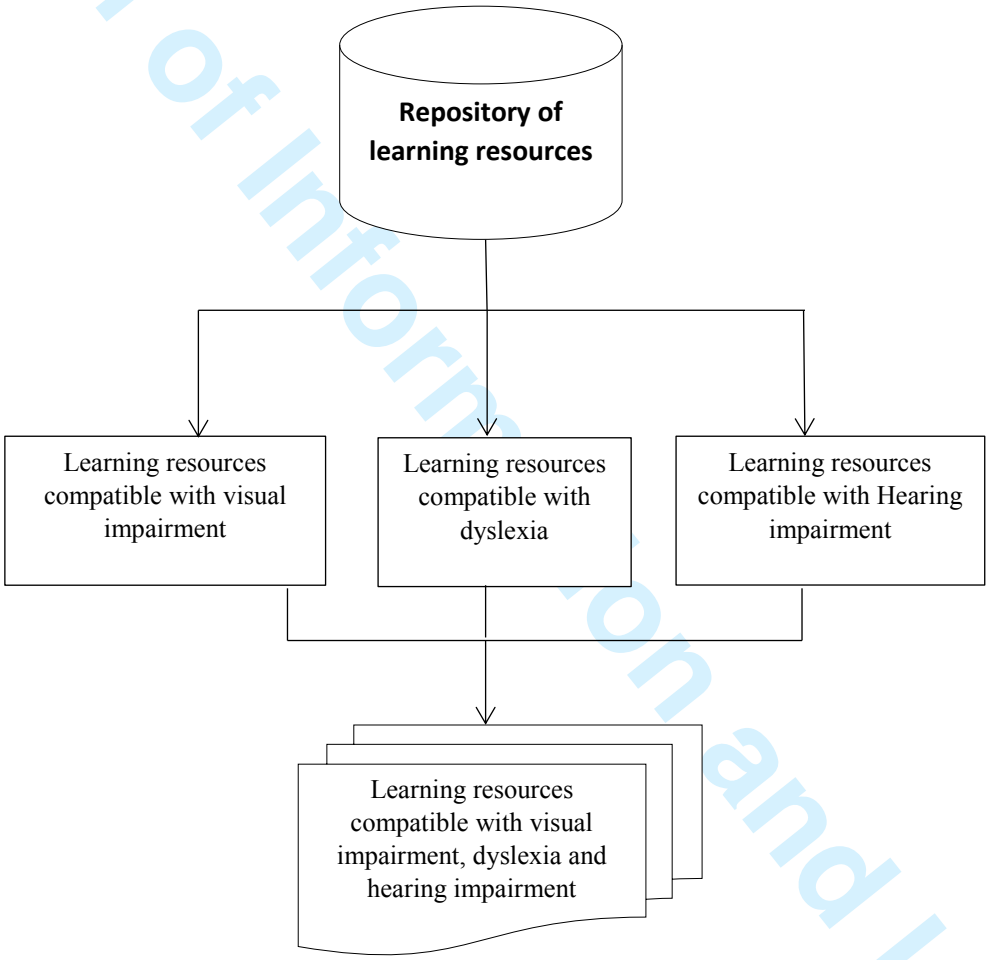

Fig. 8. Retrieving learning resources compatible with visual impairment, dyslexia and hearing impairment.