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Optimization (Efficient Allocation) of Students' Desired Statistics Lab Hours: An Application with Weights and Frequencies

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ABASTRACT:

This study looked at the efficient allocation of limited resources (10 hours per week) based on students' desired statistics lab hours and it found that both rank (relative importance or weight) and frequency based demand for lab hours based on week days was highest on Mondays followed by Tuesdays, Wednesdays, and Fridays. The demand for statistics lab hours was lower on Thursdays relative to that of Fridays even though statistics classes were offered on Mondays through Thursdays. Both frequencies and weight based assignment of lab hours with even distribution of two hours per day indicated that the lab hours should have been allocated between 10-11 am and 3-4 pm, but the weight based assignment of lab hours without even distribution per day should have been 3 hours on Mondays and Tuesdays, 2 hours on Wednesdays, and one hour each on Thursdays and Fridays. Overall, the study suggested that for efficient allocation of limited resources (10 hours of stat lab hours per week with one stat lab assistant), the statistics lab should be opened right before and right after lecture classes. The distribution of allocation of hours should be slightly more after lecture classes than before lecture classes.

INTRODUCTION:

The purpose of the paper was to find an optimal allocation of limited resources (10 lab hours per week and one lab assistant) given students' desired statistics lab hours during a week. There are two possible ways to serve students with a statistics lab. One way is to serve the most number of students (frequency) per week and the other way is to serve the most students with priorities or preferences (weights). In business schools, usually there are other labs besides statistics lab. For example, Accounting labs, Information Systems labs, Finance labs etc. Management may allocate lab hours based on criteria other than the best use of lab time for students taking statistics classes. Since faculty in each discipline determines their own preferences for when labs will be available, and since labs may need to be scheduled around facility availability, variances of this nature are the norm.

LITERATURE REVIEW:

Many variables enter into scheduling of resources. In a university setting, faculty preferences, traditional viewpoints as to which slots will fill at what times, as well as other constraints such as classroom and student teaching assistant schedules impact this issue. While student preferences have been considered in scheduling at least as far back as 1967 (Busam), it has been the normal procedure with traditional students to have them fit their schedules to university needs. This is likely to change as student bodies are recruited from nontraditional sources.

Class (hence lab) scheduling has been connected with a variety of topics such as timetabling, sectioning, and others over the years. Timetabling is a process which involves fairly setting class (and lab) schedules so that

University, faculty and student preferences are met given a limited set of resources and a complex set of resource constraints. (Hill 2008; Kumar and Kleinberg 2006).

Hill notes that "the extent to which students are able to take the courses for which they express preferences," is a measure of scheduling quality (quoted in Thompson 2005, p.198). From this, one may infer that student preferences should be considered when setting course lab times.

Beşoluk, et al. (2011), indicated student circadian rhythms impact student academic success. This also points to the importance of taking into account student preferences for lab times to increase student satisfaction and retention.

The term engagement, used by Gilardi (2011), though not well defined, apparently was intended to be a catch all for behaviors such as student faculty, student peer interaction within and outside of the classroom and how they consumed (university) services as well as the student's degree of positive psychological linkages to the academic experience.

They and others, notably Falk 2010; and Choy 2002, chronicle the dearth of traditional 18-25 year old, unemployed, white students, and the concomitant rise in numbers of very diverse nontraditional students. Falk predicts that this will increase competition among universities for traditional students whose characteristics are well known, and thus easier to serve. This is leading to an upward mobility where students who normally would attend tier 2 schools are courted by and shift to the tier 1 universities. The effect will cascade downward as tier 2 universities actively poach tier 3 schools' targeted students, etc. It will be amplified by the nontraditional students' burgeoning recognition that they may receive higher levels of service for lower cost at a more prestigious school should educational institutions enter into a bidding war.

Increased use of university services, e.g. labs, as well as perceived social integration and the meaningfulness of the learning experience (elements which labs should enhance), reduced the likelihood that employed nontraditional students would leave without a degree (Gilardi).

Additionally, nontraditional students may come back to school with insufficient academic preparation (Choy). Students who works often have conflicts with class times (thus limiting access to labs).

There is a degradation in student ability to survive in math-intensive courses such as statistics. U.S. students' rankings in Program for International Student Assessment (PISA) math scores have declined from 2003 when compared to international scores (PISA 2003; '06; '09; 2012). In 2003, U.S. PISA scores were 483 (24^{th} in the world), falling to 474 (23^{rd}) in 2006, 487 (31^{st}), finally to 481 (37^{th} in the world) in 2012. This contributes to the United States' decline on the Global Competitiveness Index from the #2 ranking in 2009-10, to #5 in the world in 2011-12 (Global Competitiveness Report 2011).

When considered together, student time preferences, declining math capabilities, lack of readiness for higher academe, increases in both nontraditional students and the concomitant competition it brings, leads the authors to consider more student based preferences when developing lab schedules. Scheduling labs at hours which fit student schedules make it easier for students to cope with the work school social life conflicts as well as make it more likely that they will obtain much needed remedial aid. This will lead to higher rates of retention and greater student satisfaction.

DATA COLLECTION AND ANALYSIS:

The desired lab hours were collected from students of two statistics classes which were offered in the spring of 2014. Seventy four students (36 in section A and 38 in section B) responded in total in two sections. One

lecture class was offered on Mondays and Wednesdays from 1-2:30 pm and the other class was offered on Tuesdays and Thursdays from 11-12:20 pm. There were no statistics classes offered on Fridays.

The frequencies and weights (preferences) were collected from a desired statistics lab hour table.The desired stat lab hour table covered Monday through Friday as rows and 10 consecutive hours (except 12-1 pm) as columns starting from 8:00 am to7 pm. The table excluded lunch hour (12-1 pm) for the stat. lab assistant from Monday through Friday. The data collection table had 50 cells (of which eight cells covered statistics classes) and each student could mark only ten cells as there is a limitation of 10 hours of stat lab per week.

Each student wrote 10 numbers starting from 1 through 10 in any 10 cells out of the 42 cells (eight cells covering classes were excluded). The most preferred lab hour was marked as "10" and the least preferred lab hour was marked as "1." The numbers 1 through 10 indicated the least preferred lab hours to the most preferred lab hours.

Two tables were created for each section one based on frequencies (responses in cells Table 2 (section A) & Table 4 (section B)) and the other one based on weights (preferences Tables 1 (section A) & 3 (section B)). Table 2 had a total frequency of 359 (36 students each with 10 frequencies should have a total frequency of 360) because one student marked one frequency on Wednesday at 2-3 pm (class time) and it was not counted. Table 4 had a total frequency of 379, (38 students each with 10 frequencies should have a total frequency of 380), because one student did not mark one frequency.

Table 1		**BU 255 A**		**Weight**							
Hours	1	2	3	4	5	6	7	8	9	10	
Days	8-9 am	9-10 am	10-11 am	11-12 pm	1-2 pm	2-3 pm	3-4 pm	4-5 pm	5-6 pm	6-7 pm	Total
M	16	49	84	90	**BU255**	**BU255**	150	78	56	49	572
T	16	51	87	**BU255**	**BU255**	71	66	38	27	27	383
W	20	44	79	60	**BU255**	**BU255**	115	39	43	27	427
R	9	18	64	**BU255**	**BU255**	61	39	4	12	17	224
F	16	29	57	42	95	63	45	14	16	9	386
Total	77	191	371	192	95	195	415	173	154	129	1992

Table 2		**BU 255 A**		**Frequency**							
Hours	1	2	3	4	5	6	7	8	9	10	
Days	8-9am	9-10am	10-11am	11-12pm	1-2pm	2-3pm	3-4pm	4-5pm	5-6pm	6-7pm	Total
M	6	12	13	14	**BU255**	**BU255**	21	15	10	9	100
T	3	9	11	**BU255**	**BU255**	12	12	7	5	5	64
W	5	9	12	10	**BU255**	**BU255**	18	10	9	6	79
R	2	5	10	**BU255**	**BU255**	11	8	1	3	3	43
F	3	8	9	9	15	11	9	3	3	3	73
Total	19	43	55	33	15	34	68	36	30	26	359

Table 3		BU 255B		Weight							
Hours	1	2	3	4	5	6	7	8	9	10	
Days	8-9am	9-10am	10-11am	11-12pm	1-2pm	2-3pm	3-4pm	4-5pm	5-6pm	6-7pm	Total
M	45	56	118	37	**BU255**	**BU255**	83	32	26	54	451
T	58	63	69	**BU255**	**BU255**	99	86	44	46	52	517
W	41	49	109	40	**BU255**	**BU255**	78	44	24	52	437
TH	44	41	61	**BU255**	**BU255**	72	66	54	41	62	441
F	25	32	58	40	48	49	25	16	13	29	335
Total	213	241	415	117	48	220	338	190	150	249	2181

Table 3		BU 255B		Weight							
Hours	1	2	3	4	5	6	7	8	9	10	
Days	8-9am	9-10am	10-11am	11-12pm	1-2pm	2-3pm	3-4pm	4-5pm	5-6pm	6-7pm	Total
M	45	56	118	37	**BU255**	**BU255**	83	32	26	54	451
T	58	63	69	**BU255**	**BU255**	99	86	44	46	52	517
W	41	49	109	40	**BU255**	**BU255**	78	44	24	52	437
TH	44	41	61	**BU255**	**BU255**	72	66	54	41	62	441
F	25	32	58	40	48	49	25	16	13	29	335
Total	213	241	415	117	48	220	338	190	150	249	2181

Two further tables (Tables 5 and 6) were created by combining both classes one for total weights and the other for total frequencies.

Table 5		Weight	Combined A&B								
Hours	1	2	3	4	5	6	7	8	9	10	
Days	8-9am	9-10am	10-11am	11-12pm	1-2pm	2-3pm	3-4pm	4-5pm	5-6pm	6-7pm	Total
M	61	105	202	127	**BU255**	**BU255**	233	110	82	103	1023
T	74	114	156	**BU255**	**BU255**	170	152	82	73	79	900
W	61	93	188	100	**BU255**	**BU255**	193	83	67	79	864
R	53	59	125	**BU255**	**BU255**	133	105	58	53	79	665
F	41	61	115	82	143	112	70	30	29	38	721
Total	290	432	786	309	143	415	753	363	304	378	4173

Table 6	Frequency		Combined A&B								
Hours	1	2	3	4	5	6	7	8	9	10	
Days	8-9am	9-10am	10-11am	11-12pm	1-2pm	2-3pm	3-4pm	4-5pm	5-6pm	6-7pm	Total
M	15	21	29	19	BU255	BU255	33	23	15	18	173
T	15	19	21	BU255	BU255	25	24	17	15	15	151
W	14	19	28	16	BU255	BU255	29	18	14	15	153
R	12	14	19	BU255	BU255	19	18	12	11	13	118
F	11	15	20	17	24	18	14	7	8	9	143
Total	67	88	117	52	24	62	118	77	63	70	738

Three additional tables (Tables 7 through 9) were created- one for section A, one for section B, and one for both sections combined (A & B).

Table 7		**BU 255A (Class Time: MW 1-2:20 pm)**				
Days	Limit: 10 hours per week and 2 hours per day (Total Weights)	10 hours per week with 2 hours per day lab assignment time	10 hours per week but with weight (preference) distribution (Weights)	Corresponding time	Ranks (Highest weight corresponds to rank 1)	Weight based assignment of number of hours per day
M	150 90	3-4 pm 11-12 pm	150 90 84 78	3-4 pm 11-12 pm 10-11 am 4-5 pm	1 4 6 8	4
T	87 71	10-11 am 2-3 pm	87 71 66	10-11am 2-3 pm 3-4 pm	5 9 10	3
W	115 79	3-4 pm 10-11 am	115 79	3-4 pm 10-11 am	2 7	2
R	64 61	10-11 am 2-3 pm				0
F	95 63	1-2 pm 2-3 pm	95	1-2 pm	3	1
Total						10

Table 8		**BU 255B (Class Time: TR 11-12:20 pm)**				
Days	Limit: 10 hours per week and 2 hours per day (Total Weights)	10 hours per week with 2 hours per day lab assignment Time	10 hours per week but with weight (preference) distribution Weights	Corresponding time	Ranks (Highest weight corresponds to rank 1)	Weight based assignment of number of hours per day
M	118 83	10-11 am 3-4 pm	118 83	3-4 pm 4-5 pm	1 5	2
T	99 86	2-3 pm 3-4 pm	99 86 69	2-3 pm 10-11 am 10-11 am	3 4 8	3
W	109 78	10-11 am 3-4 pm	109 78	3-4 pm 10-11 am	2 6	2
R	72 66	2-3 pm 3-4 pm	72 66 62	10-11 am 2-3 pm 6-7 pm	7 9 10	3
F	58 49	10-11 am 2-3 pm				0
Total						10

Table 9		BU 255 A & B Combined (Weight based distribution)				
Days	Limit: 10 hours per week and 2 hours per day (Total Weights)	10 hours per week with 2 hours per day lab assignment time	10 hours per week but with weight (preference) distribution Weights	Corresponding time	Ranks (Highest weight corresponds to rank 1)	Weight based assignment of number of hours per day
M	233 202	3-4 pm 10-11 am	233 202 127	3-4 pm 10-11 am 11-12 pm	1 2 10	3
T	170 156	2-3 pm 10-11 am	170 156 152	2-3 pm 10-11 am 3-4 pm	5 6 7	3
W	193 188	3-4 pm 10-11 am	193 188	3- 4 pm 10 -11 am	3 4	2
R	133 125	2-3 pm 10-11 am	133	2-3 pm	9	1
F	143 115	1-2 pm 10-11 am	143	1-2 pm	8	1
Total						10

RESULTS:

BU255A Class:

Weight (preference measured in weights) based results:

Lab days demand based on preference was highest on Mondays followed by Wednesdays, Fridays, Tuesdays, and Thursdays. Most students most preferred lab hours were between 3-4 pm followed by 10 am-12 pm and 2-3 pm. The least preferred time was between 8-9 am followed by 1-2 pm. Overall, most students indicated their desired preferred lab hours were right after and before their statistics classes.

Frequency (number of students) based results:

Statistics lab days demand based on frequency was highest on Mondays followed by Wednesdays, Fridays, Tuesdays, and Thursdays. Most students wanted lab hours between 3-5 pm (after statistics classes) followed by 9 am-11 am (before statistics classes).The least chosen times were between 1 pm-2 pm and early morning (8 am -9 am) followed by 1-2 pm.

BU 255B Class:

Weight (preference) based results:

Lab days demand based on preference was highest on Tuesdays followed by Mondays, Thursdays, Wednesdays, and Fridays. Most students most preferred lab hours were between 10-11 am and 3-4 pm followed by 6-7 pm and 9 am-10 am. The least preferred times were between 1-2 pm and 11-12 pm followed by 5-6 pm. Overall, most students preferred their desired lab hours right before and after their statistics classes.

Frequency based results for BU 255B class:

Statistics lab days demand based on frequency was highest on Tuesdays followed by Thursdays, Wednesdays, Mondays, and Fridays. Most students wanted lab hours between 10-11 am (before classes) and 3-4 pm (after statistics classes) followed by 8 am-10 am (before statistics classes). The least preferred time based on frequencies (number of students) was between 11 am-3 pm (this duration includes the time when classes were offered).

BU 255 A&B Combined Classes:

Weight (preference) based results for both classes combined:

Lab days demand based on preference was highest on Mondays followed by Tuesdays, Wednesdays, Fridays, and Thursdays. Lab hours demand based on preference was highest during 10-11 am followed by 3-4 pm. The least preferred hours were between 1-2 pm followed by 8-9 am, 1-2 pm, and 5-6 pm. Overall, most students preferred lab hours were right before (9-11 am) and after (2-4 pm) their statistics classes.

Frequency based results for both classes combined:

Lab days demand based on frequencies was highest on Mondays followed by Wednesdays, Tuesdays, Fridays, and Thursdays. Most students wanted lab hours between 3-5 pm (after statistics classes) followed by 9 am-11 am (before statistics classes).The least preferred hours based on frequencies (least number of students) were between 11 am-2 pm followed by 8-9 am. The highest lab demand hours on Fridays were between 10 a.m. -2 p.m. and no statistics classes were offered on that day.

BU 255A: Decisions based limited lab hours per week:

Weight based decisions with a limit of ten statistics lab hours per week with even distribution of hours per day (2 hours per day) throughout the week (M through F) is presented in **Table 7**. The data indicated that the lab should have been offered one hour in the afternoon after class and one hour in the morning before class. Based on weights and without even distribution, the lab should be opened for 4 hours (2 hours in the morning and 2 hours in the afternoon) on Mondays, 3 hours (one hour in the morning and two hours in the afternoon) on Tuesdays, 2 hours (one hour in the morning and one hour in the afternoon) on Wednesdays, and one afternoon hour on Fridays with no lab hours on Thursdays.

Frequency counts also indicate somewhat similar pattern with regard to lab offerings. The lab should be offered between 3-5 pm on Mondays and Wednesdays; 2-4 pm on Tuesdays; and 10-11 am and 2-3 pm on Thursdays. On Fridays, the lab should be open between 1-3 pm.

BU 255B: Decisions based limited lab hours per week:

Decisions based on weights (preferences) having a limit of ten statistics lab hours per week with even distribution of hours per day throughout the week (M through F) is presented in **Table 8**. The data indicates that the lab should be offered one hour in the morning and one hour in the afternoon on Mondays, Wednesdays, and Fridays and two hours each in the afternoon of Tuesdays and Thursdays. The indicated lab hours were right before and right after the statistics classes. Based on weights and without even distribution, the lab should be opened for 2 hours in the afternoon on Mondays, 3 hours (two hours in the morning and one hour in the afternoon) on Tuesdays, 2 hours (one hour in the morning and one hour in the afternoon) on Wednesdays, and three hours (one hour in the morning and two hours in the afternoon) on Thursdays and no lab hours on Fridays.

BU 255 A&B combined (Decisions based limited lab hours per week):

Decisions based on weights having a limit of ten statistics lab hours per week with even distribution of hours per day (2hours per day) throughout the week (M through F) is presented in **Table 9**.The data indicated that the lab should be offered in the morning (before class between 10-11 am) as well as in the afternoon (after class between 2-3 pm on Mondays and Wednesdays or 2-3 pm on Tuesdays and Thursdays or 1-2 pm on Fridays).

Based on weights and without even distribution, the lab should be opened for 3 hours (two hours in the morning and one hour in the afternoon) on Mondays, 3 hours (one hour in the morning and two hours in the afternoon) on Tuesdays, 2 hours (one hour in the morning and one hour in the afternoon) on Wednesdays, and one afternoon hour on Thursdays and one afternoon hour lab hour on Fridays.

CONCLUSION:

The lab hours demand based on both frequencies and weights (preference) was highest on Mondays followed by Tuesdays, Wednesdays, and Fridays. Thursday's lab demand hours seemed to be lower than Fridays even though Thursdays offered statistics classes. The demand for lab hours was higher on Fridays relative to the demand on Thursdays and it appeared to be somewhat an exception. This exception could be because of homework assignments that would be due in the morning hours of the following Monday. Based on the data, it appeared that the desired lab hours were on highest demand right before and right after statistics classes. So the allocation of lab hours would be optimal if the lab hours were assigned right before and after statistics classes.

Further study: An optimal allocation of lab hours can be studied or tested by collecting data on both the desired and actual utilization of stat lab hours during the semester.

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