Mathematical Sciences and Informatics Journal
Vol. 2 , No.2 ,Nov.2021, pp. 76-88
http://www.mijuitmjournal.com DOI : 10.24191/mij.v2i2.13796

Optimizing Schedule of Boarding School Using Vertex and Edge Coloring Approach

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Article Info

Article history:

Received June 21, 2021
Revised Sept 08, 2021
Accepted Oct 15, 2021

Keywords:

Boarding School
Scheduling
Graph Coloring
Vertex Coloring
Edge Coloring

ABSTRACT

Soft skills like time management, teamwork and effective communication are highly important nowadays. But, many students are still lack of knowledge regarding all these skills. It is because, students are too much concerned with academic excellence until they neglect the mastery of the skills that they should have. This study focused on one of the boarding schools in Malaysia located in Kedah known as Sekolah Menengah Sultan Abdul Halim (SMSAH). The aim was to increase the awareness of the importance of soft skills within themselves. The important of this study in order to achieve this goal is to optimize the school schedule using the Graph Coloring method. In this study, two approaches have been used under the Graph Coloring method which are Vertex and Edge Coloring. Greedy Algorithm has been used to solve the Vertex Coloring approach while Graph Coloring Algorithm has been used to solve the Edge Coloring approach. The algorithm that produced the lowest minimum color will be selected for implementing the schedule of the boarding school. The result has shown that the Greedy Algorithm has succeeded to produce the very minimal color for the boarding school scheduling.

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1. Introduction

In 1890s, the first boarding school in Malaysia was developed in Selangor. It was The Selangor Raja School and temporarily closed in 1894 for renovation purposes. In 1905, the school was reopened in Kuala Kangsar and known as the Malay College Kuala Kangsar. Students enrolment are between the age of 13 years old and 17 years old. They stayed and learned in this boarding school for about 5 years. Preserving peaceful and secure environment for students who are in secondary level is the main reason for parents to send their teenage kids to boarding school[1]. The controlled surrounding in school could prevent their children from involving in social problem. This is because student will be monitored daily by the resident staff on duty, known as the warden. The strict and productive schedule also be a reason why parents like to choose boarding school as the place that can train their children to be more disciplined and matured. Moreover, peers also play an important role in students' life. Peer influences are commonly seen as a factor affecting the participation of students in class and their academic success[2]. Good support from peers can help them to excel in academic achievement.

An effective scheduling of student is a schedule that contains many slots referred to recommended curricular activities and it can give impact to the student in the future. The time arrangement requires to be done excellently so that the student will feel comfortable and not burdened

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with packed schedules. A good schedule should not be too tight and not too relaxed so that the student would able to adapt school's surrounding easily and survive well in the boarding school

Soft skill can be developed in every student by involving them to activities in school or university so that they can prepare themselves to face the challenge in the future. It is because soft skills are important element that to be considered to recruit new employee for school or university's graduates[3]. Nevertheless, one of the most challenging tasks in preparing the effective timetable for effective students activities is to balance the trade-off between the academic and soft skill needed. This issue has attracted many researchers to employ timetable optimization[4] but limited studies have been focused on optimizing boarding school scheduling in relation to soft skills and academic constraint[5]. Healthy diet and menu plan is another interesting issue in a boarding school, which has been addressed by a few of the research[6][7].

This paper presents the fundamental design and implementation of boarding school scheduling by using optimization approach. The objective of the scheduling optimization is to use the optimal time of the student days without neglecting the essential constraints of the boarding school, teachers and students. The research framework and findings of this study will be applicable to be implemented in other boarding schools in Malaysia as well as to other applications related to scheduling and time table.

2. Literature Review

2.1 Boarding School Schedule

Students who are qualified to enrol in boarding school, they will be stayed and spend their time in the school for every day. They have optimal time to focus the curricular and co-curricular activities. Due to this, parents feel secured to their children's education. Good and full support from peers also give impact to students' academic achievement. Usually, all students who accepted in a boarding school have been selected based on different good criteria, including good attitude. Thus, students in boarding school tend to have very good peers support from the good attitude students[8],[9].

An excellent daily schedule supposedly can help student's development from aspects social life, soft skills and academic performance. The schedule should comprise of various aspects such as academic, religious activities, co-curricular activities, sleeping time and eating time. All these activities can train the students to manage their time and behaviour. As reported by researchers in [10], well plan activities and break time arrangement for the boarding school have shown significant impacts on the students' achievement. According to [11], resilience is an important trait that can be built on students in a boarding school. This is including the ability to overcome difficulties and to achieve goals in the face of obstacles, which can be designed and implemented through the daily school activities.

2.2 The Importance of Soft Skills for Pre-University Students

Soft skills are personal attributes needed for both academic and career success. Significant soft skills include time management, networking between colleagues, teamwork, creative thinking, and conflict resolution. Soft skills are important as it is common in this present time for employers to include such element during recruitment. Many companies are likely to recruit, maintain, and develop competent, resourceful, ethical, communicative, self-directed individuals who are ready to work, and learn and have positive attitudes and vibes. Wrong decision made by employees due to lack of knowledge and skills can be costly for a company as such mistakes will affect adversely the performance of the organization[12]. This includes worker's behaviour, health, efficiency, dedication, and withdrawal.

Someone can be extremely good with technical and job-specific skills, but they may not be successful in the workplace if they can't manage their time or work in a team. They need to be smart to balance their time between work and personal life. The best time to develop a wise time management skill is during secondary school. If they can manage their time well during their study, they wouldn't have any problems to organize their work schedule in the future. Students who practice effective time management techniques and set themselves appropriate job goals can self-regulate themselves in performing their assigned tasks.

2.3 Graph Coloring

Graph Coloring is one of the concepts in graph theory to label the graph. It is a task of labelling a graph subject by assigning color to the certain constraints that have been set. Vertex coloring, edge coloring, and face coloring are methods that can be used to solve this problem. Vertex coloring is a way to color the vertices and make sure that the adjacent vertices do not share the same color while the edge coloring is a procedure to color the edges and the adjacent edges so they do not have the same color. Face coloring is a concept of assigning a color in a planar graph without having two faces or regions that share the same color of the boundary[13]. However, it still shares the same goal which is to obtain the minimum color use in labelling.

2.4 Graph Coloring for Timetable Scheduling

According to [14], the ideal solution for scheduling problem is by allocating a certain resource in the number of time slots and optimizing it to avoid the conflicts while satisfying assorted essential and preferential constraints. In educational institutions, it has become a common thing to face problems when arranging course schedules and exam schedules. For the course schedule, the institution needs to arrange the schedule at different time interval for a course taught by the same lecturer and requires the same classroom. This will prevent class overlapping from occurring. In the context of the timetable, the nodes or vertices will act as courses and the edges that exist between the nodes to represent common students[15].

2.5 Vertex and Edge Coloring

Vertex coloring[16] and edge coloring[17] are methods that can be used to solve the scheduling problem. Vertex coloring is a way to color the vertices and make sure that the adjacent vertices do not share the same color. This approach aims to determine the lowest chromatic number, $\chi(G)$, to be used to color all the vertices in a graph, where $\chi(G)$ is also known as k-chromatic. Edge coloring is a procedure to color the edges, and the two consecutive edges do not display the same color. Similar to vertex coloring, this approach has the same goal, which is to find the minimum color to be used in coloring all the edges in a graph. However, in this approach, the minimum color is known as k-edge chromatic also refer as $\chi'(G)$. If there are no two adjacent edges that share the same color, the coloring is proper coloring. Even though vertex and edge coloring have a slightly different steps, however, it still shares the same goalm which is to obtain the minimum color use in labelling. Besides, these two approaches can be solved by implementing the algorithm in the solving step. This will contribute to the effectiveness of the results.

2.6 Greedy Algorithm

The Greedy Algorithm[18] is classified as a simple and intuitive heuristic algorithm used in optimization method that solves any scheduling problem. Given a graph, G = (V, E), the algorithm operates by arranging and sorting the set of vertices. In scheduling problems, the goal of this algorithm is to determine the minimal color to be used in assigning and labelling each vertex in a graph while ensuring that no two adjacent vertices hold the same color. Even though this algorithm does not guarantee to obtain minimal colors. However, this algorithm is still capable of producing colors that lower than $(\Delta(G)+1)$. In graph coloring, $(\Delta(G))$ is generally known as the maximum degree of a vertex in a graph. Instead of has been widely used in any scheduling problems, this algorithm also can be used in any field such as bioinformatics tools.

2.7 Graph Coloring Algorithm

Many algorithms can be used to solve the vertex and edge coloring approach, including in the Graph Coloring Algorithm[14]. The complexity of the problem will increase as the number of vertices or edges in a graph increase. So, in order to overcome the complexity, the ideal graph coloring algorithms must be implemented to the problem. This initiative also will help the researcher to find the best solution to the problem. There are many sub-algorithms stated under Graph Coloring Algorithm such as First Fit Algorithm (FF), Welsh Powel Algorithm (WP) and Degree of Saturation Algorithm (DSATUR). The goal of this algorithm is to find the lowest minimum color to be used to color each vertex in a graph and to make sure that all of it is assigned with different colors. Since it aims to label each vertex with different colors, so at the end of the result, the color that will be produced is going to be higher than the degree of a vertex in a graph, $\chi(G) \geq (\Delta(G))$.

3. Methodology

The method used in this study for optimizing and preparing the boarding school scheduling has six important steps as the following.

Step 1: Collect and obtain the organization's data

The boarding schedule for this research was obtained from Sekolah Menengah Sultan Abdul Halim, Jitra, from 2019 to 2020. The schedule consists of several variables, including number of upper form students, the number of teachers, number of classes and the number of slots for each day.

Step 2: Classify the essential and preferential constraints based on the organization's data

The essential constraints have been setting up based on the circular of the Ministry of Education Malaysia and the school. All the pre-defined constraints must be met, otherwise the schedule will be invalid. Table 1 shows the sample of essential and preferential constraints for the Sekolah Menengah Sultan Abdul Halim.

Table 1. Essential and Preferential Constraints for Sekolah Menengah Sultan Abdul Halim

Essential Constraints	**Preferential Constraints**
The assembly should be held once a week.	Reading Al-Mathurat should be held every day after the Subuh and Asar Prayer.
Sports classes must be held once a week.	Students should have 10 to 15 minutes a day for a nap.
A student cannot attend two different classes at the same time slot.	Literacy and calculation classes should be scheduled alternately.
The capacity of students in one class should not exceed thirty students	Soft skills classes should be held at least once a week.

The preferential constraint has been made based on the suitability of the Sekolah Menengah Sultan Abdul Halim schedule. The main objective is to improve the original schedule. However, if one of its cannot be fulfilled, the schedule is still considered valid.

Step 3: Construct the conflict matrix and transformed it into a graph

The conflict matrix was constructed to determine the problem that arises in the schedule if any of the subjects were scheduled at the same time slot. The schedule was divided into two classes, which are science stream and technical stream classes. Table 2 is the list of subjects for science stream class while Table 3 shows the list of subjects for technical stream class. It is necessary to set the short form of each subject as in the Table 2 and Table 3. The technical stream class has Technology Engineering and Technical Drawing subjects and excluded BIO subject as in the science stream class. Both classes must have soft skill class and co-curricular activities.

Table 2. List of subjects for science Stream Class

Short form of subjects	**Subjects**
AS	Assembly
BM	Bahasa Melayu
E	English
PI	Pendidikan Islam
SEJ	Sejarah
MATH	Mathematics
AM	Additional Mathematics
BIO	Biology
PHY	Physics
CHEM	Chemistry
IL	International Language
PE	Physical Education
CC/CS	Civic class/Counselling session
REC	Recreation
SSC	Soft Skill Class
CCA	Co-Curricular Activities

Table 3. List of subjects for Technical Stream Class

Short form of subjects	Subjects
AS	Assembly
BM	Bahasa Melayu
E	English
PI	Pendidikan Islam
SEJ	Sejarah
MATH	Mathematics
AM	Additional Mathematics
PHY	Physics
CHEM	Chemistry
TE	Technology Engineering
TD	Technical Drawing
IL	International Language
PE	Physical Education
CC/CS	Civic class /Counselling session
REC	Recreation
SSC	Soft Skill Class
CCA	Co-Curricular Activities

Table 4 shows the sample of conflict matrix for science stream class. The 'X' in the table presents the problem arises between those subjects.

Table 4. Conflict Matrix for science stream class

	AS	BM	E	PI	SEJ	MATH	AM	BIO	PHY	CHEM	IL	PE	CC/CS	REC	SSC
AS	-	X	X	X	X	X	X	X	X	X	X	X	X	X	X
BM	X	-	X	X	X	X	X				X		X		
E	X	X	-	X	X	X	X				X		X		
PI	X	X	X	-	X	X	X				X		X		
SEJ	X	X	X	X	-	X	X				X		X		
MATH	X	X	X	X	X	-	X				X		X		
AM	X	X	X	X	X	X	-				X		X		
BIO	X							-							
PHY	X								-						
CHEM	X									-					
IL	X	X	X	X	X	X	X				-		X		
PE	X											-		X	
CC/CS	X	X	X	X	X	X	X				X		-		
REC	X											X		-	X
SSC	X													X	-

It can be seen in Table 4 that Assembly (Assem) must be designed not to clash with other subjects. One more example is BM subject in the class must be designed not to clash with E, PI, SEJ, MATH, AM, IL and CC/CS. The Conflict Matrix for technical stream class is slightly different with the science Stream class as presented in Table 5.

Table 5. Conflict Matrix for technical stream class

	As	BM	E	PI	SEJ	MATH	AM	PHY	CHEM	TE	TD	IL	PE	CC/CS	REC	SSC
As	-	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
BM	X	-	X	X	X	X	X					X		X		
E	X	X	-	X	X	X	X					X		X		
PI	X	X	X	-	X	X	X					X		X		
SEJ	X	X	X	X	-	X	X					X		X		
MATH	X	X	X	X	X	-	X					X		X		
AM	X	X	X	X	X	X	-					X		X		
PHY	X							-								
CHEM	X								-							
TE	X									-						
TD	X										-					
IL	X	X	X	X	X	X	X					-		X		
PE	X												-		X	
CC/CS	X	X	X	X	X	X	X					X		-		
REC	X												X		-	X
SSC	X														X	-

TE and TD have problem only when they clashed with Assembly while other subjects that also exists in the science stream class have similar clashing problems in the technical science class. Based on the conflict matrix, coloring process can be started to be implemented in step 4.

Step 4: Begin the coloring process of the graph using Vertex Coloring approach as the following Greedy algorithm.

Step 4.1: The vertices will be classified in a specific order V_1 , V_2 , V_3 , … V_n .
Step 4.2: Assigned the first color to the first vertex.
Step 4.3: Select the next vertex and color it with the lowest numbered color on any vertices adjacent to it using $(V-1)$ vertices. If this color fits all the corresponding vertices, give it a new color.
Step 4.4: Keep repeating this step until all the vertices in the graph are colored and then the process terminates when uncolored vertices no longer exist.

Step 5: Begin the coloring process of the graph using Edge Coloring approach as the following Graph coloring algorithm.

Step 5.1: Arrange the edges of a graph in a certain order $e_1, e_2, e_3, \ldots e_n$.
Step 5.2: Selects the first edge and assigns it with the first color.
Step 5.3: Select and color the next edge with the lowest numbered color on any edge adjacent to it that has not been colored. If this color is used to color all the adjacent edges, assign it a new color.
Step 5.4: Repeat the step above until all the edges are colored completely.

Step 6: Construct a new schedule by using Vertex and Edge Coloring approaches.

4. Results and Discussions

4.1 Vertex Coloring

After constructing a conflict matrix, the undirected graph was created. The connection between two vertices was representing the 'X' labels in the conflict matrix. Figure 1 and Figure 2 show the undirected graph for the science stream and technical stream respectively.

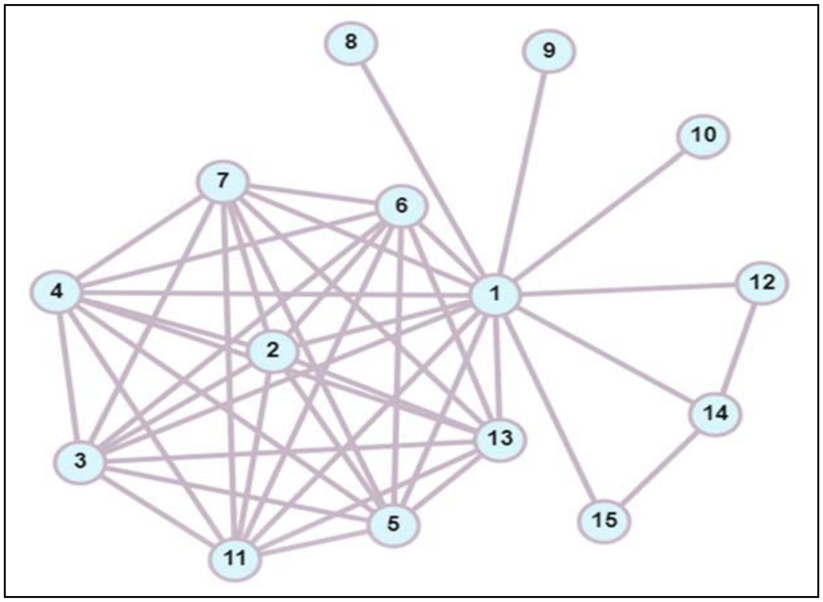

Figure 1. The undirected graph for science stream class

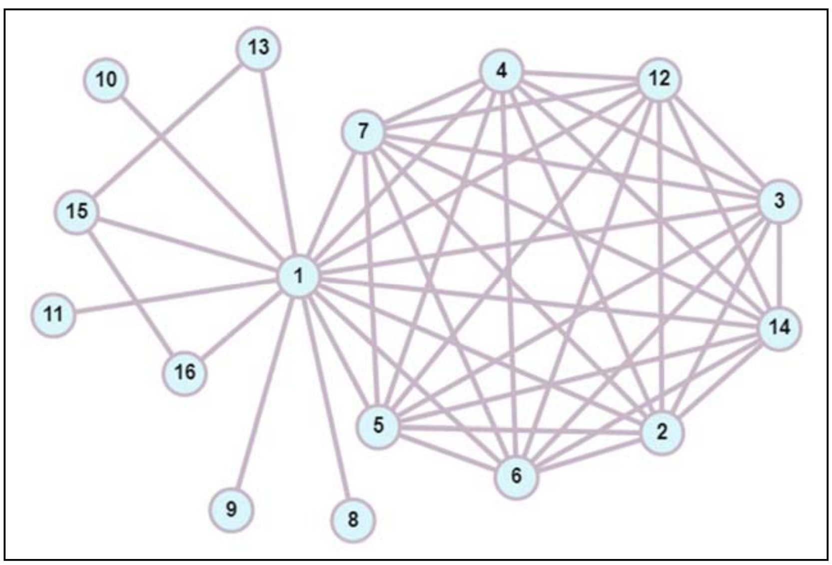

Figure 2. The undirected graph for technical stream class

Identifying vertex color has been implemented with C++ programming language based on the Greedy algorithm in step 4. The results of vertex color for the both classes are presented in Table 6 and Table 7 respectively.

Table 6. Summary of the result from the C++ program for science stream class

Vertex Number	Subjects	Vertex Color
1	Assembly	1
2	Bahasa Melayu	2
3	English	3
4	Pendidikan Islam	4
5	Sejarah	5
6	Mathematics	6
7	Additional Mathematics	7
8	Biology	2
9	Physics	2
10	Chemistry	2
11	International Language	8
12	Physical Education	2
13	Civic class/Counselling session	9
14	Recreation	3
15	Soft Skill Class	2

Table 7. Summary of the result from the C++ program for technical stream class

Vertex Number	Subjects	Vertex Color
1	Assembly	1
2	Bahasa Melayu	2
3	English	3
4	Pendidikan Islam	4
5	Sejarah	5
6	Mathematics	6
7	Additional Mathematics	7
8	Physics	2
9	Chemistry	2
10	Technology Engineering	2
11	Technical Drawing	2
12	International Language	8
13	Physical Education	2
14	Civic class/Counselling session	9
15	Recreation	3
16	Soft Skill Class	2

Any subjects that have problems as listed in the conflict matrix tables are coded with the same value for the vertex color. Vertex color 2 and 3 are the problem subjects listed in the conflict matrix tables. Next is the results of edge coloring.

4.2 Edge Coloring

Edge coloring can be done according to the Graph Coloring algorithm in step 5. As the output, Table 8 and Table 9 show the list of subjects and the edges that represent the undirected graph for both classes respectively. There were 44 edge numbers have been created for the science stream class and 45 edge numbers for the technical stream class.

Table 8. List of subjects and the edges for science stream class

Edge Number	Subjects	Edge Number	Subjects
1	Assembly – BM	23	E – SEJ
2	Assembly – E	24	E – MATH
3	Assembly – PI	25	E – AM
4	Assembly – SEJ	26	E – IL
5	Assembly – MATH	27	E – CC/CS
6	Assembly – AM	28	PI – SEJ
7	Assembly – BIO	29	PI – MATH
8	Assembly – PHY	30	PI – AM
9	Assembly – CHEM	31	PI – IL
10	Assembly – IL	32	PI – CC/CS
11	Assembly – PE	33	SEJ – MATH
12	Assembly – CC/CS	34	SEJ – AM
13	Assembly – REC	35	SEJ – IL
14	Assembly – SSC	36	SEJ – CC/CS
15	BM – E	37	MATH – AM
16	BM – PI	38	MATH – IL
17	BM – SEJ	39	MATH – CC/CS
18	BM – MATH	40	AM – IL
19	BM – AM	41	AM – CC/CS
20	BM – IL	42	IL – CC/CS
21	BM – CC/CS	43	PE – REC
22	E – PI	44	REC – SSC

Table 9. List of subjects and the edges for technical stream class

Edge Number	Subjects	Edge Number	Subjects
1	Assembly – BM	24	E – SEJ
2	Assembly – E	25	E – MATH
3	Assembly – PI	26	E – AM
4	Assembly – SEJ	27	E – IL
5	Assembly – MATH	28	E – CC/CS
6	Assembly – AM	29	PI – SEJ
7	Assembly – PHY	30	PI – MATH
8	Assembly – CHEM	31	PI – AM
9	Assembly – TE	32	PI – IL
10	Assembly – TD	33	PI – CC/CS
11	Assembly – IL	34	SEJ – MATH
12	Assembly – PE	35	SEJ – AM
13	Assembly – CC/CS	36	SEJ – IL
14	Assembly – REC	37	SEJ – CC/CS
15	Assembly – SSC	38	MATH – AM
16	BM – E	39	MATH – IL
17	BM – PI	40	MATH – CC/CS
18	BM – SEJ	41	AM – IL
19	BM – MATH	42	AM – CC/CS
20	BM – AM	43	IL – CC/CS
21	BM – IL	44	PE – REC
22	BM – CC/CS	45	REC – SSC
23	E – PI		

Then, Figure 3 and Figure 4 present the undirected graph that have been drawn based on the edge numbers(labels) for each stream respectively.

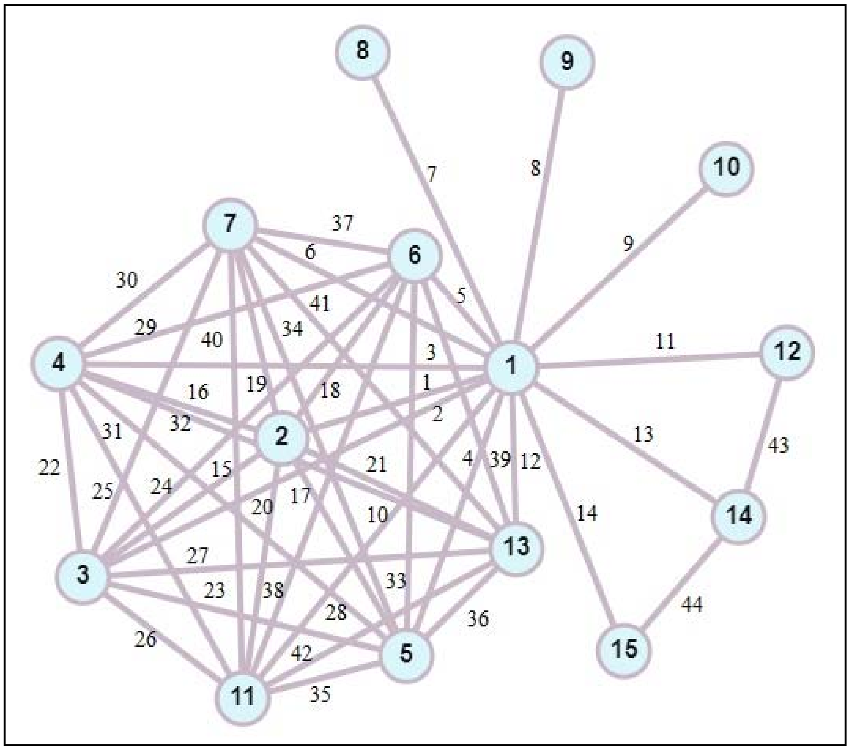

Figure 3. The undirected graph with 44 edge labels for science stream class

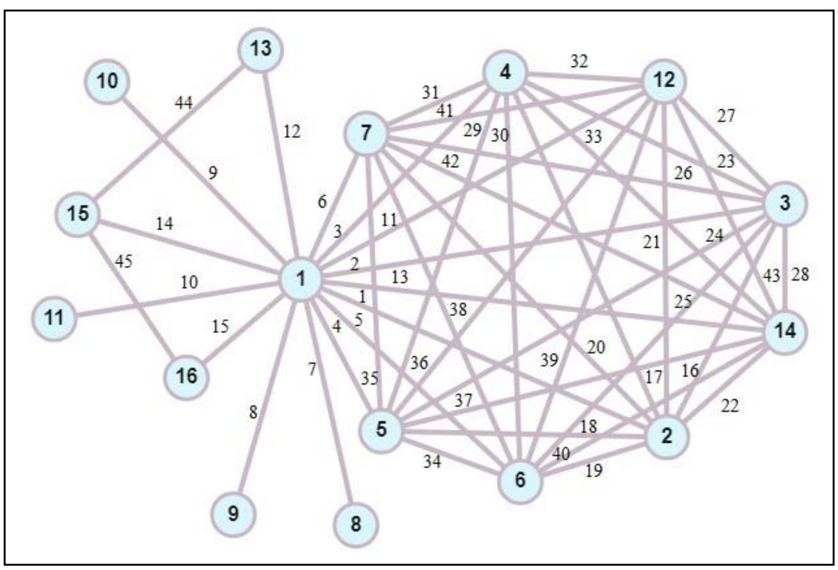

Figure 4. The undirected graph with 45 edge labels for technical stream class

Table 10 shows the summary of edge coloring results from the C++ program for science stream class.

Table 10. Summary of edge coloring result from C++ Program for sciences stream class

Edge Number	Subjects	Edge Color	Edge Number	Subjects	Edge Color
1	Assembly – BM	1	23	E – SEJ	3
2	Assembly – E	2	24	E – MATH	4
3	Assembly – PI	3	25	E – AM	5
4	Assembly – SEJ	4	26	E – IL	6
5	Assembly – MATH	5	27	E – CC/CS	7
6	Assembly – AM	6	28	PI – SEJ	2
7	Assembly – BIO	7	29	PI – MATH	4
8	Assembly – PHY	8	30	PI – AM	5
9	Assembly – CHEM	9	31	PI – IL	6
10	Assembly – IL	10	32	PI – CC/CS	7
11	Assembly – PE	11	33	SEJ – MATH	1
12	Assembly – CC/CS	12	34	SEJ – AM	5
13	Assembly – REC	13	35	SEJ – IL	6
14	Assembly – SSC	14	36	SEJ – CC/CS	7
15	BM – E	2	37	MATH – AM	2
16	BM – PI	3	38	MATH – IL	3
17	BM – SEJ	4	39	MATH – CC/CS	6
18	BM – MATH	5	40	AM – IL	1
19	BM – AM	6	41	AM – CC/CS	3
20	BM – IL	7	42	IL – CC/CS	2
21	BM – CC/CS	8	43	PE – REC	1
22	E – PI	1	44	REC – SSC	2

Table 11 shows the summary of edge coloring result from the C++ program for technical stream class.

Table 11. Summary of edge coloring result from C++ Program for technical stream class

Edge Number	Subjects	Edge Color	Edge Number	Subjects	Edge Color
1	Assembly – BM	1	24	E – SEJ	3
2	Assembly – E	2	25	E – MATH	4
3	Assembly – PI	3	26	E – AM	5
4	Assembly – SEJ	4	27	E – IL	6
5	Assembly – MATH	5	28	E – CC/CS	7
6	Assembly – AM	6	29	PI – SEJ	2
7	Assembly – PHY	7	30	PI – MATH	4
8	Assembly – CHEM	8	31	PI – AM	5
9	Assembly – TE	9	32	PI – IL	6
10	Assembly – TD	10	33	PI – CC/CS	7
11	Assembly – IL	11	34	SEJ – MATH	1
12	Assembly – PE	12	35	SEJ – AM	5
13	Assembly – CC/CS	13	36	SEJ – IL	6
14	Assembly – REC	14	37	SEJ – CC/CS	7
15	Assembly – SSC	15	38	MATH – AM	2
16	BM – E	2	39	MATH – IL	3
17	BM – PI	3	40	MATH – CC/CS	6
18	BM – SEJ	4	41	AM – IL	1
19	BM – MATH	5	42	AM – CC/CS	3
20	BM – AM	6	43	IL – CC/CS	2
21	BM – IL	7	44	PE – REC	1
22	BM – CC/CS	8	45	REC – SSC	2
23	E – PI	1			

Furthermore, from the step 6, the weekly scheduling for students from the two stream of classes have been successfully generated as presented in Figure 5 and Figure 6.

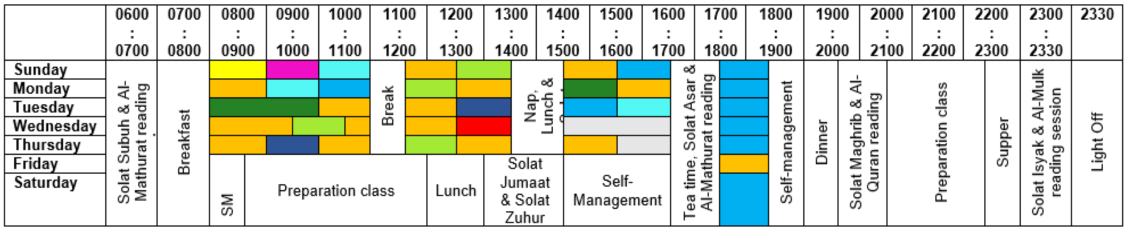

Figure 5. The new possible schedule for science stream class

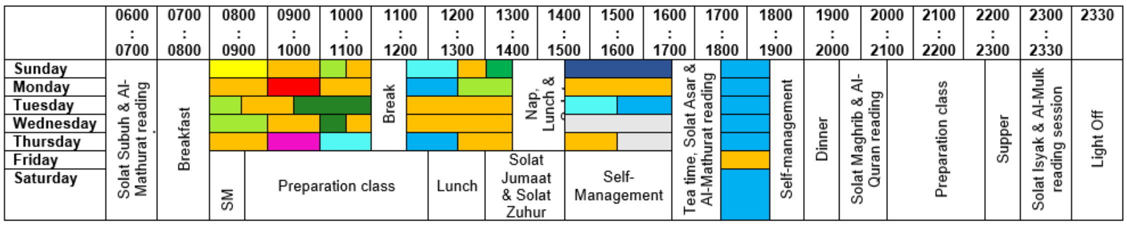

Figure 6. The new possible schedule for technical stream class

It can be seen in Figure 5 that 9 different colors have been generated for the science stream class and 10 different colors for the technical stream class. The number of colors that were provided by the graph coloring methods implemented in this research is minimal, where others activities to be slot in. This research was successfully optimizing the boarding school schedule in Sekolah Menengah Sultan Abdul Halim located in Jitra, Kedah

5. Conclusion

This research was successfully optimizing the boarding school schedule in Sekolah Menengah Sultan Abdul Halim located in Jitra, Kedah. In this study, vertex and edge coloring were used to identify any problems that arised in the schedule. The problem has been translated into the form of a conflict matrix before being transformed into a graph. Greedy Algorithm and Graph Coloring Algorithm have been implemented to optimize the schedule. Vertex coloring was followed by the sequential Greedy Algorithm meanwhile edge coloring was followed by the sequential Graph Coloring Algorithm. Both algorithms supported by the C++ software program. The analysis result showed that the Greedy Algorithm produced the lowest required minimum color compared to the Graph Coloring Algorithm. Thus, the new possible schedule has been constructed using ten minimal colors based on the results of Greedy Algorithms and followed the essential and preferential constraints that have been specified. The benefit to use this algorithm is the result does not surely produce the minimal amount of color, but it will give color results which are not exceed the amount of time available. The new schedule produced in this study showed a relaxed schedule based on the slotting activities were not too busy and tight compared to the original schedule. It gives good impact to the student so that students will be happy and not too stress to enjoy all activities that displayed in the schedule. Besides, the organization can rearrange the schedule according to the suitability of student time. Thus, the students can balance their academics as well as the skills needed in their future.

Acknowledgements

The authors gratefully acknowledge the Universiti Teknologi MARA (UiTM), Johor branch Pasir Gudang campus and Universiti Teknologi MARA (UiTM), Perlis branch.

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