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Sexting Behavior and Social Media Addiction as Predictors of Depression Anxiety and Stress among University Undergraduates

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Abstract:
This study examined the predictive influence of sexting behavior and social media addiction on the severities of depression anxiety and stress among undergraduates in a selected Nigerian university. Using a cross sectional survey, the study sample comprised of 299 participants (160 male and 139 female) with a mean age of 21 years. Participants responded to Bergen Facebook Addiction Scale (BFAS), Depression Anxiety Stress Scale (DASS) and the Sexting Behavior Scale (SBS). Descriptive and inferential statistics were used for data analysis. 13.7% severe depression, 16.9% severe anxiety and 17.3% sever stress levels were reported. Factors of social media addiction (salience, tolerance, mood modification, relapse, withdrawal and conflict) jointly and significantly predicted depression (R2 = .113 p= .000); Anxiety (R2 = .105, p=.000); and stress (R2 = .095, p= .000) among undergraduates. Sexting behavior significantly predicted the severity of depression (R2 = .171, p= .000); anxiety (R2 = .197, p= .000); and stress (R2 = .201, p=.000). Results imply that there is a high incidence of depression, anxiety and stress among the undergraduates, and that sexting behavior and social media addiction are significant predictors of depression anxiety and stress among university undergraduates.

Keywords: Sexting, social media addiction, depression, anxiety, stress, undergraduates.

INTRODUCTION

Depression has been identified as a common occurrence in the adolescents and students (de Castro, et al., 2023; January, et al., 2018; Tung, et al., 2018; Amarasuriya, et al., 2015). Depression left untreated or treated inadequately may lead to increased distress or even death (Auerbach, et al., 2018). While anxiety is a normal and healthy emotion, however, when an individual regularly feels disproportionate levels of anxiety, it might become a medical disorder. The World Health Organization (WHO, 2017) estimates that there are about 322 million people living with depression around the world (James, et al., 2018). Prevalence rates for depression in Nigeria have been reported to be over seven million accounting for 3.9% of the total population (WHO, 2017).

Mental health is considered an essential aspect of human health and although the onset of depression may occur at any stage of life, the prevalence of major depression increases steadily during adolescence and young adulthood (WHO, 2015). Depression and anxiety in adolescents may be triggered by physical changes, hormonal changes, peer pressure and other factors (Oh, et al., 2023). Additionally, adolescents are at an age bracket for undergraduate schooling and this combination holds a risk for depression and anxiety as time in the university has been described as hectic given the many life-changing events taking place in a short time span and sometimes simultaneously (January et al., 2018). In the university, students experience many firsts, including

a new lifestyle, friends, roommates, new topics, exposure to a new culture and experiences and are in the midst of a major life transition. Consequently, students who are unable to cope with managing these "firsts" may struggle through the university and may be susceptible to developing depression and anxiety (Jenkins et al., 2020; Tung, et al., 2018). Excessive social media use among other factors has been identified as one of the specific causes of depression among undergraduates (Asibong et al., 2020; Vidal et al., 2020). Pedrelli, et al., (2015) assert that college students present a unique vulnerability to depression as mental illness often appears amid the transition from childhood to adulthood.

Studies reveal high prevalence of social media addiction among university undergraduates (Salari, 2023) and that the addiction is linked to poor mental health (Sujarwoto et al., 2023; Cain, 2018; Berryman et al., 2018; Kircaburun et al., 2018). The general public's use of social media has increased across practically all cohorts of the human life course (Kemp, 2020), although younger people have been disproportionately impacted (Elhai et al., 2020; Stieger et al., 2020). Most current university undergraduates belong to "Generation Z", which is described as the group born after 1996. Having grown up in the era of digital technology, this group are referred to as "digital natives" due to their early exposure to the internet and social media at a young age, further compounded by increased internet usage for educational and other purposes necessitated by the COVID-19 epidemic (Gómez-Galán et al., 2020). Taken together, these factors may expose learners to a variety of experiences, both positive and harmful.

The results of earlier research on the relationship between social media use and mental health among university students have been consistent. Studies have demonstrated the detrimental effects of excessive screen time on mental health (Rajkumar, 2020; Twenge et al., 2020). Using social media during the COVID-19 epidemic was associated with depression and secondary trauma in Chinese citizens (Zhong et al., 2021). Social media use and psychological distress are also related (Huckins et al., 2020; Sundarasen et al., 2020). Social media use was found to have a negative correlation with depression (Zhao, 2020). Also, in research on American university students, social media use was found to increase stress (Pahayahay & Khalili-Mahani 2020). In a systematic review of eleven studies measuring social media use and depressive symptoms in children and adolescents, McCrae, et al., (2017) report a trend of statistically significant relationship between excessive social media use and depression across several studies. With an estimate of over 3.2 billion social media users worldwide, and a steady increase in average daily social media use (Emarsys, 2019; Chaffey, 2019) and the millenials (the generation considered to have the broadest access to technology) rank highest in social media usage (Emarketer, 2019; Gafni & Geri, 2013), it is important to examine associate factors in this cohort in order to protect and enhance their mental health and general well-being.

Sexting, the act of sending, receiving, or forwarding sexually explicit messages, photographs, or images, primarily between mobile phones, computer or other digital devices of oneself to others (Gámez-Guadix et al., 2017; Klettke, et al., 2014) has been associated with social media use and addiction (Maheux, et al., 2020). There is however no generally agreed definition of sexting in the scientific community. Thus, while some authors describe it as sending of any kind of sexual image-based only content, (Barrense-Dias et al., 2017) others affirm the inclusion of coercion as a vital part of sexting behaviour (Englander, 2012). Yet others opine that sexting is voluntary (Gámez-Guadix et al., 2015). Some definitions include sending text messages with sexual contents that have no images (Morelli et al., 2016), while other definitions exclude them (Silva et al., 2016). There is a growing body of research on the negative effects of sexting behaviour on the mental

health of adolescents (Brenick et al., 2017; Kosenko et al., 2017). Mori, et al., (2019) has stated that sexting behaviors were significantly associated with internalizing problems, such as anxiety and depression and that, younger adolescents who sext reported stronger symptoms of depression and anxiety. There is a knowledge gap on the interaction between social media addiction, sexting behaviour and internalizing problems among Nigerian young people. This current study, therefore, aims to assess this interaction thus contribute to bridging the knowledge gap. We thus hypothesize that factors of social media addiction will jointly and significantly predict the severities of depression anxiety and stress. Also, that sexting behaviour will significantly predict the severities of depression anxiety and stress among undergraduates.

MATERIALS AND METHOD

Adopting the multistage sampling technique, 299 undergraduates were recruited across several faculties at a private University in Osun state, Nigeria. Questionnaires were administered directly to respondents.

Research Instrument

Three standardized research instruments; Bergen Facebook Addiction Scale (BFAS) (Andreassen, et al., 2012), Depression Anxiety Stress Scale (DASS) (Lovibond & Lovibond, 1995), and the Sexting Behavior Scale (SBS) (Dir, et al., 2013).

The BFAS is concerned with assessing respondents' experiences during the past one year related to Facebook use. It specifically measures six symptoms of addiction: salience, mood modification, tolerance, withdrawal, conflict, and relapse. The scale is an 18-item instrument, with a 5-point Likert response scale from 1=very rarely, 2 = rarely, 3=sometimes, 4= often, 5=very often. Total score ranges from 6 to 30 with higher scores reflecting higher addiction levels. The BFAS possesses acceptable psychometric properties for Nigerian population (Akpunne, et al., 2020).

The Depression Anxiety Stress Scale (DASS) is a self-report 42-item questionnaire, with 3 subscales measuring the negative emotional states of depression, anxiety and stress. Each subscale consists of 14 items. The subscales of the DASS have been shown to have high internal consistency, with reliability coefficients ranging from 0.71 to 0.81 and to yield meaningful discriminations in a variety of settings (Brown et al. 1997; Anthony et al. 1998; Crawford & Henry 2003). Exploratory and confirmatory factor analyses have also consistently sustained the proposition of three subscales.

The Sexting Behaviour Scale (SBS) (Dir et al., 2013) assesses the frequency and prevalence of the following sexting behaviors: receiving sexts; sending sexts; and content of messages (i.e., pictures or sexually suggestive content). There are also items assessing other behaviors, such as using social networking sites to exchange messages or publicly post sexually suggestive content. The scale consists of 11 items with responses based on a 5-point Likert scale from 1 (never) to 5 (frequently or daily) and has good internal consistency (α = .883). The internal reliability of the SBS for the study sample was .893. Sexting frequency is expressed as the mean score of the SBS

RESULTS

Socio-Demographic Data of Respondents

The sample of the present study comprised of 160 (56.7%) male and 139 (46.3%) female undergraduates of whom over half (62. 3%) were aged between 19 and 22 years. (Table 1).

Table 1: Socio-demographic characteristics of participants

Variables		**Frequency**	**Percentage**
Gender	Male	160	53.7
	Female	139	46.3
	Total	299	100.0
Age categories	15-18	62	21.4
	19-22 years	180	62.3
	23 – 28 years	57	16.3
	Total	299	100
Education level	100 level	58	18.3
	200 level	77	26.1
	300 level	88	29.8
	400 level	76	25.8
	Total	299	100

About a third of respondents (33.8%) reported mild anxiety and depression (30.3%) levels. Table 2 reveals the patterns of depression anxiety and stress among respondents for the present study.

Table 2: Patterns of Depression, Anxiety and Stress among respondents

Variables	**Prevalence**		
	Mild %	**Moderate %**	**Severe %**
Depression	20.4	29.5	15.7
Anxiety	33.8	27.8	16.9
Stress	30.3	29.2	17.3

A multiple regression analysis was conducted to investigate the joint effect of social media addiction on the severities of psychopathological symptoms (Depression, Anxiety and stress) in the present cohort. Factors of social media addiction (salience, Tolerance, Mood Modification, Relapse, Withdrawal and conflict) jointly and significantly predicted depression (R^2 = .113, F (5, 299) = 5.497, *p*= .000; Anxiety (R^2 = .105, F (5, 299) = 5.143, *p*=.000; and stress (R^2 = .095, F (5, 299) = 4.603, *p*= .000. (Table 3)

Table 3: Multiple Regression Analysis Showing the Influence of social media addiction on severities of depression, anxiety and stress.

							N = 299		
	Depression			**Anxiety**			**Stress**		
Variables	**β**	**T**	**Sig.**	**β**	**T**	**Sig.**	**β**	**t**	**Sig.**
Salience	-.036	-.379	.705	-.013	-.138	.890	.068	.693	.489
Tolerance	-.050	-.479	.633	-.101	-.979	.328	-.083	-.810	.419
Mood Modification	.146	1.913	.057	.122	1.587	.114	.198	2.627	.009
Relapse	-.078	-.821	.412	-.058	-.626	.532	-.086	-.920	.359
Withdrawal	.097	.984	.326	.246	2.532	.012	.133	1.361	.175
Conflict	.271	3.121	.002	.125	1.451	.148	.105	1.196	.233
R		.34			.234			.308	
R^2		.113			.105			.095	
F –ratio		5.497			5.143			4.603	
P		.000			.000			.000	

The model further reveals that 11.3%, 10.5% and 9.5% of variance observed in severities of depression, anxiety and stress respectively, is explained by the factors of social media addiction (salience, tolerance, mood modification, relapse, withdrawal and conflict) in the present cohort.

A second multiple regressions were conducted to test the second hypothesis that sexting behaviour will jointly significantly predict the severities of depression, anxiety and stress among respondents. Results reveal that sexting behavior significantly predicted the severity of depression (R^2 = .171, F (5, 299) = 56.798, *p*= .000; anxiety (R^2 = .197, F (5, 299) = 68.219, *p*= .000; and stress (R^2 = .201, F (5, 299) = 70.091, *p*=.000 (Table 4). The model further reveals that 17.1%, 19.7% and 20.1% of variance observed in depression, anxiety and stress respectively is explained by sexting behavior among the undergraduates. This hypothesis is therefore accepted.

Table 4: Regression Analysis Showing the Influence of sexting behavior on depression, anxiety and stress

							N = 299		
	Depression			**Anxiety**			**Stress**		
Variables	**β**	**T**	**Sig.**	**β**	**T**	**Sig.**	**β**	**t**	**Sig.**
Constant		30.99	.000		1.25	.21		2.11	.03
Sexting Behavior	.41	7.53	.000	.44	8.26	.00	.44	8.37	.00
R		.41			.44			.44	
R^2		.17			.19			.20	
F –ratio		56.78			68.29			70.09	
P		.00			.00			.00	

DISCUSSIONS

The present study aimed to determine the extent to which social media addiction is related to depression and anxiety among university undergraduates in Osun State, Nigeria. In agreement with previous studies a high prevalence of social media addiction was reported in this study (Salari, 2023; Kemp, 2020; Akpunne & Ajirotutu, 2018). This result mirrors that of Li, et al., (2018) in a study of the relationship between online social networking addiction and depression. They found a bidirectional association between online social networking and depression among adolescents as depression significantly contributed to the development of social network addiction with depressed individuals experiencing more deleterious effect from addictive online social networking use. In a Chinese study, Hussain, et al (2020) performed a systematic review investigating social network use disorder and its association with depression and anxiety. The review established a pattern of association between social network use disorder, depression and anxiety. Also, in a related Nigerian study Akpunne and Akinnawo (2019) reported that problematic smartphone uses strongly predicted the severities of anxiety depression and psychological distress among selected Nigerian university undergraduates. The effects of excessive internet use on mental health have also been reported in literature (Rajkumar, 2020; Twenge et al., 2020). For instance, among Chinese population, social media use was associated with depression and secondary trauma (Zhong et al., 2021). Also, according to Pahayahay and Khalili-Mahani (2020) social media use was reported to increase stress among American university students as well as poor mental health among Spanish university students (Gómez-Galán et al., 2020). Again, social media use was reported as strong correlate of psychological distress (Huckins et al., 2020; Sundarasen et al., 2020; Zhao, 2020).

Sexting behavior was equally found to significantly predict the severity of depression, anxiety and stress among participants. This result is consistent with those obtained from other studies with larger samples. In a national telephone survey of American youths who were internet users (Mitchell, et al., 2012), a quarter of the respondents reported feelings of embarrassment and anxiety at receiving sexually explicit images. In a similar study, Ybarra & Mitchell (2014) found more frequent occurrence of psychosocial problems in teens who reported sexting regularly. Studies also show that symptoms of some internalizing problems might be linked to sexting depending on the response received from the sext. For instance, Borgogna et al., (2023) affirmed that individuals who sext but got no response reported more depression, anxiety and insomnia compared when compared with other groups. Research finding have also revealed that increase in depressive symptoms are associated with greater use of the internet (Holoyda et al., 2018). Furthermore, the more frequent the problematic internet use, the higher the prevalence of sexting behaviour (Medrano et al., 2018). Similarly, Gámez-Guadix and De Santisteban (2018) in a study among Spanish adolescents established that a higher degree of depressive symptoms predicted a higher degree of sexting behaviors. Studies show positive relationships between sexting behaviour and anxiety symptoms. For instance, Chaudhary et al., (2017) reported that young people who engaged in sexting reported more symptoms of anxiety than those who did not. Also, Cooper et al. (2016) found that sexting victimization was linked with negative psychological outcomes, such as anger, feelings of sadness, and anxiety disorders. Adolescents who received unwanted sext or were coerced to sext reported poor mental health, and those who received or sent unwanted but consensual sext reported higher severity of anxiety, stress, and depression and had lower self-esteem (Klettke et al., 2019). Also sexting behaviour is linked to suicidal behaviour (Medrano et al., 2018).

The present study has certain limitations such as the sampling technique adopted and a relatively small sample size may make it difficult to generalize our findings. It is recommended that future studies adopt other research enquiry methods in assessing the varied effects of social media use and addiction. Despite these limitations, the findings of the present study provide a framework that can prove useful to health professionals and policy makers in designing mental health initiatives for technology use in adolescents.

CONCLUSION AND RECOMMENDATIONS

From the findings, it can be concluded that social media addiction and sexting behavior are strong predictors of depression, anxiety and stress among university undergraduates. Further studies to aid identification of individual students with severe levels of depression, anxiety and stress resulting from involvement in social media addiction and sexting is recommended. Upon such identification, appropriate psychotherapeutic interventions would prove very helpful.

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Gender Bias in Educational Material and Teaching Practices in Schools: A Case Study of Public Secondary Schools in Iganga District

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Abstract:
This study investigated gender bias in educational materials and teaching practices in a case study of public secondary schools in the Iganga district and objectively focused on; examining the indicators of gender bias in the preparation of educational materials and content delivery, identifying factors contributing to gender bias in educational programs, and examining the functional attempts made to eliminate gender bias to enhance teaching practices. Qualitative Oral-narrative results from teachers were obtained and reported in story form, while results from headteachers were obtained and reported verbatim. Findings indicated that there were several indicators of gender bias in the public secondary schools in Iganga District. This was reflected in leadership, where female headteachers were scarce, with only two schools having female principals. Besides, the internal administrative responsibilities were biased against females, as heads of disciplinary committees were predominantly male teachers, as were directors of studies and other positions. The causes for these, as per the findings, were: the perception that some jobs were best performed and suited for females; the flexibility aspect, as men were found to be so tough and rigid; and the favouritism aspect. Functional mechanisms for reducing gender biases in public secondary schools included, among other things, posting anti-gender bias messages on classroom and office walls, balancing responsibilities, and suggestion boxes. Conclusively, in almost all public secondary schools in Iganga District, there is no female head of the disciplinary committee an indicator of gender bias in the assignment of disciplinary committee responsibilities. Many female teachers are denied certain responsibilities because they are either married or unable to attend to their responsibilities at certain times of the day. The major recommendation is that every teacher should be required to ensure that gender-sensitive messages are disseminated and posted on walls and in appropriate places.

Keywords: Educational Materials, Iganga District, Gender Bias, content delivery, public secondary schools

BACKGROUND OF THE STUDY

According to UNESCO, gender equality needs to be taken into consideration across the educational system in terms of access, content, teaching and learning environment and methods, learning outcomes, and chances for life and work. UNESCO indicates that despite significant improvements, there are still significant gender differences in schooling across a variety of contexts, most frequently harming girls, but in some areas, boys also face disadvantages. Worldwide, 125.5 million boys and 118.5 million girls do not attend school. Nearly two-thirds of all adults who cannot read are still women (UNESCO, 2021).

The duty of developing action plans to address the ongoing inequities between male and female academics and administrators at all levels has been given to educational leaders in Europe. Because universities, like any other institution, continue to distinguish between male and female in terms of "advantage and disadvantage, exploitation and control, action and emotion, meaning, and identity," they remain gendered (Eileen, 2020).

In secondary schools in Malaysia, Indonesia, Pakistan, and Bangladesh, a quantitative content analysis was carried out to identify gender stereotypes in educational settings. The combined female share in textual and pictorial indicators is 40.4%, which suggests a pro-male bias in textbook findings. Only 35.2% of picture content in Malaysia and Bangladesh is female, according to a cross-country analysis. In Malaysia and Indonesia, the ratio of female to male characters is roughly equal (44.4% and 44.1%, respectively), whereas this percentage is only 24.4% and 37.3%, respectively, in textbooks from Pakistan and Bangladesh (Kazi, et al., 2018).

It is commonly assumed that investing in the education of women would have positive social and economic effects (Moyo et al., 2020). It is not unexpected that gender imbalance in school enrolment has declined over the past several decades in many developing nations given the evidence of the social and private advantages of female education, as well as many international accords and national efforts. Between 1970 and 2009, the average number of years that women spent in school rose from 2.2 to 7.2 in developing nations (Moyo & Perumal, 2020).

Further studies looked at current gender-sensitive education toolkits for instructors in low- and middle-income countries to identify recurring themes crucial for secondary school teachers working in the Eritrean environment. Findings suggest that the teacher should pay particular attention to the following: involving students in learning, creating a gender-sensitive classroom, using language and teaching materials, health and maturity issues, and involving parents and the community to promote gender sensitivity (Korenius, 2015).

According to Dennis et al. (2018), the policies and educational cultures of Botswana, Lesotho, Namibia, South Africa, and Swaziland prioritize discourses that marginalize, suppress, and obscure gender and sexual minorities. The researchers contend that a genuine engagement with the pervasive reality of heterosexist exclusion and marginalization is necessary if educational institutions in the region are to incorporate all learners.

There are still limited instances of coeducational interventions inside the educational system, according to Mara et al.'s 2020 report on Uganda. The study also shows how access has been the major focus of coeducational treatments and how some types of sexism still exist in classrooms due to concealed curricula. As a result, the study highlights the need for legislative change based on coeducational interventions as well as specialized teacher preparation for gender and equality (María, et al., 2020).

Aim of the Study

The study was set to investigate gender bias in educational materials and teaching practices in a case study of public secondary schools in the Iganga district.

Objectives

a) To examine the indicators of gender bias in the preparation of educational materials and content delivery in public secondary schools in the Iganga District

b) To identify factors contributing to gender bias in educational programmes
c) To examine the functional attempts put across to eliminate gender bias to enhance teaching practices in public secondary schools in Iganga District

Theoretical Review

Bonnie G. Smith claims that gender theory, which was created by women in the 19th century, served as the study's guiding principle. The main argument is that gender roles should be viewed by society as a collection of traits that men and women have jointly developed to influence one another's lives. It discredits the notion that a woman is not formed but rather is born (Bonnie, 2000). The study is informed by the idea because it emphasizes the need for society to stop seeing men and women or males and females as distinct groups based on artificial distinctions. The purpose of this study, which was designed to outline many ways stakeholders might contribute to addressing the issue of gender prejudice in educational institutions, particularly secondary schools, is to examine how gender theory fits in the margins.

LITERATURE REVIEW

By research objectives, the literature cites studies on gender discrepancies conducted by various academics. The most recent citations were used in the scholarly publications from which the literature was gathered.

Gender Bias in Educational Materials and Content Delivery; Indicative Tales

Tony, et al. (2022) studied school leadership and gender in Africa and found that little new information is being produced on this crucial subject, and sources in the majority of African nations were not found. African women principals are demonstrated to be more collaborative and collegial than men. As a result, there is a critical need for ministries of education to review their recruitment and selection practices to address barriers that prevent women from becoming school principals. Roper (2019) contends that gender bias in sciences and medicine is pervasive and persistent in today's faculty and students, even though the majority of faculty and scientists believe they are fair and unbiased. This is contrary to numerous well-designed studies that have been published in prestigious peer-reviewed journals. According to recent studies, discrimination against women negatively impacts wages, tenure, respect, professional employment, grant application success, and student grades.

The recruitment, progression, and promotion of women in academia continue to be low despite tremendous advances in recent decades. Women make up a significant share of the academic talent pool and acquire more than half of all PhDs, yet they are still underrepresented in teaching and leadership roles (Mitchelle, et al., 2020). In their systematic study of gender inequalities and the factors that contribute to success and failure in math and scientific contests, Anneke et al. (2019) provide some important findings. Results show that gender stereotypes play a significant role in the mechanisms causing low female participation rates in mathematics and science competitions and beyond, particularly in physics and chemistry. These mechanisms are influenced by gender stereotypes' effects on self-concept and interest (Charles, M., & Khan, B. M., 2022).

In general, biology classes seem to draw more female students, whereas physics classes are likely to draw more male students. Between educational levels, from secondary to tertiary education and higher levels like doctoral studies, gender involvement also varies. For instance, women

receive just 27% of bachelor's degrees in Europe and 18% of all bachelor's degrees in the United States in tertiary physics education (Fan, et al., 2017).

Modern Indian education has been started following the British education system after the fourth decade of the 18th century. According to the conventional concept, boys make more noise than girls in the classroom. The seating arrangement of primary school is divided into two rows, one side is allotted for boys and the other side is for girls. It creates a division among the children without the awareness of gender (Sudeep, 2022). According to Zhuofei (2021), gender inequality in K–12 education has five key expressions and causes: instructional materials, teacher attitudes, educational opportunities, traditional family conceptions, and family investments in education. The researcher mainly discovers that: 1) K12 textbooks display gender discrimination through illustrations and contents; 2) In K12 education, teachers' unbalanced care and stereotypes towards male and female students also lead to gender discrimination in classes; and 3) The concept of son preference and discrimination against women in the workplace will push families to become more inclined to provide men with more educational resources.

Contributive Factors to Gender Bias in Educational Programmes

The lack of progress toward gender parity, pervasive gender stereotypes that cause hiring discrimination and fewer opportunities for women to advance in their careers, a lack of social capital (such as support networks) (Charles, M., Kuteesa, M. D., et al, 2023 which limits women's opportunities to obtain tenure and learn about grant funding mechanisms, and the perception that their academic environment is unwelcoming all contribute to the low number of women in science, technology, engineering, and mathematics (STEM) faculty positions (Bettinah, et al., 2020). At various stages of their professions, research shows that women experience a variety of "chutes" that prevent them from advancing in their education. These include unconscious prejudice in choices about teaching evaluations and grant funding, the belief that women are less competent and produce work of inferior quality, and lower rates of citation (Mitchelle, et al., 2020).

Another study looked at how gender bias in attitudes and outcomes, such as anxiety, pleasure, self-confidence, and self-efficacy, were affected by the extensive use of computers in schools. The findings indicate that boys are preferred in computer anxiety, self-confidence, and self-efficacy despite intense computer use; however, there are no differences in computer enjoyment. There is no proof that frequent computer use lessens gender inequalities in these results (Roser & Xavier, 2018). Women still have less access to education than men do everywhere in the world. 1 in 4 young women ages 15 to 24 will not complete elementary school. 58% of those who don't finish that basic education belong to that group. Two-thirds of all illiterate people on Earth are female. Girls' futures and the opportunities they will have been significantly impacted when they receive an education that is below that of boys (Kenneth, 2022).

Women suffer the most when religious freedom is violated. According to the World Economic Forum, gender inequality worsens when extremist ideologies (like ISIS) invade a community and impose restrictions on the right to practice one's religion. Researchers from Georgetown University and Brigham Young University were also successful in establishing a link between religious intolerance and women's capacity to participate in the economy. The participation of women makes an economy more stable when there is greater religious freedom (Geordan, Melanie, & Kate, 2019). Many women worldwide lack control over either their bodies or having children. It's frequently incredibly tough to get birth control. The World Health Organization

estimates that more than 200 million women who don't want to become pregnant don't use contraception. There are several causes for this, including a dearth of choices, restricted access, and cultural and religious hostility. Globally, 40% of pregnancies are unplanned, and while 38% of them end in births, 50% of them do result in abortions. These moms frequently lose their independence and turn to the state or another individual for financial support (Hayde, Margaret, & Gary, 2020).

The division of labour is one of the factors that contribute to gender inequality in the workplace. Most societies have an ingrained notion that men are just more capable of handling particular tasks. These are frequently the positions with the highest salaries. Women experience lower income as a result of this discrimination (Charles, M., Kuteesa, M. D., et al, 2023). Women also shoulder the majority of the responsibility for unpaid labour, so despite their participation in the paid workforce, they perform extra tasks that are never compensated financially (Eileen, 2020). The general mentality of a society has a big impact on gender inequality, even though it is less obvious than some of the other reasons on this list. Every area, including employment, the legal system, and healthcare, is heavily influenced by how society views the distinctions and relative worth of men and women. Although laws and structural changes can advance equality, there is frequent pushback after major changes because gender beliefs run deep. (Charles, M., & Khan, B. M., 2022). When there has been progress, such as greater representation of women in leadership positions, it is also typical for both men and women to ignore other instances of gender inequality (Bettinah, et al., 2020).

Functional Attempts to Eliminate Gender Bias to Enhance Teaching Practices

From 2016 to 2017, the UN Women Egypt Country Office (ECO) initiated a campaign in Greater Cairo, Minia, Luxor, Aswan, and the Red Sea to reduce the gender gap in education, both in formal and informal settings. The program sought to: enhance the quality of formal educational institutions and community mechanisms to support young women's and girls' education; conduct needs analyses to identify and address the main barriers to girls' access to safe education; bring together the business community and educational policymakers to better link education to employment needs; and advocate for addressing the root causes of gender-based discrimination by expanding community (UN, 2022). Girls have less access to education and fewer opportunities than boys, even though education is a proven catalyst for gender equality and sustainable development (Wikigender, 2017). A sexist teaching built on a false and disguised curriculum perpetuates outdated notions and assumptions about female roles. Women thus have a higher likelihood of experiencing precarity and unemployment throughout their lifetimes. This, together with the daily gender-based abuse that girls experience, generates new and ongoing mental health difficulties that are not taken seriously by their teachers or schools (Plan International UK, 2020).

Despite hearing messages of empowerment at school, girls face a threatening reality when they are unable to reach their full potential. To make sure that students comprehend any subject, teachers must first reflect on their classroom procedures and the intentions, goals, and values that direct them (Charles, M., Kuteesa, M. D., et al, 2023). Then, teachers should think about how they interact with students because teachers need to avoid giving students expectations that are solely based on gender or sex roles (Kisha, 2020). The UNESCO Institute for Statistics (UIS) is disaggregating all sex-related indicators to the greatest extent feasible to assist nations in their efforts to carry out and live up to their pledge that they would have closed the gender gap by

2030. The UIS also creates gender parity indices and is working to create new indicators that will better represent, include, and treat both boys and girls equally (UNESCO, 2022).

The 2030 Education Framework for Action, which is part of the organization, aims to "Ensure equitable and inclusive education of quality and to Promote Lifelong Educational Opportunities for everyone." To achieve gender equality, SDG-5 of UNESCO calls for the empowerment of all girls and women (UNESCO, 2022). The most significant barriers that prevent girls and women from exercising their legal right to receive and complete their education and benefit to the fullest extent are geographical isolation, poverty, minority status, early marriage and pregnancy, disability, gender-related violence, and traditionally developed attitudes regarding the role and status of women (Andrews, 2019).

Numerous environments offer learning opportunities and the chance to continue one's education, typically at the expense of women and girls, while there are also places where boys and men face disadvantages. Despite significant advancements, more than 17 million girls will never be able to enter a classroom or a school, and generally, females continue to drop out of school at a higher rate than boys (Siqueira, 2021).

Fissures Leading to the Study

The recruitment, progression, and promotion of women in academia continue to be low despite tremendous advances in recent decades. African women principals are demonstrated to be more collaborative and collegial than men. There is a critical need for ministries of education to review their recruitment and selection practices. Gender bias in attitudes and outcomes, such as anxiety, pleasure, self-confidence, and self-efficacy, were affected by the extensive use of computers in schools. There is no proof that frequent computer use lessens gender inequalities in these results. Girls are underrepresented in science, technology, engineering, and mathematics faculty positions. Girls have less access to education and fewer opportunities than boys, even though education is a proven catalyst for gender equality and sustainable development. The UNESCO Institute for Statistics (UIS) is disaggregating all sex-related indicators to assist nations in their efforts to close the gender gap.

The prior literature helps provide insights into numerous gender-related issues that improve knowledge of the study's specific objectives. However, there is still a paucity of knowledge on the signs of gender differences, the causes of them, and the practical measures taken to address them. Additionally, the study was carried out at Iganga District public secondary schools, which have various administrative and geographic structures. Therefore, until this study was conducted, no literature applicable to governments outside of Africa or other nations could be extrapolated to the study region.

METHODOLOGY

Research Design

The researcher used a primarily qualitative data collection and analysis technique in this study. The qualitative technique was used to explore the emotions and sentiments of the teachers regarding commitment to policy and students' welfare in public secondary schools.

Study Population

The study was conducted in the Iganga district with 200 participants, including 128 students, 64 teachers, and 8 head teachers. These were carefully chosen among eight (8) public secondary

schools, including Bukoyo Secondary School, St. Paul Nasuuti Secondary School, Nkuutu Memorial Secondary School, Iganga Secondary School, Iganga High School, Nakigo Secondary School, and Makuutu Seed School.

Data Presentation and Analysis

Explanatory data were presented in the form of paraphrased statements and verbatim responses from the key respondents and other respondents. The results did not in any way include the numerical findings. The findings were not rated numerically, but rather by emphasizing them verbatim.

FINDINGS OF THE STUDY

This section aids in understanding the findings obtained from the respondents in public secondary schools in Iganga District. The arrangement is the gender of respondents; results concerning indicators of gender bias in educational materials and content delivery; factors contributing to gender bias; and functional approaches to curbing gender partialities.

Gender of Respondents

According to findings, teachers in the public secondary schools in the Iganga District are mostly males. This may have influenced the findings in such a way that female teachers' perspectives were underrepresented. Most of the secondary schools did not have representation from female teachers, which specifically justifies why such a study as this is a step in the right direction.

Results for the Indicators of Gender Bias in Preparation of Educational Materials and Content Delivery in Public Secondary Schools in Iganga District

One of the identified causes of gender bias on the side of students is dropout. Findings revealed that from senior one to senior four, and in some other three schools up to senior six, the minimum number of streams per class is three. However, observations indicated that as students advanced in classes, their numbers reduced, and this reduction was mostly on the female side.

The attendance rate, just like enrollment, helps establish how gender performs in terms of regular school attendance. The attendance of students in the Iganga District about gender varied with class. According to the findings, school attendance at the senior level is usually regular and higher for female students. However, though in many schools' females are the majority, the trend changes such that, with time, the number of students attending is more frequent for males than for females. On this subject, the principal of School B was quoted as saying: *When students reach grade three, significant differences in attendance begin to emerge, with boys putting in more effort to attend schools with fewer students enrolled. After secondary school, the gap widens so much that few girls are likely to advance to senior four or senior six…*

In terms of gender sensitivity and content delivery, results indicated that in designing schemes of work, School A scored highly in responding to gender issues, followed by School B. However, generally, gender sensitivity in preparation and content delivery is still low. On the other hand, there was much attention given to lesson planning in secondary schools, where headteachers could not discriminate against teachers based on gender when demanding lesson plans. Asked whether gender sensitivity is considered in content delivery, the headteacher of school B had this to say: *At this school, we believe that the food for thought for every stakeholder is to see that students receive adequate materials in the teaching-learning process. Fortunately, there is no*

discrimination when it comes to this kind of responsibility. I must make sure that regardless of whether one is a male or female teacher, there are lesson plans made.

There are also concerns about the issue of the head and deputy head teacher, whereby it was indicated that in many secondary schools except school B, which is Iganga Girls Secondary School, it is rare to find a female headteacher. Equally, there are always two or three deputies in public secondary schools. However, it is also not common to find a female headteacher or female deputy headteacher, which also reflects gaps as far as gender equality is concerned. Asked about the comment about gender sensitivity in secondary school administration, the headteacher of School B stated: *Well, you find that as bad as gender bias is in schools, this one is particularly different. It is good to always have a female headteacher because it is a single-sex school, and I hardly think that a male headteacher can understand the concerns of a female student. Besides, I am truly convinced that it will be a little difficult for a female student to freely share concerns about her private life with a male school leader. This is where the gender issue requires much more attention while discussing it…*

Furthermore, findings revealed that there is gender bias in the assignment of disciplinary committee responsibilities. In other words, the study results indicate that in almost all public secondary schools in Iganga District, there is no female head of the disciplinary committee, yet each secondary school comprises teachers of each gender. One of the comments made by the principal of School D was: *Let us now discuss something to which you rarely pay attention. Have you seen many secondary schools appointing female teachers to lead the school's disciplinary committee? In most cases, the people in charge of discipline are deputies in charge of administration. However, besides these, there is always space for another administrator. Unfortunately, female teachers are not given priority.*

The other issue was about the spaces for convenience. Under normal circumstances, it is good to have separate toilets or latrines with clear labels on structures. However, from the findings, it was indicated that even with the labels, you may find males continuing to go and use latrines or toilets meant to be used by female teachers.

Results for Factors Contributing to Gender Bias in Educational Programmes in Public Secondary Schools in Iganga District

Observation has shown that the adolescence stage affects female students more than their male counterparts. This is because in many schools, the enrollment rate is normally high for both male and female learners, but numbers keep reducing with cases of pregnancy among female students in the different schools. In the words of one of the head teachers, it was indicated as follows: *…However, as students advance to higher classes, the number of streams reduces from three to two and even to one. This signifies an unsteady retention rate for students and mind you many of the drop-outs are female students, who as they cross over to upper primary, many of them drop out due to adolescence-related consequences.*

In terms of allocating responsibilities, gender bias comes sin when it comes to specific responsibilities. When it comes to catering for female students in dormitories, the matron is needed. However, at the staff, there is a need to have a senior woman teacher. Here the cause for gender bias is that the responsibility is directed to female students, not their male counterparts. In response to some of the reasons why gender bias exists in schools, the head teacher of school D indicated: *The most obvious is the nature of the responsibility to which one has been assigned.*

When we want to appoint a senior official to be in charge of female students, we can appoint John or Moses; even parents can sue us. We need to appoint a lady who can reach out to the dormitories and make sure everything is in order. The reason men are disadvantaged in this way is that they have their weaknesses, which, I think are natural when they get close to the opposite sex, and vice versa…

More results reveal that on many occasions, male teachers take on certain decisions that their female counterparts cannot equally take on. For instance, when it comes to disciplining students, findings revealed that many female teachers tend to be soft while male teachers are always tough and command the attention of the students when they say something. It is for this reason that when it comes to appointing leaders of the disciplinary committee, it is always male teachers taking on the responsibility.

On the other hand, findings revealed that many female teachers are denied certain responsibilities because they are either married or unable to attend to their responsibilities at certain times of the day. Results revealed that if, for instance, a female teacher is married, it is not easy to call her for a commitment at 5.00 p.m. Such a person, as the findings indicate, will be busy with domestic chores. Asked about why gender bias predominates in most school responsibilities, the headteacher at school D had this to say: *As you talk about the issue of gender bias, there is yet another issue that we need to look at with a keen eye. First of all, we relate to and supervise female teachers who are married and have lots of responsibilities back in their homes. This alone can make someone who is a fully trained administrator give certain responsibilities to men and others to female teachers. What we look for here is a family-work balance, or else you will end up messing up people's marriages.*

The findings also showed that there were several cases in which male teachers expressed anxiety about their ability to fill particular roles. Some teachers asserted that similar to the matron and senior female teachers, there would be a senior male teacher in charge of boys' issues in addition to the warden. Almost all public secondary schools were found to be lacking in this type of structure. According to the study's objective, the inability of administrators to balance positions of responsibility on both sides is what leads to this divide. One is always left wondering if male students don't face the same difficulties as their female colleagues. The concern about the cause for bias on the side of males was also raised by one head teacher who indicated; *At times, you may find that the assignment of responsibilities is, for sure, biased against men, as you say. However, as a headteacher with some experience, I've noticed that there are many cases where male teachers are difficult to delegate to. They are always feeling superior, and many think they cannot tolerate instructions. This is why, in certain schools, you will find that a female teacher may start acting in a position they are not qualified for.*

Finally, but not least, the causes for gender bias or factors contributing to gender bias in public secondary schools in Iganga District include; favouritism. According to findings, it is possible to find public secondary schools in Iganga District where a head teacher favours either female or male teachers. This automatically dictates the occurrence of the gender bias theory.

Results for the Functional Attempts Put Across to Eliminate Gender Bias to Enhance Teaching Practices in Public Secondary Schools in Iganga District

The question of whether gender advocacy messages were disseminated in particular secondary schools was investigated. This was done to see if the different stakeholders—in particular, the head teachers, the staff room, the classrooms, the complex, and the buildings—had access to

these communications. Results showed that head teachers' offices successfully reflected gender advocacy messaging. In response to the functional measures in place to eliminate gender bias, headteacher school B indicated: *I, for one, keep encouraging teachers, whenever possible, not to discriminate against anyone when assigning responsibilities. There is a tendency—I heard that teachers in some other schools tend to give more marks to one gender than the other. I want to tell you that this hearsay has helped me as a tool to fight favouritism and encourage equality among teachers and students in this school.*

Another review investigated whether or not some public secondary schools accomplished much to advance gender equality in the classroom. According to the messages, among other things, positive gender-based behaviour by teachers and students can be disruptive to the teaching and learning process. Boys picking on females, bigger students picking on both boys and girls, bigger students picking on smaller students, mocking, abusive language and gestures, sexual overtures, touching and groping, or sharing notes are just a few examples of this. In response to the question about whether gender-sensitive advocacy is implemented in the classroom, responses from headteacher school C revealed that: *At least whenever we meet as headteachers, there are certain government programs to which we give much attention. Gender equality is one of them, and for us as headteachers, we believe this must start at the classroom level. Students are the real owners of institutions. It must be realized that there are no separate fee requirements for male and female students. Therefore, we encourage equal treatment among students themselves and between students and teachers.*

The investigation into privacy about gender responsiveness was based on several issues, including separate restrooms for boys and girls or female and male teachers, changing rooms, incinerators, separate urinal locations, counselling rooms, and easy access for SNE students to all buildings in the school or college. These difficulties show how seriously schools take the planning and division of pit latrines and bathrooms for boys and girls. In the responses of headteachers, it was indicated that: *We have done everything possible to ensure that the issue of privacy is addressed. Here, the school prioritizes the idea of having separate toilets for males and females. And by the way, it is not only reflected on the side of students; rather, it is everywhere, even on the side of teachers. Males cannot make use of females' facilities when it comes to convenience.*

Two secondary schools have semi-public changing rooms set up so that individuals may change their clothing privately, either one at a time or according to their gender. Men and women may have separate changing areas, or there may be an open area without cubicles or stalls designated for either gender. A person may occasionally change into a different set of clothes in a restroom's toilet cubicle. Responding to ways gender sensitivity is catered for, the headteacher for School E stated: *This being a school with an Islamic foundation, there are changing rooms here. The females have their changing rooms. We respect privacy so much in this school and hate to see any violation of the rules that govern privacy. Here we try to protect female students from any form of harassment by advocating for the use of long skirts. We discourage minidresses and skirts.*

Typically, suggestion boxes are required in classrooms. Notes regarding topics for discussion in class at the weekly meeting can be placed in the box by students. The majority of the time, students write about a situation that involves one or more people or that has an impact on the entire class. Findings showed that although there were suggestion boxes available in schools, they were rarely used.

CONCLUSION AND RECOMMENDATIONS

The conclusions were drawn from the study's findings. The recommendations, on the other hand, are based on the gaps identified per the specific objective of the study.

Conclusions of the Study

According to the findings, school attendance at the senior level is usually regular and higher for female students. In terms of gender sensitivity and content delivery, results indicated that school A scored highly in responding to gender issues. In almost all public secondary schools in Iganga District, there is no female head of the disciplinary committee. However, each secondary school comprises teachers of each gender. There are concerns about the issue of separate toilets or latrines for male and female teachers. Findings show that there is gender bias in the assignment of disciplinary committee responsibilities.

In terms of the factors contributing to gender bias, it was concluded that male teachers are more likely to be tough and command the attention of students when they say something, while female teachers tend to be soft when disciplining them. Many female teachers are denied certain responsibilities because they are either married or unable to attend to their responsibilities at certain times of the day. Public secondary schools in the Iganga District lack structures to balance the responsibilities of male and female teachers.

The study looked at whether or not some public secondary schools accomplished much to advance gender equality in the classroom. Results showed that head teachers' offices successfully reflected gender advocacy messaging. Findings showed that suggestion boxes were available in schools but rarely used by teachers and students.

Recommendations

Findings indicate that language has to be changed such that "students" or "friends" are preferred over "girls and boys." These nicknames portray guys as hard and girls as soft. The results show that advocacy messages are crucial and effective change agents for gender equality. Therefore, it should be required of every instructor to see to it that gender-sensitive messages are disseminated and posted on walls and in appropriate places. It is also important to balance responsibilities among teachers. Most importantly, male teachers ought to be prepared to respect the female gender by assigning them responsibilities to take care of them. If we can have male chefs, we can have male teachers take charge of certain aspects of female students.

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American Sign Language and English Proficiency Among Children with Disabilities

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Abstract:
A continuous cycle of mistreated children is being neglected in the education system. The debate on using American Sign Language (ASL) as a teaching mechanism in the education system for disabled children is ongoingly debated without a decisive conclusion. In order to advance this field of study and promote impartiality to disabled children in their educational pursuits, this study pitches this question: how does teaching in ASL impact the English grades of children with disabilities? A case study revealed many research papers, experiments, and studies that persistently contrasted each other. One paper detailed the negative side effects of learning ASL as a first language on the children's English language skills while another asserted ASL as directly factoring to improvements in the children's English proficiency. Based on this case study, a methodology and study design are spelled out circling on applying a field experiment with a control group and an experimental group dividing up a section of 16–18-year-old children with autism, dyslexia, and deafness. In this experiment, the control and experimental groups will receive teaching on an English language skill, one in pure English and the other in ASL. Once the lesson is concluded, both groups will partake in a pop quiz and the results are compared. The expected result is a positive correlation between ASL and English proficiency.

Keywords: American Sign Language, ASL, English Proficiency, English Language Skills, Social Psychology, Disabled Childre, Autism, Dyslexia, Deafness

INTRODUCTION

In a world where communication lies at the basis of human interaction, the essence of non-verbal communication is neglected. This evinces difficulty for people leaning on the likes of sign languages. American Sign Language (ASL) is a particular form of signing that, despite its absence of sound, is composed of phonological segments that determines ASL as similar to spoken languages, including English (Lidell & Johnson, 1989). Deaf people are commonly associated with plying ASL, yet research suggests that even the non-deaf were capable of utilizing ASL to overpower their communication disabilities, pinning ASL as a universal language (Toth, 2009).

Despite the grasp ASL holds in contemporary communication, its importance diminishes when planted into reality, precisely in education. Anne Toth (2009), Head of Data Policy at the World Economic Forum, conducted a research project covering deaf children between the ages of 0-6 years old diagnosed with autism, Down Syndrome, Fetal Alcohol Spectrum Disorder, and other learning disabilities. The author claimed that deaf children and hearing children displayed augments in their vocabulary acquisition and application of the oral language. ASL, in this study, is contemplated to benefit disabled children in learning spoken languages. Building off this, Markku Jokinen (2009) expressed dismay at the lack of research on the consistent end of deaf people falling victim to "linguistic genocide", the tragic practice of forcefully destroying a

language, in this case, ASL. Although sign language should be accepted as a mother tongue for the deaf, this natural human right is denied to them around the world, as the author urges.

Critically, ASL is neglected in education such as at schools and universities, where ASL is the direst component in serving proper education to disabled children (Robinson & Henner, 2018).

In order to study the link between ASL and English for disabled children, my research raises this question: How does teaching in ASL impact the English grades of children with disabilities?

This research zooms into three specific disabilities: autism, dyslexia, and deafness.

Autism is the "primary defect in terms of a language or coding problem" (Rutter, 1968).

Furthermore, dyslexia is a "neurodevelopmental disorder that is characterised by slow and inaccurate word recognition" (Peterson & Pennington, 2012). Finally, deafness was coined as hearing loss factored by genetics and environmental factors (Sheffield & Smith, 2019). Focusing on these distinct disabilities, in spite of their loose relation to each other, permitted the ability to develop an overall understanding of all the disabled children while also scoping into the disabilities most availed by ASL. Each of the three disabilities had unique factors that had to be considered during the experiment and required individual research to be gathered.

LITERATURE REVIEW

Importance of Communication

When families have a disabled child, the lack of knowledge on how to nurture their child disrupts familial relationships (Sen & Yurtsever, 2007). Families place their trust in schools to tend to their children. For the education system to place its foremost endeavors into caring for disabled children, the incorporation of ASL in teaching is highly debated. Education relies on the proper use of communication and effective translation of knowledge from the teacher to the student especially for a disabled child suffering from autism, dyslexia, or deafness where information could be easily lost in both the teacher's and student's absence of understanding each other. Dammeyer (2010), in his study of a Danish population, characterizes the significance of communication through their study of psychosocial difficulties in children with hearing loss.

They conclude with a clear implication of the importance of communication despite the barrier of hearing loss supported by the reasoning that if the sign language and oral language skills are adequate for hearing loss children then they do not have a significantly higher level of psychosocial difficulties. Communication, besides seizing the core of human interaction, also assists in understanding the difficulties and ability levels of children suffering from disabilities. The key takeaway is the efficacy of communication whether it be through oral languages or sign languages (Dammeyer, 2010).

Literacy Development in Dyslexic Children

In the discussion of the language skills of dyslexic children, one controversial issue has been the high-risk children are at for having reading difficulties (Hulme et. al, 2015). Hulme and his co-authors, in a study on early language skills and dyslexic children, insisted that "variations in reading skills are highly correlated with variations in oral language skills" (pg. 1). The author didn't mention the service of ASL in the early ages of children at the risk of dyslexia, but the nature of reading skills correlating to oral language skills. Building off the previous statement, another study corroborated

that reading comprehension itself is governed by the children's decoding skills as well (Storch & Whitehurst, 2002). Eighteen years later, Snowling and their partner's study (2020) advance the field through the notion of dyslexia falling on a spectrum of IQ and the importance of taking action towards students with poor decoding abilities. Decoding abilities not only alter reading skills but also might sway how ASL impacts English proficiency for dyslexic children. Thus, the reason for the vague expected results equipped later in the paper and the desperate need for this experiment to clarify the best teaching method for dyslexic children, to apply that to instruction, and to deliver superior and fruitful education to students.

Sign Language Pronouns by Autistic Children

Sheild and his associate investigators (2015), who concentrated on autistic children developing ASL at an early age due to having deaf parents, report that at the weeny ages of one and two, autistic children consistently switched up pronouns such as "me" and "you" (pg. 3).

Further, "[t]here is some evidence that linguistic symbols which have motivated, non-arbitrary (iconic or indexic) forms can be beneficial to both first-language (L1) and second-language (L2) learners" and "are faster at matching signs and pictures when those pictures resemble iconic qualities of the sign" (pg. 3). In other words, signing has evidence of aiding the user in learning other language skills. The ability to use sign advances the child's visual and correlating skills, in turn, driving them when learning other languages. Bonvillian, Nelson, and Rhyne (1981) agree with Sheild and his partners' general claim by declaring that speech skills for autistic children can be gained from simultaneous signing. Signing follows effortlessly for autistic children as in the sample of 100 autistic children for this study, all of them exhibited exemplary techniques in sign language.

Deaf Children's Bilingual Abilities

In Freel and her researchers' (2011) study on deaf children's ASL proficiency and reading abilities, it was uncovered that "a significant positive relationship between a measure of ASL proficiency and a measure of reading skills, was supported [by the data]" (pg. 21). They also emphasize that "teachers of the deaf often do not take advantage of ASL skills as a bridge to English literacy" urging for ASL as a teaching mechanism in deaf children's education (pg. 1). A need for ASL grammar courses and the lack of it in schooling is mentioned as well, a contrast to how all children all required to take English and English grammar courses. Mounty, Pucci, and Harmon (2012) from Gallaudet University support the previously mentioned authors by illustrating the strengths of deaf children's bilingualism in ASL and English. In essence, ASL, based on the case study and experiment conducted by Freel and her investigators and Mounty and her partners harbors pivotal information on the high leverage of ASL in the education of English for deaf children.

Gap

Current research on ASL and disabled children comprised various studies on individual disabilities: autism, dyslexia, and deafness. Other auxiliary pre-existing studies examined ASL and the constituents that altered it. However, there was short of pre-existing studies that tethered on ASL affecting English language skills among these disabled children. There is research studying the interdependence between ASL and deaf children, enough to develop a background understanding of the topic but not enough to make resolute conclusions on how ASL affects disabled children, not simply children that are deaf, and how ASL alters English proficiency specifically, rather than the entirety of the children's education. The foremost rationale to pinpoint this topic was to figure out the distinctive correlation that exists between ASL, children with disabilities, and English language skills. This correlation is paramount as it can provide teens and the education system an

understanding of whether ASL can improve disabled children's understanding of English language skills. The ongoing debate on whether ASL has positive or negative repercussions on English language skills was especially a concrete reason to dig deeper into this area of psychology.

Hypothesis

As presented in the literature review, the broad extent of this topic is fixated on a mixture of positive and negative influences of ASL on English language proficiency for disabled children. In the current study, I predict that the time spent teaching ASL will be positively associated with increased English reading skills and overall higher quiz grades among disabled children.

METHOD

Study Design

The design will consist of a field experiment to observe the natural setting of the classrooms. Students suffering from autism, dyslexia, and deaf children will be divided into two groups: a control group and an experimental group. Both groups will be taught a lesson on the English language. The lesson will be approximately an hour long and the control group will learn the lesson in English while the experimental group will be taught in ASL. Once the lesson is complete, both groups will receive identical pop quizzes on the material. The entirety of the pop quiz will be constructed by classic multiple-choice questions. Some reference questions will be provided to base the official questions from when performing the experiment. In order to avoid other variables from disrupting the flow of the experiment, the teacher instructing the lesson will be the same for both groups to ensure the lesson reaches the participants equally. There will also be an "Additional Information" section that gathers light, qualitative data on the participant's family history with disabilities and ASL and their own experiences with how ASL influences their mastery of the English language. All the questions in this section are optional and used solely for the purpose of analysis. Any questions that will reveal the identity of the participant will not be shared with anyone but the investigator. The analysis and data can survive with a one-time pop quiz but to gather more accurate and exact results, the study can take place throughout a month with pop quizzes every week, each time with a new lesson, and increased time spent teaching the lesson.

Participants

Participants are required to be between the ages of 16 and 18 with a focus on the large suburban school districts in North Texas. This demographic was categorically chosen to represent this study as teens have comprehensive and detailed pre-existing research that advances this study. Furthermore, the ages are closer together and will allow for the lesson to be taught to an age range that will grasp it. Once the questions for the experiment are finalized by the teacher based on the lesson being taught, the Informed Consent Form (see Appendix A) along with a detailed overview of the experiment will be submitted to the Institutional Review Board (IRB) denoting that participation is anonymous and participants are free to leave whenever during the experiment. This will also ensure the ethicality of the study design and practices. As soon as the IRB approves the procedures, the experiment will flow as described. Approximately 40 to 60 participants are ideal for this study.

Research Instruments

Quantitative data will be collected through the multiple-choice questionnaire. The number of questions each participant answered correctly will be recorded and grouped into the categories of autistic, dyslexic, and deaf children. Then, the average number of correct answers from the three categories within the control group will be calculated as well as the average number of correct

answers from the three categories in the experimental group. The average can be calculated by combining the number of correct answers of each person in the specific category divided by the amount of people in the category. This is the mean number of correct answers earned by the particular category in either the control or experimental group. The numbers of each category in the control group will then be compared to the number of the corresponding category in the experimental group. Following this, other measures such as median (middle number of correct answers), mode (most occurring number of correct answers), standard deviation (dispersion of the data set), range (difference between the greatest number of correct answers and the least number of correct answers), and even a box-and-whiskers plot (a type of graph measuring minimum, Q1, median, Q3, and maximum) can be used to analyze the data set flawlessly. Questions for the pop quiz can also be gathered from recent STAAR tests, but the questions in Tables 1-5 are drawn from "Test Your Language", a free language test website to calculate the user's language proficiency. Table 1 focuses on testing English grammar.

Table 1: Example English grammar questions based on "Test Your Language"

Q1	Q2	Q3	Q4
Don't be too loud.	Samantha …… her	He is …… out the	There …… in
Bob …… to take a nap.	teeth as soon as she wakes up.	trash.	Chicago.
A.	A.	A.	A.
try	brushes	taking	snows
B.	B.	B.	B.
tries	will brush	took	snowed
C.	C.	C.	C.
tried	brush	take	is snowing
D.	D.	D.	D.
is trying	is brushing	is taking	is snow

Table 2 displays example English idiom questions from "Test Your Language".

Table 2: Example English idiom questions based on "Test Your Language"

Q1	Q2	Q3	Q4
What is the meaning of "face the music"?	What is the meaning of "hit the nail on the head"?	What is the meaning of "stick your neck out"?	What is the meaning of "an old hand"?
A. control the situation	A. accept the consequences	A. risk it	A. tired
B. take the risk	*B.* memorize it	*B.* watch out	*B.* an old person
C. accept responsibility	*C.* absolutely right	*C.* look in front of you	*C.* lazy
D. agree	*D.* experience	*D.* get out of the way	*D.* experienced

Table 3 shows example English slang questions straight from "Test Your Language".

Table 3: Example English Slang questions based on "Test Your Language"

Q1	Q2	Q3	Q4
What does "what's up" mean?	What does "let's hang out" mean?	What does "have a blast" mean?	What does "have a crush" mean?

A. what is above you	A. hang our stuff	A. have a lot of fun	A. being depressed
B. something going up	*B.* let's go outside	*B.* ignore someone	*B.* really like someone
C. what is upstairs	*C.* go out	*C.* have a lot to eat	*C.* destroy
D. how are you	*D.* spend time together	*D.* use a lot of fireworks	*D.* very tired

Table 4 is example irregular verb questions from "Test Your Language".

Table 4: Example Irregular Verb questions from "Test Your Language"

Q1	Q2	Q3	Q4
Have you	She spoke too softly. I couldn't	But we heard everything she	We went shopping and I
your lost dog yet?	_____her.	_____.	_____a new pair of jeans.
A. finded	A. here	A. sayed	A. buyed
B. find	B. heard	B. said	B. bought
C. found	C. hear	C. say	C. buy

Qualitative analysis is also critical. Following the pop-quiz questions will be a standard set of explanatory and descriptive questions. They will be used exactly as written despite the lesson being taught and graded on. The questions will be open-ended responses as well as "yes, maybe, and no" questions. Likert-scale questions and multi-select questions (M-S Questions) will be sprinkled throughout the questionnaire to provide enhanced information. To ensure fairness for all participants, the questions will remain optional and anonymous. The main objective of these questions is to gather the history of the participants and to understand how the factors described in the literature review play into the experiment. These factors such as learning ASL as a first language, having deaf parents or hearing parents, and their perspective on whether ASL impacts their English language. These will be used to gain further understanding and develop complex analysis from the experiment. Furthermore, an effective combination of quantitative and qualitative questions allows for a "better organized understanding of the results" (Lee & Smith, 2012). Table 5 will focus on ASL in the participants' personal life. The total number of questions in the "Additional Information" section is 15. The entire set of questions in the "Addition Information" portion is displayed in Appendix B.

Table 5: Questions on ASL in Participants' Family History and ASL Impact on English Proficiency

Q1	Q2	Q3	Q4
Is American Sign Language your first language?	If so, do you speak American Sign Language at home?	How fluent are you in American Sign Language?	Are one, both, or neither of your parents or guardians suffering from hearing loss?
Answer Choices: Yes, Maybe, No	Answer Choices: Yes, Maybe, No	Likert-scale Question (1-Not at all; 10-A lot)	Answer Choices: One, Both, Neither

EXPECTED RESULTS

As stated in the hypothesis, the prediction is that among each category, the average number of correct answers on the pop quiz will be higher for the expected group than the control group. This will naturally claim that the time spent teaching ASL will benefit the overall disabled children. However, after the conduction of the case study displayed in the literature review, each category might have varying outcomes. Dyslexic children have the possibility of delivering any sort of results—negative, neutral, or positive—as the focus of the bulk of studies has been the children's reading abilities without a focus on their signing skills, thus the results lie open.

Whereas dyslexic children have an open analysis, the data for deaf children is predictable in that ASL will hold critical importance in their learning of the English language. For autism, ASL appears to ameliorate the child's visualization and correlation abilities which has a high chance of benefitting them while learning English, producing a possible positive correlation between ASL teaching and English proficiency. The expected data, regardless of its clear contrast, will yield a general understanding of whether ASL is worth placing into the education system.

Designating the disabilities most linked to ASL teaching in this research will grant a wide spectrum of results. While that may surface as disadvantageous, it is rather beneficial in comprehending the overall efficacy of ASL on the children's English skills all while gaining specific information on each of the disabilities.

DISCUSSION

Limitations

Due to limited time, there were some hindrances in this study. The main limitation was the lack of conducting an authentic experiment. Without the experiment, the method and study design will be unable to be modified and tweaked for other investigators and researchers in this field of area. However, the case study conducted in this paper and the literature review developed an accurate experimental design that will certainly produce results and advance the current research on ASL and English proficiency in disabled children.

Implications

If results deliver as expected by this study, the inclusion of ASL will be highly encouraged to teach lessons in schools for disabled children, thus allowing for a better and more efficient form of learning for the students. Some children might benefit from ASL as a form of communication in teaching while others might not, as be detailed in the literature review. Instead of following a teaching style with only English, the objective of this paper is to encourage the addition of ASL in the classrooms that could benefit the students lagging in their studies to promote a far more inclusive education system individual to each student's strengths and weaknesses.

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APPENDICES

Appendix A

Informed Consent Form

[redacted]

1. KEY INFORMATION ABOUT THE RESEARCHERS AND THIS STUDY

CONSENT TO BE PART OF A RESEARCH STUDY

Study title: Fear of Failure and Its Impacts
Principal Investigator: [redacted], High Schooler, [redacted]
Faculty Advisor: [redacted]

You are invited to take part in a research study. This form contains information that will help you decide whether to join the study.

Taking part in this research project is voluntary. You do not have to participate and you can stop at any time. Please take time to read this entire form and ask questions before deciding whether to take part in this research project.

2. PURPOSE OF THIS STUDY

The purpose of this study is to examine the impacts of American Sign Language on English language skills in children with disabilities of autism, dyslexia, or deafness. This is to promote an enhanced and efficient education system for all children.

3. WHO CAN PARTICIPATE IN THE STUDY

Who can take part in this study?
Teens between the ages of 16 and 18 with autism, dyslexia, or deafness in suburban North Texas are allowed to participate in this study.

4. INFORMATION ABOUT STUDY PARTICIPATION

What will happen to me in this study?
The participant will learn an English language skill and will be required to partake in a pop quiz. The student will be grouped into the control or the experimental group through a random draw. If placed in the control group, the participant will learn the lesson in pure English whereas if they are grouped into the experimental group, they will be taught in American Sign Language. The participant is also encouraged, but not forced, to engage in the "Additional Information" section which will help the investigator advance their analysis of the experiment.

How much of my time will be needed to take part in this study?
A one-time experiment is all that is needed. The experiment, including the lesson and pop quiz, will range approximately 60 to 90 minutes.

5. INFORMATION ABOUT STUDY RISKS AND BENEFITS

What risks will I face by taking part in the study? What will the researchers do to protect me against these risks?
The experiment is anonymous and any personal information such as name, address, email, phone number, etc. will not be asked. Any information in the "Additional Information" section that will reveal the identity of the participant will be censored and all questions are fully optional to heed IRB regulations. There is no risk to the participant in partaking in this study.

How could I benefit if I take part in this study? How could others benefit?
You may not directly receive any personal benefits from participating in this study. However, others may benefit from the knowledge gained through this experiment, and future generations will grow up in a more equitable education system.

6. ENDING THE STUDY

If I want to stop participating in the study, what should I do?
You are free to leave the study at any time. If you leave the study before it is finished, there will be no penalty to you. If you decide to leave the study before it is finished, please tell one of the persons listed in Section 9. "Contact

Information". If you choose to tell the researchers why you are leaving the study, your reasons may be kept as part of the study record. The researchers will keep the information collected about you for the research unless you ask us to delete it from our records. If the researchers have already used your information in a research analysis it will not be possible to remove your information.

7. PROTECTING AND SHARING RESEARCH INFORMATION

How will the researchers protect my child's information?
Research data is collected anonymously so none of your child's information will be needed and none of the questions require answers that will identify your child.

What will happen to the information collected in this study?
We will keep the information we collect about your child during the research for future research projects and studies on American Sign Language and its impacts on English proficiency. Your child's name and other information that can directly identify your child will be stored securely and separately from the research information we collected from your child.

8. CONTACT INFORMATION

Who can I contact about this study?

- Please contact the researchers listed below to:
- Obtain more information about the study
- Ask a question about the study procedures
- Report an illness, injury, or other problem (you may also need to tell your regular doctors)
- Leave the study before it is finished
- Express a concern about the study

Principal Investigator: [redacted]
Email: [redacted]
Phone: [redacted]

Faculty Advisor: [redacted]
Email: [redacted]

If you have questions about your rights as a research participant, or wish to obtain information, ask questions or discuss any concerns about this study with someone other than the researcher(s), please contact the following: [redacted]

10. YOUR CONSENT

Consent/Assent to Participate in the Research Study
By signing this document, you are agreeing to be in this study. Make sure you understand what the study is about before you sign. I/We will give you a copy of this document for your records and I/we will keep a copy with the study records. If you have any questions about the study after you sign this document, you can contact the study team using the information in Section 9 provided above.

I understand what the study is about and my questions so far have been answered. I agree to take part in this study.

Print Legal Name: _____
Signature: _____
Date of Signature (mm/dd/yy): _____

Parent or Legally Authorized Representative Permission
By signing this document, you are agreeing for your child's participation in this study. Make sure you understand what the study is about before you sign. I/We will give you a copy of this document for your records. I/We will keep a copy with the study records. If you have any questions about the study after you sign this document, you can contact the study team using the information provided above.

I understand what the study is about and my questions so far have been answered. I agree for my child to take part in this study.

Print Participant Name

Print Parent/Legally Authorized Representative Name

Relationship to participant: • Parent • Spouse • Child • Sibling • Legal guardian • Other

Signature Date

Reason second parent permission was not collected:

- Parent is unknown
- Parent is deceased
- Parent is incompetent
- Only one parent has legal responsibility for care and custody
- Parent is not reasonably available*; explain:

** Note: "Not reasonably available" means the other parent cannot to be contacted by phone, mail, email, or fax, or his or her whereabouts are unknown. It does not mean that the other parent is at work or home, or that he or she lives in another city, state, or country.*

Date of Signature (mm/dd/yy):

Appendix B

"Additional Information" Section

1. Are one, both, or neither of your parents or guardians suffering from hearing loss? (Multiple Choice Question)
    1. One
    2. Both
    3. Neither

2. Is anyone in your family, friends, or relatives suffering from deafness? (Multiple Choice Question)
    1. Yes
    2. Maybe
    3. No

3. If so, please state how many. (Open-Ended Question)

4. Is anyone in your family, friends, or relatives suffering from autism? (Multiple Choice Question)
    1. Yes
    2. Maybe
    3. No

5. If so, please state how many. (Open-Ended Question)

6. Is anyone in your family, friends, or relatives is suffering from dyslexia? (Multiple Choice Question)
    1. Yes
    2. Maybe
    3. No

7. If so, please state how many. (Open-Ended Question)

8. Have you learned American Sign Language as a first language? (Multiple Choice Question)
    1. Yes
    2. Maybe
    3. No

9. Are you fluent in American Sign Language? (Multiple Choice Question)

1. Yes
2. Maybe
3. No

10. If so, do you speak American Sign Language at home? (Multiple Choice Question)
    1. Yes
    2. Maybe
    3. No

11. How fluent are you in American Sign Language? (Likert-Scale Question)

1	2	3	4	5	6	7	8	9	10
(Not at	all)								(A lot)

12. How fluent are you in English? (Likert-Scale Question)

1	2	3	4	5	6	7	8	9	10
(Not at	all)								(A lot)

13. What other language are you fluent in? (Open-Ended Question)

14. Do you think American Sign Language helps your ability to understand English language skills? (Multiple Choice Question)
    1. Yes
    2. Maybe
    3. No

15. Would you like to be taught in American Sign Language? (Multiple Choice Question)
    1. Yes
    2. Maybe
    3. No

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Increasing Community Involvement in Law Enforcement Through Procedural Justice to Improve Ties with The Community

John Motsamai Modise

1. South African Police Service

Abstract:
This research paper examines how a procedural justice policing approach affects how people perceive their duty to follow police orders. It investigates whether the degree of confidence that a citizen has in law enforcement during a police-citizen encounter may have an impact on how procedural justice functions in relation to their duty to uphold the law. The effectiveness of procedural justice in enticing citizens to uphold the law is examined, as well as the possibility that citizens' trust in the authorities may play a role in this. Numerous studies have examined how procedural justice affects people's attitudes toward and cooperation with the police and other elements of the criminal justice system, but many of these investigations did not break down procedural justice into its different strands, such as police procedural justice. The public's perception of the police will increase if they execute their authority in a procedurally fair manner, according to Tyler's process-based model of policing. In the past, process-based study has largely ignored public trust in the police in favor of focusing on the sources of legitimacy. Tyler's process-based policing model argues that the police can improve the public's view of their legitimacy and dependability by exercising their power in a procedurally fair manner. Up until now, process-based research has mostly disregarded the legitimacy of the police and focused on the sources of legitimacy.

Keywords: public encounters, procedural justice, policing, training, policing, trust, legitimacy, Procedural justice theory, obligation to obey police; Police-citizen encounters.

INTRODUCTION

"Treating people with dignity and respect, giving citizens 'voice' during encounters, being neutral in decision-making, and conveying trustworthy motives" are the four guiding principles of procedural justice. Research shows that these principles help to build relationships between authorities and the community in which the community: 1) has trust and confidence in the police as honest, unbiased, benevolent, and lawful; 2) feels obligated to obey the law and the orders of legal authorities; and 3) believes it shares similar interests and values with the police. An increase in community views of police legitimacy, or the conviction that authorities have the right to impose appropriate behavior, is closely related to procedurally just policing. It is crucial to the growth of good will between police and communities. According to research, people are more likely to follow the law and cooperate with the police when they perceive the power of the police to be legitimate. Establishing and keeping police legitimacy encourages the acceptance of police judgments, correlates with high levels of law compliance, and increases the likelihood that communities and police will work together to fight crime.

Police departments have stressed more and more recently how crucial it is to strengthen police-community ties in order to increase public confidence in the force. This prioritization of activities is supported by centuries of research showing that individuals are more likely to trust, consider as legitimate, and indicate they would obey police when they perceive them as respectful, unbiased, and fair (Donner et al., 2015). Procedural fairness as a result has been dubbed the mythical "silver bullet" for enhancing police-citizen relations, especially between officers and communities of color. Although it has been shown in numerous studies that general perceptions of procedural justice are linked to better police-citizen relations, it is less obvious how pre-existing attitudes affect police relations with minorities based on a specific encounter. Furthermore, less is known about how well police procedural justice works to build confidence with people who might feel discriminated against.

It is crucial to comprehend how minorities view and react to police treatment. Studies have shown that ethnic and racial minorities have a more negative perception of police and are far less likely to trust police than non-minorities (Kahn et al., 2017). To improve minorities' trust and confidence in the police, police departments endeavor to establish procedurally fair practices; yet, this may not be sufficient to alter deeply rooted unfavorable perceptions. Researchers have questioned whether procedural justice applies equally to everyone in the case of people who may believe that police have predetermined biases against them personally or their ethnic or religious group more generally (Madon & Murphy, 2021; Williamson et al., 2022). Multiple researches have found that the positive procedural justice effect on police perceptions is universal across populations (Brown & Reisig, 2019), although other academics have questioned the effect's applicability to all populations.

Although we firmly believe that procedural justice is essential to policing, the findings of Murphy et al. (2020) raise doubts about whether procedural justice will ever be implemented correctly. We argue that it is critical to comprehend the lens through which people view contacts with the police, particularly for those who feel they are a part of a stigmatized group and who likely expect routine bias from police. According to one stigmatized minority group, they had low levels of trust in the police and experienced considerable levels of police discrimination. It becomes sense to believe that many people assume they may encounter unjust police treatment.

CONCEPTUAL FRAME WORK: THE PROCESS-BASED MODEL OF POLICING

This research primarily adheres to the model put forth by Van Craen (2016), who contends that interpersonal confidence is crucial in bridging IPJ and external procedural justice. Even though the relationship between internal and external procedural justice may be reciprocal (i.e., improved external justice may enhance IPJ), Van Craen's model suggests that the connection is most likely to have its roots within the police department because supervisors play a crucial role in influencing officers' operational styles and occupational attitudes, especially in the formative years of their careers.

Police officers' perceptions of process-based justice from organizational supervisors (i.e., IPJ) are connected to their equitable and just stances toward assisting community members (e.g., external procedural justice; (Roberts & Herrington, 2013; Van Craen & Skogan, 2017; Wu et al., 2017). The social learning theory (Bandura, 1971) is typically used to explain this idea of "fair policing from the inside out," with an emphasis on supervisor modeling (Van Craen, 2016). In other words, this framework assumes that police officers will emulate the procedurally right behaviors

of people in positions of authority and high status, such as their immediate superiors, and incorporate the values and rules they have learned into their daily operations.

It is essential to note that there are some significant differences between the decision to trust authorities and their agents in a social context and the decision to trust other members in an organizational setting with regard to the nature and frequency of contacts and interactions. Colleague interaction and information sharing are expected as a regular part of working within a company. A fair process provided in a respectful manner by managers within a police department, who have control over resources, rewards, and disciplinary actions, is likely to win back officers' confidence and strengthen their adherence to institutional rules and policies (Cohen-Charash & Spector, 2001). According to Conchie and Donald (2006), a trusting environment fosters fair exchanges between individuals and their direct supervisors as well as the organization as a whole. This in turn favorably correlates with operational cooperation among organizational members, which can also be interpreted as members' rational choice (Colquitt, et al., 2001; Masterson et al., 2000). Such an understanding of justice within the employing company fosters a kind workplace culture and favorable attitudes toward the business (Cohen-Charash & Spector, 2001).

In the context of policing, supervisors build up and create a bank of trustworthiness from prior contacts, on which they can rely during future incidents, by engaging in frequent interactions to gain subordinates' recognition of integrity and ability. Organizational commitment and subsequent team success depend on the trust built up through cooperative efforts in the past. Procedural injustice can cause officers worry and emotional exhaustion even though it increases their adherence to organizational rules and suppresses deviant attitudes and behaviors within agencies (Donner, et al., 2015; Wu, et al., 2017). Studies carried out all over the globe have largely confirmed the relationship between internal and external procedural justice. For instance, in the US, IPJ is connected to external procedural justice among Chicago police officers both directly and indirectly (via confidence in citizens) (Van Craen & Skogan, 2017). Through moral alignment with supervisors and citizens, as well as citizen confidence, IPJ in China also serves as a direct or indirect predictor of external procedural justice (Sun, Han, et al., 2019). A second study discovered that Chinese officers' work satisfaction and anger mediate the relationship between perceived internal accountability and external accountability. (Wu et al., 2019). IPJ was favorably correlated with citizen trust in Croatia, but it wasn't a good indicator of external procedural justice (Ivkovic et al., 2019). The study by Haas et al. (2015) on the Argentina police may be the most pertinent to this one. It found that higher levels of IPJ and confidence were associated with higher levels of compliance with managers and rules.

Building untrustworthy relationships within a company could have disastrous effects on both the individual and the organization. An officer's skepticism and vigilance may spark a range of unfavorable behaviors toward the supervisor if he or she sees unfairness while interacting with them. Officers may assume organizational procedural injustice when the perceived unfairness can be attributed to institutionalized procedure.

Relationships that inspire distrust can result in resistance to collaboration and information sharing within a company (Toma & Butera, 2009), as well as personal emotional responses like frustration, anger, and fear. The organization may incur additional expenses as a result of members' subpar work performance and compromised psychological well-being as a result of distrusting relationships (Gurtman, 1992; McKay, 1991). It is important to observe that accepting managers and other authority figures does not always eliminate mistrust. After all, trust serves as a social

relationship's connecting thread between the trustor and the fiduciary (Blau, 1964; Wheatcroft et al., 2012).

According to the procedural justice theory, fairness in the police's use of processes is essential for good police-public interactions (Murphy, 2015; Woo et al., 2018; Solomon, 2019). In fact, the process-based model of policing places more emphasis on how the public and the police engage than on the results of those interactions (Grant & Pryce, 2019; Nix, 2017). The likelihood of receiving positive feedback from the community is higher if the police follow fair protocols when dealing with them (Maguire et al., 2016).

In Australian research that distinguished between procedural justice considerations for youths and adults, Murphy (2015) found that procedural justice was more important for securing cooperation from youths than for adults. This is a significant discovery because, in the Kenyan context, a large portion of the post-election violence discussed further in this article involved young people who felt excluded by the nation's authorities (Klopp & Kamungi, 2008; Roberts, 2009). Therefore, procedural justice provided by judicial authorities, such as the courts and the police, may stop future post-election unrest and bloodshed in Kenya and other regions of the African continent. Procedural justice may be especially essential to those who feel marginalized by society, as Murphy (2015:69) explained.

In conclusion, confidence is the essential component of procedural justice, which turns attention away from the outcomes of reward distributions and toward the distribution process itself. While the public is generally more interested in police officers' competence, dependability, alignment with community priorities, and politeness when dealing with citizens (Stoutland, 2001), going further to look into the procedural justice in the chain of command within law enforcement organizations would be helpful in understanding policing (Van Craen, 2016). While a lack of organizational trust can result in institutional inefficiency, a toxic work environment (Cohen-Charash & Spector, 2001), and even diffuse externally (Van Craen, 2016; Van Craen, 2016), it can also have serious political repercussions (Tyler, 1990; Wu et al.; 2012).

PROCEDURAL JUSTICE

The foundation of procedural justice policing is a knowledge of police-citizen interactions informed by psychology. Procedural justice focuses on how much a person feels they have been treated fairly, given "voice," treated with respect and dignity by authorities, and dealt with impartially during a personal meeting with a representative of authority (Tyler, 2006). The procedural justice literature initially focused on how people's views of the legitimacy of legal authorities were influenced by fair treatments in terms of result as well as the decision-making process, with the simple but fundamental question of why people follow the law in mind (Tyler, 1990). Political confidence resulting from procedurally fair treatment, which has its roots in social psychological studies, can impact the stability of the organizations responsible for enacting or upholding laws (Rohl, 2018). When people believe institutional decisions are just and beneficial for the people, they tend to regard legal authorities as legitimate (Tyler, 2006), and as a result, they feel obligated to obey the authorities (Tyler & Huo, 2002).

Tyler's procedural justice paradigm postulates that (perceived) procedural justice raises public confidence in the police and that the resulting confidence incites helpful public behavior. Tyler (2005: 325, 327, 333) claims that confidence in the police "shapes public cooperation," "increases citizens' deference to the directives of the police," and "motivates compliance with the law" in his

theory on process-based policing. Studies conducted in various nations (Dirikx and Van den Bulck, 2014) and among numerous ethnic groups have also supported this assertion (Jackson et al., 2012; Murphy and Cherney, 2012).

People lose trust in the police when they think they are abusing their power, which makes them less likely to cooperate with the police. (Tyler, 2005: 339). In this process-based policing paradigm, the relationship between compliance and trust is predicated on the notion that people are more likely to comply with and cooperate with the police when they have faith in their intentions which is considered to be the essence of trust (Tyler and Huo, 2002). Stoutland (2001) and Skogan and Frydl are two other academics who have made contributions to the creation and dissemination of the concept of trust-based compliance and collaboration. (2004). According to the former author, "if police sincerely work to build trust..., residents have reasons to become eager for police protection and ready to work with law enforcement". Skogan and Frydl (2004: 291) stressed that if citizens trust the police, they will call them when they need assistance and assist them in identifying offenders in accordance with this.

Although Tyler and his colleagues (Sunshine & Tyler, 2003; Tyler & Huo, 2002) theorized about the importance of procedural justice in fostering good relations between the police and the public, the policing literature now contains a significant number of studies that connect procedural justice with other components of the process-based model of policing. When police officers handle the general public fairly and with respect, they are more likely to have their cooperation and trust in the police (Pryce, 2016; Pryce, 2018). Citizens are more likely to work with the police and be more satisfied with the police and the criminal justice system if they believe that the actions of legal authorities and agents of social control are legitimate because citizens' behavior and actions are intricately connected to the values, they hold dear and also share with others and with authority figures (Johnson et al., 2014; Tyler et al., 2010). In reality, findings from the literature already in existence have demonstrated that if the police behave in a procedurally fair way, interactions between them and the public would be more successful, increasing public satisfaction with the police (Hinds & Murphy, 2007; Mastrofski et al., 1996; Pryce, 2018).

Four elements make up police procedural justice: participation, neutrality, respect and dignity, and trustworthy intentions. When an officer acknowledges a citizen's contribution during a conversational-style interaction, it is considered participation. When an officer interacts with a citizen in a neutral manner, they base their choices on the law rather than their own emotions. When an encounter between an officer and a citizen is positive and the officer sincerely affirms the citizen's personhood, dignity and regard are demonstrated.

A police officer's willingness to help a citizen during an interaction is highlighted by trustworthy motivations. Simple tasks like giving directions and giving advice fall under this category of assistance. The policeman must also show a general concern for the welfare of the individual. Participation and neutrality are the first two elements that come under quality of decision-making, while respect and dignity and reliable motives are the last two (Nix, 2017; Sunshine & Tyler, 2003). Citizens' perceptions of police procedural justice also indicate that, in the absence of one or more procedural justice elements, officers may encounter less-than-desirable levels of citizen collaboration and compliance. Police procedural justice is typically operationalized as the quality of decision-making and the quality of treatment, despite the fact that this four-part conceptual structure of police procedural justice is a mainstay in the current criminological literature (Pryce, 2019; Sunshine & Tyler, 2003).

Although fewer studies have examined the relative effects of these two procedural justice components on legitimacy and willingness to cooperate with the police, the majority of studies have combined these two aspects of procedural justice into a single independent variable in regression analyses (Nix, 2017; Pryce et al., 2017; Tyler et al., 2010). Last but not least, the significance of procedural justice in enhancing the relationship between the police and the public has been amply recorded, whether in cross-sectional or experimental studies. Thus, this study contributes to the growing body of work on procedural justice (Grant & Pryce, 2019).

PROCEDURAL JUSTICE AND POLICING IN PRACTICE

When police are impartial, treat people with respect, exhibit fairness and trustworthy motives, and give people a chance to express their concerns to officers before decisions are made, these behaviors are typically regarded as being procedurally just (Tyler, 1990). Most scholars believe that procedural justice effects are always favorable or "invariant" across people, groups, and contexts based on study findings in the literature (Wolfe et al., 2016).

The treatment of people when they deal with authorities like the police is addressed by the theory of procedural justice (Tyler, 1990). People's perceptions of fairness and reasonableness in the way they are treated will determine whether they view the police as genuine (Nivette, Eisner, and Ribeaud 2020). Additionally, treatment can be personally experienced by people or learned about through the experiences of others, which can contribute to generalized ideas about the law and those who uphold it (Tyler, 2003). Tyler identifies the following as the main characteristics of fairness in interactions with the authorities and in the results:

- Voice – the chance to give their side of the story;
- Respect – treatment is polite and dignified;
- Neutrality – decisions are unbiased;
- Trustworthiness – the police show their interest for the public and community.

Importantly, some research indicates that utilizing these components regularly can help people perceive the legitimacy of the police, even if they have lost interest in them (Madon, Murphy, and Sargeant, 2017). However, it must be acknowledged that procedural justice cannot guarantee the perceptions of legitimacy it offers. According to Bottoms and Tankebe (2012:168), many encounters between the police and others are inherently uncertain, which makes legitimacy "elusive and multi-faceted." The fundamental components of procedural justice are all open to various readings and reactions. For instance, Camp et al. (2021) study of body camera recordings of police interactions with American citizens took tone of speech into account. They discovered that police officers spoke to white males in a more cordial manner than they spoke to black men, whose tone eroded confidence in the force.

Working with procedural justice can be challenging, despite the fact that police officers frequently engage in interactions that bear threat and danger. Procedural justice can still guide how such encounters are policed even if police officers are forced to use physical force in the face of difficulty (Worden and McLean, 2017a). Different views and interpretations of how procedural justice is working against the acknowledgment of legitimacy may exist, and the social and historical context of any interactions may have an impact (Worden and McLean, 2017b). For instance, during the Covid pandemic, the police's use of PPE, such as face masks and medical gloves, impacted people's views of procedural justice (Sandrin and Simpson, 2022). Police forces were required to guarantee compliance with measures during the pandemic years, which began

in 2020 and coincided with the passing of legislation to protect public safety in nations like the UK. This posed a challenge to the police in terms of legitimacy views, necessitating the adoption of a procedurally just strategy (Farrow, 2020).

Predictive analytics, which bases specific crimes and/or an individual's criminality on data sets that create algorithms, will have a greater impact on how police interact with the public (Baraniuk, 2018). There is concern that algorithms could learn to continue to target minority communities because such data sets may contain historical seeds that support stereotypes and activities that target particular groups (Brantingham, Valasik, and Mohler, 2018). According to Nagtegaal (2021), perceptions of procedural justice are more favorable for simpler practices in situations where police practices are decided by algorithms. However, an excessive reliance on predictions at the cost of comprehending the complex and dynamic factors at play can have a negative impact on how procedural justice is perceived (Babuta, 2017).

Integrating Procedural Justice with Trust

According to procedural justice theory, citizens value both equitable procedure and fair treatment when assessing their interactions with the police. To do this, citizens must have a chance to express their concerns (have a voice), be treated fairly and respectfully (have respect believe that an officer's choice was based on the available information have neutrality, and have faith in the police should behave ethically (Tyler, 2006). According to research, both general populations and minority groups trust the police more if they believe they are acting fairly and impartially (Donner et al., 2015; Maguire et al., 2017; Tyler, 2005). A theory of enhancing citizens' confidence in government, according to Yang (2005: 273), "is incomplete without an explanation of administrators' trust in citizens because trust is mutual and reciprocal." This is in line with Kääriäinen and Sirén's (2012) assertion that "mutual trust" is a prerequisite for successful police-public relations efforts: Higher levels of civilian confidence in police are associated with perceptions of police as more procedurally just (Murphy et al., 2020).

However, it appears that both stigmatized and unstigmatized people are affected differently by procedural justice. According to a study by Madon and Murphy (2021) on Australian Muslims, those Muslims who believed that the police were less biased toward their culture had a stronger sense of procedural fairness. Procedural justice had a weaker correlation with police confidence in people who believed that officers were biased against them. These results imply that when taking into consideration people's preexisting attitudes and beliefs about police, procedural justice effects may differ. Furthermore, research has shown that certain community members are less inclined to trust or willingly aid police in the future if they believe that police are biased or operate in an unfair manner. Murphy et al., 2020; Madon & Murphy, 2021; Cherney & Murphy, 2016). This is consistent with more thorough research that demonstrates a relationship between perceptions of police bias or discrimination and lower levels of trust in the police across various minorities (Van Craen & Skogan, 2015; Kearns et al., 2020).

The fact that the aforementioned studies depend on data from cross-sectional surveys to make inferences about the connection between procedural justice and public confidence in the police, however, is a significant flaw in their methodology. Although the methodology of these research has contributed greatly to the body of knowledge, it naturally limits the conclusions that can be made about the influence of police treatment on public perceptions of police (Johnson et al., 2017). Furthermore, a large portion of the literature currently in print explores how people around the world view whether or not police procedures are usually just. Few studies have looked at how

trust is affected by procedural justice or injustice during a particular police-citizen encounter. Therefore, it is less obvious to what degree procedurally fair or unfair treatment affects minorities' trust in the police. Also unexplored is whether pre-existing stigmatization emotions influence how procedural justice affects public confidence in law enforcement. Experimental methodology is necessary to more fully comprehend which get beyond the limits of the existing research, these variables are causally related to one another in police-citizen interactions.

A theory of enhancing citizens' confidence in government, according to Yang (2005: 273), is incomplete without an explanation of administrators' trust in citizens because trust is reciprocal and mutual. According to this, but concentrating specifically on the area of public safety, Kääriäinen and Sirén (2012) claimed that "mutual trust" is necessary for productive collaboration between the police and the public: police agents' and citizens' confidence in one another. They were shocked to learn that "policing research has focused only on the first part of this equation." Despite the fact that (Kääriäinen and Sirén, 2012: 277) have emphasized police officers' procedural justice as a crucial element for boosting the public's confidence in the police, the issue of how trustworthy police behavior can be achieved has not been fully addressed. Although this connection has only been hypothesized (for some exceptions), some authors (Schafer, 2013; Tankebe, 2011; Tyler, 2011) have proposed that it may be related to the effectiveness of interaction and communication within police organizations.

The officers' confidence in their superiors is the second related gap. According to a well-known theoretical piece by Bottoms and Tankebe (2012), police research should pay much more attention to the interaction between junior and senior power holders. My examination of the confidence literature supports their claims. Officers' confidence in supervisors has been the subject of few empirical studies (De Angelis and Kupchik, 2009; Wheatcroft et al., 2012), and there are also few theoretical reflections on this subject (Roberts and Herrington, 2013; Schafer, 2013).

INTERACTIONS BETWEEN POLICE AND CITIZENS AND PROCEDURE JUSTICE

The impacts of procedural justice on crucial outcomes including cooperation, the obligation to obey the law, police legitimacy, and public confidence in the police have been studied using experimental methodologies (e.g., Maguire et al., 2017). Randomized controlled field trials were first employed in study to examine how changing a police practice affected the public's perception of police (MacQueen & Bradford, 2015). Although these trials have a lot of methodological advantages, they cannot persuade police to apply an unfavorable or unfair procedural rule (Maguire et al., 2017). It would be unethical for police departments to instruct their officers to abuse people in order to research the effects of such treatment. However, by changing both the fair and unjust treatment of residents by police, experimental vignette designs that examine a wider range of police-citizen interactions and their impacts have been employed (Brown & Reisig, 2019).

A dearth of research has explored the impact of procedural justice—or lack thereof—on public confidence in law enforcement, despite the increasing use of experimental procedures to evaluate both procedurally just and unjust treatment. Maguire et al. (2017) investigated the impact of witnessing positive, negative, and neutral police treatment of citizens during traffic stops on participants' duty to obey police orders, willingness to cooperate with police, and trust in police using a randomized video vignette design with college students in the USA. The study's findings showed that seeing a film that was entirely devoted to law enforcement operations enhanced

each of the three final factors. In contrast, procedurally unfair police actions had a negative effect on participants' evaluations of all three outcome variables.

The impact of procedural justice and fairness on important outcomes for racial and ethnic minorities has not been well studied in many experiments. Furthermore, nothing is known about how minority group members' faith in the police is impacted by their opinions of procedural justice or injustice during a police interaction with a citizen. Johnson et al. (2017) state that because minorities are frequently the targets of disproportionate enforcement, it is crucial to take into account how they react to various police-citizen encounters. Johnson et al. (2017) used a randomly generated traffic stop video vignette with a sample of college students, altering the driver's race and the police officer's reaction to it to be either positive, negative, or neutral (Black or White).

According to research by Johnson et al. (2017), watching a video in which police handled the driver in a procedural manner. Manner had a significant, positive impact on participants' faith and confidence in the police. The authors did, however, find that there is an uneven association between perceptions of police unfairness and sentiments toward the force, with procedurally unfair treatment having a stronger influence than procedurally just treatment. Black respondents had a higher negative assessment of the police in regard to all three scenarios involving police treatment, despite the fact that the race of the vignette's driver had no influence on their opinion. Lastly, an increasing body of experimental research on procedural justice has made an effort to deepen our understanding of the causal links between police behavior and public opinion of the force. Only a small number of studies have examined the effects of both fair and unfair police conduct on the public's trust in law enforcement; one such study focused specifically on the treatment of ethnic minorities by the police. In 2017, Johnson et al. In an attempt to lessen these disparities, the new study also looks at how minority members' perceptions of stigma impact their confidence.

PROCEDURAL JUSTICE TRUST AND COMPLIANCE

Procedural justice is the study of observed fairness in decision-making processes and how people are treated by decision-makers (i.e., an authority). Four factors are frequently used to describe procedural justice as well as voice, objectivity, respect, and dependability (Tyler and Murphy 2011). The first two, which deal with decision-making processes and incorporate voices, also deal with fairness; the second two, which deal with how people are treated by authorities, do so. During interactions with institutions of authority, people appreciate the chance to explain their situation or give their point of view. When given a "voice" (Tyler and Murphy 2011), people report feeling more satisfied with interactions because they perceive individuals in positions of control have made thoughtful decisions. Evidence that the authority they are working with is impartial is also welcomed by people. Making choices based on the facts of the case, rather than an officer's biases or personal opinions, is known as being neutral (Tyler 1990).

Additionally, it involves guaranteeing consistency and equality of treatment for all groups. According to Tyler (1990), people are highly receptive to cues that authority view them with respect and dignity. Because they feel they have a right to be treated with respect and decency, people react extremely negatively to displays of rudeness and demeaning interpersonal treatment. Last but not least, individuals look for indications that indicate the objectives and character of the legal authority they are working with (i.e., their credibility). People react

favorably to authorities when they believe they are nice and compassionate and are sincerely attempting to do what is best for the people they are working with (Tyler and Murphy, 2011).

The tremendous impact that procedural justice has on people's attitudes and behaviour is demonstrated by a large body of research. (Murphy, Hinds, and Fleming, 2008; Hinds and Murphy, 2007). We are aware that, in a number of settings, including policing, procedural justice can have a particular and positive effect on people's faith and confidence in authorities. For instance, procedural fairness promotes trust in law enforcement, according to Tyler and Huo's (2002) research. More so than other instrumental variables, procedural justice was a significant predictor of public confidence in police in their research of 1,656 Californians who had direct interactions with law enforcement.

Tyler (1990) further demonstrates, using survey data from 1,575 Chicago residents, that the quality of the treatment citizens experienced from police was the primary factor determining their trust and confidence in police. Research on procedural justice also demonstrates a connection between confidence in authority and ensuing cooperative behavior. Using survey data from 1,653 New Yorkers of different ethnic backgrounds (Whites, African Americans, and Hispanics), Tyler (2005) demonstrated that trust and confidence in police were a major predictor of the public's willingness to cooperate with police in crime fighting efforts across all ethnic groups studied. When people trusted the police, they were more likely to help them (DeCremer and Tyler 2007; see Scholz and Lubell 1998 for findings in other regulatory contexts). These findings are important because it seems that people's degrees of trust in law enforcement will influence how willing they are to assist and defer to officers in a variety of policing operations. It's crucial to comprehend why people respect the police because, as Tyler (2004) indicates, if people don't generally obey them, the police's ability to maintain order is put in jeopardy.

Despite being abstract, the concept of "trust" is one that is firmly established in experience. Based on their contacts with other individuals and previous experiences with organizations, people develop expectations about how they will be treated in the future (Goldsmith, 2005). If someone has been treated poorly, they are likely to have negative expectations for subsequent interactions, which can breed mistrust in the person or organization they engage with. "To say we trust you means we believe you have the right intentions toward us and that you are competent to do what we trust you to do," said Hardin (2006: 17) in defining trust. Hardin emphasizes both the interpersonal and practical elements of trust in this passage. It's crucial to distinguish between interpersonal and instrumental confidence (Murphy 2004). According to instrumental-based trust, trust is associated with competence and personal views about the likelihood of getting good results from dealing with authorities. For instance, in the context of policing, assessments of public safety may be connected to instrumental-based confidence. The argument in favor of this point of view states that individuals will make an immediate, costly effort, such as obeying the law, in the hopes of gaining some form of future, collective advantage, such as a decrease in crime rates and an increase in public safety.

Receiving these benefits was a positive experience, and this increased faith and confidence in the police, increasing the likelihood that more people would continue to follow the law. This viewpoint contends that if police do their duties effectively, deal with community concerns, and reduce crime, the public will have more faith and confidence in the institution of policing. On the other side, the negative experience of not receiving those advantages from the police would lead to a reduction in both trust and confidence in the police as well as compliance with the law. But

as Jackson and Bradford (2009) pointed out recently, confidence goes beyond simple public perceptions of how well and quickly police carry out their duties to also include a sense that the police are aware of community needs and treat people fairly. Therefore, interpersonal or socially based confidence is faith that is founded on social ties and treating others fairly. People will trust an authority figure's intentions, develop a long-term commitment to accepting its decisions, if people think that the police are striving to be fair, treat individuals with dignity and respect, and genuinely care about the public, they will be more likely to obey its laws (Tyler and Huo, 2002).

It would seem that establishing trust and confidence in the police depends on both how they behave and how the public perceives them. While not negating the influence of police performance in building trust and confidence in police, it has been suggested that interpersonal encounters may actually be more significant for determining a person's trust and confidence in authority. Researchers like Tyler and Huo (2002), Levi 1998, and Folger and Konovsky (1989) assert that the key to fostering trust is to act in a way that the public will regard as ethical.

POLICE LEGITIMACY

Hinds and Murphy (2007: 30) provide evidence that "[...] in contemporary, democratic societies, police legitimacy rests on public consent." In other words, the public is required to follow the police and their commands for them to be legitimate. Furthermore, it is impossible to disregard a person's choice to acknowledge the legitimacy of police authority and the power it possesses. According to Hinsch (in Jackson & Bradford, 2010: 3), moral compatibility between individuals and the criminal justice system should be the focus of the conversation. "If one follows these criteria, then judgements among individuals about the legitimacy of an institution must be based to some extent on assessments of the congruence between its goals, practices, and behaviors and their own," she writes.

According to Jackson (2010), legitimacy is more than just an explanation for power; it also serves as a justification for the power, which is known as "moral alignment" between people and the criminal justice system they use. Because of this, researchers must take into account a normative, ideological, or moral component of legitimacy. It is important to remember that legitimacy is founded on the expression of shared values. Jackson's framework of legitimacy was thus built on the understanding that "an individual confers legitimacy on the justice system when that individual feel: a) an obligation to obey the authority; b) that the authority expresses shared morals; and c) that the justice system follows its own internal rules" (Jackson, 2010: 10–11). People's faith in the legal system is almost inescapably shaped by their experiences; extant research indicates that the public's perceptions of the police are largely shaped by factors beyond their control, but authorities can also use their performance to build or deplete this stock of legitimacy and other attitudes toward them. Citizens' subjective perceptions of procedural fairness are influenced by a number of factors:

- When given the chance citizens are pleased when they "state their version towards the tale" and justify their behavior in front of the officials.
- Community members think governmental choices are supported by facts, they are pleased with.
- When people perceive that they have been treated with dignity and respect, they are more pleased.

- When people believe in the intentions of the authorities, they are more likely to be satisfied. This is especially true when the authorities' justifications for their actions show that they have considered the requirements and concerns of the populace.

The procedural justice paradigm of policing is centered on police legitimacy, or public confidence in and sense of duty to obey the police. Such perspectives are obviously crucial, but they are also crucial because research indicates that they contribute to a number of other desirable outcomes, including adherence to the law, information sharing with the police, collaboration on neighborhood issues, and acceptance of their decisions and directions during interactions with the latter. In accordance with Tom Tyler's based on processes regulation paradigm, trust is influenced by how authorities are perceived to use their authority. As a result, it would seem that trust may be increased by enhancing the procedural justice with which police behave. The National Research Council's Committee to Review Research (2004:291) defined legitimacy as "the judgments that ordinary citizens make about the rightfulness of police conduct and the organizations that employ and supervise them" with regard to the police in particular.

Tyler, though, has emphasized the significance of acknowledging authority as a mark of its legitimacy. Tyler (2004: 87) defined legitimacy for his seminal study of Chicago as "a perceived obligation to obey" as well as "support for legal authorities." Tyler emphasizes the importance of the latter concept, saying that "when people feel that an authority is legitimate, they authorize that authority to determine what their behavior will be in a given set of circumstances."

Nevertheless, latent constructions of support or confidence for the police are distinct from the construct of obligation, according to empirical research examining the characteristics of these legitimacy constructs. Reisig, Bratton, and Gertz (2007) concluded that trust and obligation are separate constructs with only weak relationships to one another during their examination of the construct validity of process-based measures. Underlying these identifiers is a two-dimensional structure that Jacinta Gau (2011) found. Furthermore, Reisig et al. (2007: 1022-23) discovered that while obligation had no effect on either compliance or cooperation, confidence did. As a result, we view obligation and trust as two separate social psychological aspects.

The most popular social psychological theory of legitimacy is Tyler's paradigm of process-based regulation. This concept holds that the supply of procedural justice while using police power to interact therewith the general population is the main antecedent of legitimacy (Tyler, Goff, and MacCoun 2015). The focus of procedural justice is on how rather than whether power is used. Police officers do not have to choose between being equitable and tough; they can be both, according to Schulhofer, Tyler, and Huq in 2011.

Although Tyler's model has been the conceptual cornerstone of social psychology research on police legitimacy, it would be a stretch to say that there is a consensus on what legitimacy is. Justice Tankebe (2013: 2014) states that police legitimacy has four dimensions: lawfulness, procedural justice, distributive fairness, and efficacy. She emphasizes that legitimacy should not be mistaken with either confidence or obligation. James Hawdon (2008) asserts that legitimacy is different from confidence. Ben Bradford and Jonathan Jackson (2009) indicate the fact that a great deal of the studies in the public's views regarding law enforcement depends upon the premise that citizens are drawn to a single outlook about the police that shapes their judgments about various aspects of the police, even though there may be significant differences among trust, confidence, support, satisfaction, and legitimacy. We recognize these warnings but do not

agree with their conclusions. Given these divergent ideas about authenticity and the potential for misinterpretation with organizational legitimacy, we lay the appropriate focus on trust and obligation.

People's opinions of the police are correlated with their subjective experiences with the police in one-on-one conversations, including either free-will interactions when people report crimes or ask for help and compulsory encounters when people are apprehended by police officers. The association demonstrates reciprocal causal relationships: police satisfaction with individual contacts promotes police satisfaction generally, while perceptions of police performance in particular police-citizen encounters are likewise influenced by police attitudes overall (Brandl et al. 1994).

THE INVARIANT EFFECT OF PROCEDURAL JUSTICE ON LEGITIMACY

The Relationship Between Procedural Justice and Police Legitimacy Needs to Be Reexamined Procedure justice, defined as the perception of fairness in a specific institution's decision-making and interactions with participants acting on its behalf (Tyler, 1990), has emerged as a leading theory in criminology and legal psychology. There is a large body of research emphasizing a strong and positive relationship between an individual's perceptions of procedural justice, their evaluations of the reliability of criminal justice institutions, such as the police, courts, and tribunals, as well as courts and prisons (Gau et al., 2012; Tyler & Wakslak, 2004), as well as their compliance with law-abiding behavior.

Researchers have discovered that there is a positive correlation between procedural justice and legitimacy in the context of encounters with the police that is significant across nations and demographic subgroups (Bradford et al., 2014a; Sun et al., 2017). Additionally, the empirical data seems to hold true for various meanings of legitimacy. For instance, Bottoms and Tankebe (2012) argued against the validity of measures drawing on the "obligation to obey" with an institution's norms, which prompted other researchers to investigate the "obligation to obey" and "trust" aspects of legitimacy independently (Baker & Gau, 2018; Wolfe et al., 2016). However, other researchers made a distinction between a person's "duty to obey" and their "moral alignment" with a particular organization (Hough et al., 2013; Jackson et al., 2012a; 2012b).

The observed relationship between procedural justice and legitimacy is almost always found to be positive, significant, and strong, at least for the body of research based on cross-sectional data, regardless of the measurement method or sample configuration. This was supported by Walters and Bolger's (2019) meta-analysis, which found that only one of the 64 studies they examined found a negative relationship between procedural justice and legitimacy (Reisig & Mesko, 2009). Most researchers have, more or less explicitly, interpreted these results as evidence of a causal impact of procedural justice on legitimacy, with a few notable exceptions (Murphy, 2005; Walters, 2018). Both intuitive and in line with the theoretical framework, this view. Police legitimacy and procedural justice need to be reevaluated.

It only needs to be understood that the formation of legitimacy beliefs comes before procedural justice and is an independent process that is entirely determined by the actions of agents of a given authority. Making such conclusions from a corpus of research, which is dominated by observational studies, which are most frequently cross-sectional surveys, is challenging (Murphy et al., 2016). This interpretation of the data ignores the fact that views of procedural justice and legitimacy are both subjective reports, and that for cross-sectional designs, their temporal order

cannot be determined. Some of these issues were noted by Nagin and Telep (2017). They came to the conclusion that there hasn't been a convincing case for causality after carefully examining how the procedural justice model has been used in policing studies. They identified third common causes (also known as third variables or confounding factors) and reverse causal paths as two key problems that previous procedural justice research has been unable to ignore. They demanded clearer proof regarding the causal impact of procedural justice as a result.

THE IMPORTANCE OF TRUST BETWEEN POLICE COMMUNITIES

The public's perception of the authorities' ability to act justly and efficiently (typically the police and courts) is referred to as confidence. Jackson (2010: 1) stresses the significance of people believing that the police and courts have the authority to regulate and prescribe proper behavior. In general, three viewpoints are used to study police trust: (1) police compliance; (2) police procedural fairness; and (3) police distributive fairness. Citizens' subjective expectations that police will act in certain expected ways, such as with honesty, respect, and effectiveness, are the foundation for citizens' trust in the police. These expectations are the result of both direct and indirect interactions with cops (Jackson & Gau, 2016). Depending on how they or someone they know has been treated in the past, people decide whether or not to trust the police. Hardin (2002) said.

Thus, people's perceptions of the police's treatment of people who are similar to them play a critical role in establishing their level of trust. The police must be trusted by both the public and the officers. If people don't trust the police, they might be less likely to ask for help or collaborate with them freely (Murphy et al., 2014). Police collaboration may suffer from public mistrust, making their job more difficult (Sunshine & Tyler, 2003). According to research, think that all Muslims are now viewed by the authorities as "suspects" (Cherney & Murphy, 2016). Numerous Muslims feel stereotyped and stigmatized as a result of the rise in Islamophobia over the past 20 years and the increased police monitoring (Blackwood et al., 2013; Spalek, 2010). However, it is not believed that one side of this mistrust is unjustified because many Muslims also believe that authorities are untrustworthy of them. The fact that many Muslims' reports mistrusting the police in this situation is not surprising (Cherney & Murphy, 2016; Madon & Murphy, 2021). One method to promote more confidence in these settings has been suggested procedural justice theory.

"The nature of trust and confidence needs to be addressed as a separate issue in and of itself if public trust and confidence in the police are not connected to objective performance. What constitutes the foundation for the perception of police legitimacy? We can assess policing policies and practices using a new paradigm if we can understand how public perceptions of police legitimacy evolve (Tyler, 2011: 255). According to Tyler (2011: 258), public perception and sentiments toward the police are significantly influenced by the manner in which and the caliber of a police officer's performance as well as his attitude toward the public during legal proceedings. The police must therefore put into practice strategies that support a community-based strategy that prioritizes public opinion, focusing on how the public perceives the police and the actions of the police.

Tyler (2011: 263) is certain that these societal perceptions influence how people respond to the police. Additionally, because it affects perceptions of and participation in the justice system, public confidence in policing is crucial and required. Furthermore, institutional legitimacy and widespread adherence to the law are significantly impacted by public confidence in the justice system. Jackson, Bradford, Hough, and Murray (2012: 30) define police legitimacy in this manner

and connect it to legal legitimacy, cynicism, and adherence to the law by defining it as "obligation to obey and moral.

PROCEDURAL JUSTICE-BASED MODEL OF POLICE ACTION

The application of this collection of research to police practice is not straightforward, though. The comprehensive research on procedural justice and legitimacy serves as the foundation for the procedural justice model of policing that is described by Stephen Schulhofer et al. (2011). They raise an important point: people can still be satisfied with their interactions with police even in cases where the outcomes are negative for them, as long as they believe they were treated fairly. The outcomes, such as whether or not a citizen is ticketed, searched, or even arrested, are not indicative of the subjective experience of those citizens.

As they stress, the implication is that police are not required to choose between "toughness" and "fairness." When officers carry out enforcement actions while mindful of procedural justice, they can be both "tough" and fair: "Instead of attempting to instill fear or project power, officers would aim to treat citizens courteously, briefly explain the reason for a stop, and, absent urgent circumstances, give the citizen an opportunity to explain himself before significant decisions are made" (Schulhofer et al. 2011: 352).

Since no enforcement is not recommended by the procedural justice paradigm. It concerns how police power is used, not whether it is used. When it comes to the forms that procedurally just policing takes on the street and its justification, the procedural justice model is extensive. However, it is rather condensed when it comes to the administrative measures that police agencies should take to put the model into operation. One of these measures is the creation of protocols for procedurally just enforcement (Schulhofer et al. 2011).

... such actions could be made a standard component of every officer's conduct while on duty. Operational policies within each department could formalize the proper actions in relation to street stops, such as the requirement for polite treatment, the duty to inform the citizen of the reason for the stop, and the right to an opportunity to explain the situation. The rules governing police stops might simply be summarized on a card that officers may carry and deliver to those they stop. The rights that must be upheld would be listed on the card, along with the procedures for submitting a complaint against unfair treatment. These rights include the right to an explanation of the grounds for the stop and the right to present one's case before decisions are taken (Schulhofer et al. 2011: 354).

In addition, we would anticipate that police agencies who used this model would set and implement policies governing the proper use of force by their officers in compliance with procedural justice. According to Schuck and Rosenbaum (2011) and Skogan, Van Craen, and Hennessy (2014), they would train their operators in social interactions with citizens. They would keep an eye on the present indications of police performance, such complaints and the use of force, and, realizing the limitations of these metrics, they would give supervisors the task of conducting on-the-spot inspections of the quality of police-citizen interactions. Accountability mechanisms ought to prioritize results over mere output counts. If unit commanders are to be held responsible for results and for putting up sincere attempts to influence those results in ways that are desired, then outputs are significant primarily as the results or byproducts of successful tactics. Compstat's measurement of outcomes is typically limited to criminal activity, which means that significant outcomes that should be the focus of police attention are left out. Mark

Moore outlines several performance factors, or results, that demonstrate the importance of law enforcement. These include:

- Lessen abuse by criminals;
- Bring criminals to justice;
- decrease fear and increase physical safety;
- Ensure protection in public areas;
- Utilize money resources in a fair, effective, and efficient manner;
- Fair, efficient, and successful use of force and authority;
- Fulfill client demands, and gain credibility with those under police scrutiny (Moore 2002: 131–33).

IMPLICATIONS OF "CUSTOMER SATISFACTION"

By employing a customer example, police managers should create a mindset and policing strategy that is more customer-focused. It is conceivable that considering the people with whom law enforcement engages as clients will boost awareness of both what the public expects of the police and the value of interpersonal ties. Police officers would be more approachable with the public if they adhered to the procedures that define procedural justice, such as asking for and taking into account citizen accounts of their interactions with police, acting civilly, and disclosing their actions and motives. According to a study, these procedural elements are significant for people who contact with the authorities. Even though the customer comparison has its limitations, its dimensions' ambiguity encourages or permits officers to interpret it in various ways.

A true customer in a private market transaction is someone who decides to look for a good or service, finds a supplier, calculates the cost, and then participates in a transaction that involves paying the agreed price for the good or service. The price that the consumer is ready to pay for them symbolizes the absolute minimum value that she sets on them. Both parties are freely exchanging goods and services. If the product or service met her expectations in respect to the price she paid for it, it will determine whether she was ultimately satisfied with it. The benefit of the good or service will probably only benefit her and her family, and it won't benefit any other persons not participating in the transaction.

This kind of consumer is comparable, in certain respects, to someone who phones the police to report a loud party or the theft of a bicycle. He asks for a service, such as official acknowledgement and documentation of a crime of which he is the victim or third-party action to cease a situation that he considers to be a disruption. He may decide to forego any help in locating the bicycle or in making an insurance claim, or he could decide to put up with the commotion that the party represents until it stops on its own without his help. It is fully voluntary and on his own initiative that he interacts with the police.

However, this transaction is non-voluntary because the person has no other options in the police market and is often required to contact his municipal or town police force in order to acquire police assistance from any organization. The service is free to him since the community has already paid for it, in addition to any taxes he may pay (which he must pay whether he uses the service or not). As a result, when the service is rendered, he does not pay a set fee for it.

A community member is still a consumer who pays for the officers' availability and presence even if she never asks for assistance from the police with a particular problem. The benefits from the police services for which she pays are shared by the entire community, not just her and her family. These are collective, not individual, services. In another sense, the payment for these services is not voluntary because taxes that support police activities are forced payments.

According to Mark Moore (2002), an officer's ability to provide prompt service to a more urgent situation may be compromised by the time she spends providing high-quality service to one complainant. This is because it's possible that sacrificing offering customers high-quality service might allow police to be ready to respond to emergency calls. In principle, police are not permitted to offer "customers" what they demand when doing so would go against their legal or resource restrictions. Assumed offenders have "obligation encounters" with police, so the police also deal with citizens who come into touch with them (Moore 2002). What kind of assistance is rendered to those who are detained by the police for booking, those who receive traffic tickets, and those who are pulled over for questioning on foot? Given that they may have transgressed moral and/or legal boundaries, to what kind or degree of service are they entitled? At the absolute least, their rights to be protected from arbitrary intrusions into their person and property, to be subject to no more force than what is required to overcome any resistance they may offer, and to be subject to no more force than the minimal standard of service stipulated by the Constitution, must be respected.

We would expect an even better quality of service than that, in the form of treating residents and officers with respect, given its inherent value as well as its potential instrumental usefulness in obtaining compliance and reducing injuries. However, "client" could be a preferable term to use when referring to these persons who employ police services as "customer" is probably overused. Like the beneficiaries of many human services, many persons who deal with police, including those of those who need their assistance, frequently lack knowledge of what they ought to. Some of them can't think clearly because of their mental illness or intoxication. Even if they do not take drugs or have a mental disorder, they may not be qualified to assess the quality of the available service options. This is true of many consumer decisions. A single mother of a rebellious kid who calls the police in a panic may not know what the cops can or should do to assist. If we assume that the consumer is always right, the customer service example will be flawed.

Consequently, there are several reasons why the customer service analogy is flawed: clients, as we will refer to those who receive police services, are typically not voluntary in the sense that they do not have a meaningful range of choice in service providers; some interactions are clearly uninvited; some clients might not be able to make an informed decision; and clients might not have access to crucial information that would enable them to assess the quality of the services they receive. We could also point out that, unlike companies in the private sector, police do not reward repeat customers; nonetheless, they would reward public "loyalty" if it implied support and cooperation from the public. Customer happiness study, which also offers some further insight into the degree of satisfaction that the public has with the police, is consistent with these findings. The first is that "products" are more likely to please customers than "services" are (Fornell et al. 1996). Services are "co-produced" by the provider and the consumer, which means that the provider has less control over the production process and is less likely to standardize it (Anderson, Fornell, and Rust 1997).

BENEFITS OF PROCEDURAL JUSTICE FOR THE POLICE

Because it affects outcomes at the individual, team, and organizational levels, the idea of organizational justice is essential. Research indicates that organizational fairness is linked to benefits such as:

- trust,
- job performance and satisfaction,
- organizational commitment, and
- organizational citizenship behaviors (Colquitt et al., 2013).

The association between organizational justice and unfavorable outcomes such unproductive work behaviors, turnover, and burnout is consistent with the fact that workers who believe that procedures and outcomes are fair tend to engage in less of these bad behaviors (Colquitt et al., 2013). Ensuring just and equitable processes and outcomes is crucial for businesses to treat their workforce equitably. Organizations can ensure transparent and equitable organizational processes to maintain employee commitment to the organization's goals.

KEY TAKE-AWAYS IN PROCUDURAL JUSTICE IN THE ARTICLE

1. The three primary types of organizational justice are distributive, procedural, and interactional;
2. Employees experience distributive justice when they think that results are fair;
3. The objective of procedural justice is to ensure that decisions are made fairly;
4. Interactional justice emphasizes how a person is treated when choices are made;
5. Interactional justice is the outcome of effective communication;
6. When employers involve workers in decision-making, there is an improvement in perceptions of justice;
7. Perceptions of fairness are influenced by state and trait;
8. Organizational fairness affects both individuals and teams;
9. Individual, team, and organizational results are affected by organizational justice.

RECOMMENDATION OF PROCEDURAL JUSTICE FOR THE POLICE

Recommends that adherents have a clear legal framework for the enforcement of competition law, including laws and regulations defining and governing competition, rules, policies, or guidance regarding the identification and handling of confidential information, and fair and clear rights and obligations for parties and third parties. As a result, adherents should:

1. Assure the transparency and predictability of the application of competition law by making the following provisions: the competition authorities' legal framework and procedures, as well as the relevant deadlines and procedures for filing requests for judicial review of decisions, must be made public;
2. Subject to the preservation of confidential information, publishing the facts, legal foundation, and sanctions pertaining to decisions, including decisions to settle cases; promoting transparency of competition authorities' enforcement priorities; and;
3. Supporting the implementation of international competition law enforcement transparency and procedural fairness best practices.
4. Ensure that law enforcement is impartial, independent, and professional by ensuring that it is carried out by accountable public bodies that are free from political interference or pressure, and that interpret, apply, and enforce competition law based on relevant legal and economic arguments rooted in sound competition policy principles;

5. Ensuring that all pertinent information and evidence are properly considered by competition authorities and judges;
6. Enforcing competition law with clear and transparent rules that prevent, identify, and resolve any material conflicts of interest among competition authorities and court personnel;
7. Ensuring that competition authorities have the knowledge of competition law, economics, or other pertinent subjects, as well as adequate human, financial, and enforcement resources, to carry out their responsibilities successfully;
8. Maintaining officials' duties to keep information received in their official capacity confidential; and;
9. Supplying authorities with sufficient investigative and cooperative instruments to carry out competition law enforcement efficiently.

Make Sure That the Application of Competition Law Is Impartial, Reasonable, and Consistent in All Instances That are Similar, In Particular By:

1. Tailoring inquiries to the gravity and specifics of each case, and preventing the competition authority or parties from incurring unnecessary costs or obligations;
2. Tailoring inquiries to the gravity and specifics of each case, and preventing the competition authority or parties from incurring unnecessary costs or obligations;
3. having uniform rules and guidelines for the procedures used in competition law enforcement, including information requests, inspections, and interviews, as well as making sure that these procedures do not stray outside the parameters of the inquiry;
4. Applying internal controls to guarantee the legality, proportionality, and consistency of procedural procedures;
5. Evaluating an investigation's progress at crucial points and choosing whether to continue an investigation or end it;
6. Ensuring impartial decision-making by carefully evaluating the facts and proof and implementing internal checks and balances for judgments;
7. making sure that all correspondence between the decision-maker (e.g., competition authority or court, as appropriate) and the parties and third parties is in writing or, if oral, is documented, as much as is practical, in written minutes that are part of the case file or record.

Protect Privileged and Confidential Material

Considering the public's interest in open and efficient competition law enforcement, as well as the right to a defense and other legal rights, in particular by:

1. Ensuring that the competition authorities take the necessary precautions to prevent the unwarranted disclosure of confidential information that they are in control of; and
2. Take into account establishing, revising, or enhancing procedures for handling privileged communications between lawyers and clients and upholding any relevant legal privileges.

Make Sure You Can Receive a Fair Evaluation

Decisions, including intermediate mandatory procedural decisions, are made by an adjudicative body (a court, tribunal, or appellate body) that is autonomous and distinct from the competition authority. Therefore, adherents ought to:

1. Allowing courts to examine facts, evidence, and the merits of judgments regarding the enforcement of competition laws;

2. Demand that all decisions be made in writing, solely on the basis of records, and comprise information about the relevant findings of fact, legal conclusions, and sanctions;
3. Consider the character and complexity of the case as you work to finish the review in a reasonable amount of time.

Review their legal framework, public policies, and rules, procedures, and guidelines for the competition authority on a regular basis to make sure they adhere to this recommendation, to enhance their enforcement methods, and to pursue convergence with best practices.

CONCLUSION

According to the process-based model of regulation, when the public views authoritative figures as reliable and legitimate, compliance, cooperation, and empowerment are more likely to occur. While academics have focused a lot of attention on the causes and effects of legitimacy, trust has received much less attention. The current research showed that levels of trust among citizens are partially influenced by perceived collective efficacy. However, when procedural justice views are taken into account, the impact of perceived collective efficacy is heavily muted. These two results close significant voids in the process-based literature. If Tyler's process-based model were strictly followed, it would imply that procedural justice should totally override (i.e., mediate) the impact of perceived collective efficacy on citizen trust levels.

However, our results show that even after taking procedural justice into consideration, perceived collective efficacy is still important. This indicates that (a) perceived collective efficacy, while not as important as procedural justice, is crucial to the explanation of trust in and of itself, and (b) procedural justice is a main antecedent of trust. Therefore, when examining public confidence in the police, future study should not ignore the impact of citizen perceptions of collective efficacy. Having said that, there are a number of theoretical and practical consequences that call for more discussion. Literature on the foundations of police confidence. Procedure fairness, which includes respect, objectivity, and status recognition, appears to be crucial in how people evaluate how much confidence to place in law enforcement. Our findings show that, despite being different concepts, the process-based model explains citizen confidence in the police in a manner similar to how it explains assessments of police legitimacy.

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The Relationship Between Physical Learning Environment and Academic Achievement of Learners in Inclusion: Across-Sectional Survey with Secondary School Students in Uganda

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Abstract:
This study examined the student's perception of their school physical learning environment (Specifically, how accessible, Appropriate and Suitable) and how it relates to academic achievement of all learners in an inclusive secondary school setting. Data was collected using self-administered questionnaires from 309 Participants including learners, teachers and head-teachers. We examined the relationship between the elements of physical learning environment (accessibility, suitability and appropriateness) and academic achievement of learners with and without special educational need. Data was analyzed using statistical package for social scientist (SPSS) version 25.0. Results showed that there was a moderate positive statistically significant relationship between physical learning environments and academic achievement of learners in inclusive secondary schools in Uganda (r=, 452, p<0.01). Results also showed that the elements of physical learning environment namely; Accessibility of physical learning environment (r=. 431, p<0.01); Suitability of physical learning environment (r=. 410, p<0.01) and appropriateness (r=. 335.p<0.01) had a positive statistically significant relationship with academic achievement of all learners including those with special educational needs. Results from the multiple regression analysis showed that 27% of academic achievement of learners was determined by the elements of physical learning environment with accessibility and suitability of the physical learning environment were the most significant predictors of academic achievement for all learners. We concluded that physical learning environment is fundamental in determining academic achievement of all learners in inclusive secondary schools in Uganda. Interventions should therefore target accessibility and suitability of the physical learning environment if academic achievement of learners in inclusive secondary schools is to be enhanced.

Keywords: Physical learning environment, accessibility, suitability, appropriateness, academic achievement

INTRODUCTION

It is well recognized that the physical learning environment of the school has a significant impact on how well inclusive secondary schools are able to physically and instructionally engage all students (Ackar-Jnr & Danso, 2019). According to Duruji, Azuh, and Oviasogie (2014), a variety of physical learning environments, including classrooms, restrooms, ample seating, safe play areas, boreholes or water sources, ventilation, desks, lighting, change rooms, walkways, desks, libraries,

and laboratories, are linked to effective teaching and learning as well as academic achievement for all students, regardless of individual differences.

Research has demonstrated that having a well-maintained physical school infrastructure is a prerequisite for all students' academic success, and this is particularly true for inclusion students (Ackah-Jnr & Danso, 2019; Korir & Kemboi, 2014). Nevertheless, the issue of how well inclusive schools' physical learning environments—where students interact, learn, and socialize with one another or with teachers—are frequently disregarded (Ucci et al 2015).

However, inclusion asserts that in a secure physical learning environment, all students may study, participate, and achieve academic success (Ackah-Jnr, 2016, Evanita, 2021). Thus, students—especially those with disabilities—are more likely to succeed academically when they receive the proper attention, resources, and support in an age-appropriate general education classroom (Ramelow et al., 2015; Wang et al., 2021).

Similar to other developing nations, Uganda has acknowledged educational inclusion and committed to implementing it through a number of national legislative frameworks and policies, such as the Education Act of 2008, the Disability Act of 2008, the UPE (1997) and USE (2007), and most recently, the inclusive education policy of 2019.

Uganda has also regionally developed all-inclusive pilot school geographically to complement regular schools to teach children with disabilities in addition to maintaining special schools for learners with severe disabilities (MoES, 2018). The inclusive schools support the operationalization of Uganda Government policy objective to implement inclusive education, which aims to provide accessible and equitable education to all children with mild special educational needs in mainstream schools and full enrolment of hard to reach and out of school children (MoES, 2016).

The goal of the current study was to determine how much the physical learning environment in inclusive secondary education influences students' academic achievement. The majority of studies (Duruji, Azuh, & Oviasogie, 2014) concentrated on the physical infrastructure of the school; however, the present study will utilize Ackah-Jnr and Danso's (2019) operationalization of the physical learning environment in terms of its appropriateness, suitability, and accessibility, as well as how these elements relate to the academic achievement of all learners in inclusion.

LITERATURE REVIEW

The Physical Learning Environment

In terms of physical structures, the idea of a physical learning environment refers to the areas, furnishings, and resources found in educational institutions. The physical aspects of the school and classroom, such as the lighting, ventilation, room size, desks, chairs, white board, computers, restrooms and changing areas, safe play areas, and clean water sources, are the main focus of the physical learning environment. MoES (2011).

Research has shown that, particularly in inclusive education settings, a student's comfort level, capacity to learn, and academic success can all be impacted by their physical learning environment (Achah-Jnr, 2016; Eimuhi & Ogedegbe, 2016). As a result, a well-designed physical learning environment improves students' psychological comfort and social interactions with teachers and their peers (Ackah-Jnr, 2016). An inclusive school's physical learning spaces should

be planned to be easily accessible, encourage student participation, and support academic success for all students (Ackah-Jnr & Danso, 2019).

All students' physical and mental health depend on the school's physical learning environment, which includes the playground for sports, the school compound, and other physical activities (Ackah-Jnr, 2016). Therefore, learners' opportunities to participate in and engage in effective outdoor play, sports, and games, as well as benefit from such physical activities in school, are limited by the physical learning environment of inclusive schools, such as hilly compounds or story buildings (Wang et al, 2021). Dear Ackar Jr. (2016), as a result, an inclusive school climate lowers needless barriers to learning and boosts all students' academic access, engagement, and accomplishment.

This study adds to the discussion on the relationship between academic achievement in inclusive schools and the physical learning environment by examining the suitability, appropriateness, and accessibility of the physical learning environments in Ugandan inclusive schools and how they individually or collectively relate to academic achievement in inclusion.

Academic Achievement

Academic Achievement indicates performance outcomes that demonstrate the amount to which a person has fulfilled specified goals that were the focus of activities in instructional environments, specifically school, college and university (Szumski et al, 2022). Academic accomplishment is mentioned in a number of international frameworks as a factor in guaranteeing high-quality, equitable, and accessible education, including (UNESCO, 2017; World Bank, 2015; Salamanca, 1994; EFA, 2000, SDG 4).

Academic achievement is defined by frameworks like the Salamanca 1994 Framework, which takes both success in the classroom and outside of it into account (Suleymanov, 2014). Research has indicated that while evaluating academic performance in schools may be done with ease using grades and test scores, evaluating success outside of school is more difficult because there are no systems in place for follow-up (Dessesmontet et al, 2012).

Empirical evidence has revealed that most times academic achievement of regular learners is higher than those of learners with special educational needs when placed in inclusive educational setting and this is true at all levels of education (Ekeh & Oladayo, 2013, Farrel et al, 2007, Dyson, 2006). They pointed out that if obstacles to instruction are removed and students with special needs receive the necessary support services and attention, their academic performance may match or exceed that of typical students in the same classroom (Ekeh & Oladayo, 2015).

Additionally, studies reveal that students with special needs who participate in inclusion programs achieve better academic goals than students who do not (Ekeh & Oladayo, 2015; Szumski et al, 2017). According to studies conducted by Ekeh and Oladayo (2015) and Dessemontet et al. (2012), regular students in inclusive schools achieved better academically than regular students in non-inclusive schools. According to this research, students who were raised in inclusive classes performed better academically than students who were reared in non-inclusive classrooms.

All of the mentioned studies, however, used inclusionary primary school students as opposed to those in normal primary schools. There are not enough studies on learners' performance in secondary education. Thus, in light of the physical learning environment, the current study will

examine the academic achievement of students in Northern Ugandan secondary schools who have special educational requirements and those who do not.

The Relationship between Physical Learning Environment and Academic Achievement of Learners in Inclusion

Many research studies have examined the relationship between students' academic performance in regular schools and their physical learning environment (Kagoda, 2011; Duruji et al, 2014; Kigenyi, Kakuru & Ziwa, 2017; Wolf, Barry & Fraiser, 2007). Some of these studies have found a strong positive relationship between academic performance and physical learning environment (Kigenyi et al, 2017), while others have found a moderate but statistically significant relationship between academic achievement and physical learning environment (Kagoda, 2011; Kamarruddin et,al, 2009). Wolf et al. (2007) found that students' academic progress in schools was predicted by their physical learning environment. Whereas these studies produce outstanding findings most of them had incredibly big sample sizes (wolf et al, 2007; Duruji et al, 2014) and all of them were conducted in regular schools with emphasis on physical learning environment and academic achievement.

Similar studies have also been carried out in inclusive schools, focusing on the relationship between the physical learning environment and the academic achievement of all students (Ackah-Jnr, 2016; Ackah-Jnr &Danso, 2019; Gietz &McIntosh, 2014; Hewett et al, 2017; Blecker & Boakes, 2010; Ezike, 2018). The findings of these studies demonstrate a strong statistically significant relationship between academic achievement and the physical learning environment, with classrooms, ventilation, restrooms, play areas, desks, changing rooms, and clean water sources being among the physical infrastructure.

However, most of these studies were conducted using mixed method (Ackah-Jnr, 2016; Ackah-Jnr & Danso, 2019) while some studies relied on teacher's perception of the quality of the physical learning environment (Blecker & Boakes, 2010) and some were qualitative in nature (Hewett et al, 2017). The current study is purely quantitative in nature with a reasonable sample size of 309 respondents consisting of both learners and teachers on their perception of the school physical learning environment and how it related to academic achievement of all learners in inclusion. Based on this approach our study may yield unique findings that will contribute to the conversation.

- H01: There is no relationship between Physical Learning environment (Accessibility, appropriateness and suitability) and academic achievement of learners in inclusion.

METHOD

Participants and Procedures

The study used cross-sectional survey research design to collect data from all-inclusive secondary schools from three Districts of Northern Uganda (Gulu, Lira and Arua). The sample comprised of 309 students (61.8% males; 38.2% females) with 63.8% learners with disabilities and 36.2% without disabilities. Regarding the nature of disabilities, 18.8% of the participants were visually impaired, 17.2% were physically impaired, 13.6% hearing impaired, 4.5% were deaf, 5.7% were blind and 4.0% were mentally retarded. These participants were included in the study based on the following criteria's;(i) all learners with disabilities in the school were included in the study, (2) Regular learners who are close friends with those with disabilities or their attendants and (3) Learners from all- inclusive secondary schools. The all –inclusive schools are those secondary

schools with annexes of special needs and they are regionally established by the ministry of education and sport for instance, Gulu High secondary school in Northern Uganda, Nancy secondary school in Lango sub-region and Nvara secondary school in West Nile region. Data was collected from those who met the above criteria with permission from the district education officer, school administration and active involvement of the department of special needs and inclusive education in the selected school.

Instruments and Measurements

Physical learning environment was measured using the Basic requirement and minimum standard monitoring tool (BRMS) developed by the ministry of education and sports (MOES, 2001). The tool consisted of (18) items measuring Physical learning environment. With (7) items measuring accessibility of the physical learning environment, (6) items measuring the suitability of the physical learning environment of the school and (5) items measuring appropriateness of the physical learning environment in the inclusive schools. The items were scored on a five-point likert scale ranging from 1=strongly disagree to 5=strongly agree. We asked questions such as; an area or space that is appropriate for all learners exist, the school buildings (Dormitories, class, toilet, offices, staffroom) are ramped making it easily accessible for all learners, and the physical environment is suitable for all learners including those with disabilities. The questionnaire was reliable for the current study, with acceptable internal consistency (α =0.89).

Academic achievement was measured using the inclusion index tool (Azorin& Ainscow, 2020). The tool consisted of (61) items; with (16) items measuring academic achievement of learners in inclusion while the remaining items measured other aspects of the inclusion matrix (Access, presence and participation). The items were scored on a five-point likert scale ranging from 1=strongly disagree to 5=strongly agree. We asked questions such as; what grade did you obtain in the recent assessment, what was your position in the class in the most recent assessment. The instrument revealed a strong internal consistency of (α=0.97) for the (16) items measuring academic achievement.

Procedures

After ascertaining the suitability of the tools, we embarked on recruitment of research assistant for the study. Through a rigorous and transparent process, we recruited research assistants who were graduates grounded in English, knowledge of inclusive education and from the indigenous population. We also included all the teachers in the special needs annex of the inclusive school, a department responsible for handling special issues. These research assistants were trained on the basics of the questionnaire administration processes, handling of respondents and interviewing techniques. The research assistants were trained to administer the questionnaire within 45-50 minutes.

Ethical Consideration

As a general requirement for graduate research, our proposal was submitted to Gulu University research and ethics committee (GUREC) an affiliate to Uganda National council of science and technology (UNCST) a body that oversees all scientific investigations in Uganda. After successfully defending the proposal, approval was granted to collect data (Protocol no. GUREC-2023-523). Subsequently written informed consent and assent forms were developed for all the respondents. Refreshments were served to all respondents and a moderate transport refund of 10,000shs was given to respondents. We also employed a counsellor and a nurse who were on

standby just in case a learner broke down during data collection. We catered for confidentiality, access, voluntary participation and protected respondents from bodily harm.

DATA ANALYSIS

The study used Pearson product moment correlation coefficient was used to measure the relationship between physical learning environment and academic achievement of learners in inclusion. Linear and multiple regression analysis were also run to ascertain the degree of predictability of study variables. In this study all our statistical analyses were run using IBM SPSS statistical software, version 25.0. Associations between variable with a $p < 0.05$ were considered statistically significant.

RESULTS

Results of the analysis shows that there is a moderate positive statistically significant relationship between physical learning environment and academic achievement of all learners in inclusion (r=. 452, p<0.01) with all the constructs of physical learning environment showing a positive statistically significant relationship with learners' academic achievement, Accessibility of physical learning environment (r=. 431, p<0.01), Suitability of physical learning environment (r=. 410, p<0.01) and Appropriateness of physical learning environment (r=.335, p<0.01). We therefore reject the Null hypothesis and state that there is a positive statistically significant relationship between physical learning environment and academic achievement of learners in inclusion in secondary education in Uganda. Implying that the physical learning environment is an important determinant of learner's academic achievement in inclusion in secondary education in Uganda.

Results of multiple regression analysis show that 27% of learner's academic achievement is determined by the physical learning environment and the other 73% was determined by other unknown factors. The model also shows that Accessibility of the physical learning environment (p<0.05) and suitability of the physical learning environment (p<0.05) are the only statistically significant predictors of academic achievement of learners in inclusion. Implying therefore that interventions should emphasize the accessibility and suitability of the physical learning environment in order to enhance learner's academic achievement. Results also show normal p-p plots for physical learning environment and a detrended normal p-p plot for learner's academic achievement implying that parametric tests were desirable for the data processing.

Table 1.0

		Achievement for all learners	Physical environment	Accessibility	Suitability	Appropriateness
Achievement for all learners	Pearson Correlation	1	.452**	.431**	.410**	.335**
	Sig. (2-tailed)		.000	.000	.000	.000
	N	309	309	309	309	309
Physical environment	Pearson Correlation	.452**	1	.860**	.881**	.864**
	Sig. (2-tailed)	.000		.000	.000	.000
	N	309	309	309	309	309
Accessibility	Pearson Correlation	.431**	.860**	1	.634**	.595**
	Sig. (2-tailed)	.000	.000		.000	.000

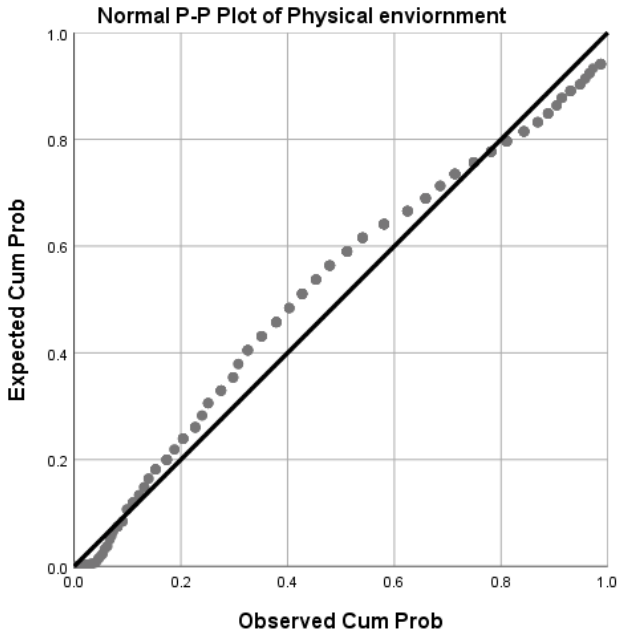
	N	309	309	309	309	309
Suitability	Pearson Correlation	.410**	.881**	.634**	1	.662**
	Sig. (2-tailed)	.000	.000	.000		.000
	N	309	309	309	309	309
Appropriateness	Pearson Correlation	.335**	.864**	.595**	.662**	1
	Sig. (2-tailed)	.000	.000	.000	.000	
	N	309	309	309	309	309
**. Correlation is significant at the 0.01 level (2-tailed).						

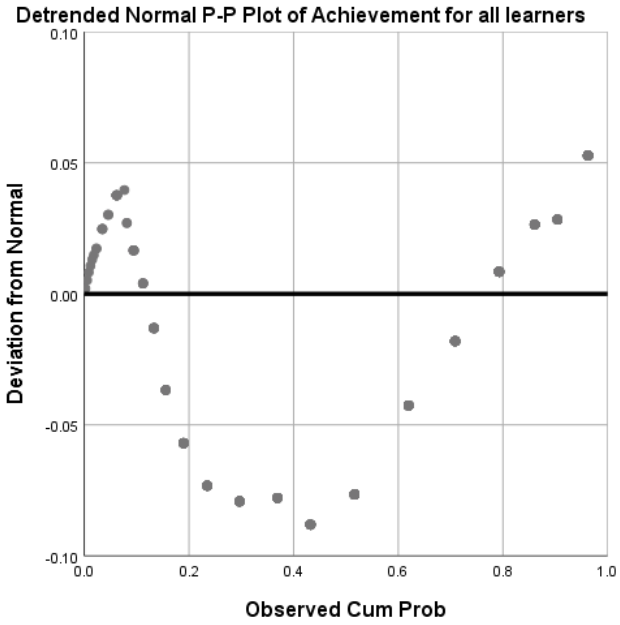
Table 2.0

		Achievement for all learners	Physical environment
Achievement for all learners	Pearson Correlation	1	.452**
	Sig. (2-tailed)		.000
	N	309	309
Physical environment	Pearson Correlation	.452**	1
	Sig. (2-tailed)	.000	
	N	309	309
**. Correlation is significant at the 0.01 level (2-tailed).			

Table 3.0

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	22.242	1.722		12.915	.000
	Accessibility	.256	.063	.277	4.039	.000
	Suitability	.206	.070	.217	2.937	.004
	Appropriateness	.026	.068	.027	.377	.706
a. Dependent Variable : Achievement for all learners						





DISCUSSION

The study assessed the relationship between Physical learning environment and academic achievement of all learners in inclusive secondary education in Uganda. It has been suggested that Physical learning environment is a fundamental determinant of academic achievement of learners in inclusive secondary education (Ezike, 2018; Madudili, 2021). In this study we argue that Physical learning environment is an important determinant of Academic achievement for learners in inclusion. We noted that the accessibility, suitability and appropriateness of the physical learning environment was an antecedent to enhanced academic achievement of all learners in inclusion.

We hypothesized that there was no relationship between the physical learning environment and academic achievement of learners in inclusion. Results however showed that there was appositive statistically significant relationship between physical learning environment and academic achievement of all learners. We therefore rejected our Null hypothesis and accepted the alternative, which states that there is a positive statistically significant relationship between physical learning environment and academic achievement of all learners in inclusion. This finding is in agreement with a study by (Kigenyi et al, 2017, Kagoda 2011, Ucci, et al, 2015) who noted that the success of learners in any academic task depended on the quality of the physical learning environment of the school especially how the classrooms are organized, the availability of teaching learning aid and ventilation.

Results from the multiple regression analysis showed that accessibility of the physical learning environment and suitability of the physical learning environment were the most statistically significant predictors of academic achievement of learners in inclusion. This result is supported by studies by (Ackah-Jnr &Danso, 2019;Kamarrudin et al, 2009) who emphasized that learners academic achievement especially in inclusive setting depended heavily on the accessibility of the physical learning environment in terms of availability of ramps, toilets with enough stances, water source in school and classroom arrangement, similarly s study by (Hewett et, al, 2017;Evanita, 2021) noted that a suitable and appropriate physical learning environment was fundamental to academic achievement of all learners including those with special educational need.

LIMITATION

The study was conducted in inclusive secondary schools in three districts in Uganda (Gulu, Lira, Arua). We suspect that the government had invested heavily on improving the quality of learning environment in these schools given that it accommodates both learners with and without special educational needs. We believe that if the study was conducted in non-inclusive setting may be results would be different, therefore future studies should consider the physical learning environment of non-inclusive schools. Secondly being a cross-sectional study, the associated weaknesses of a cross-sectional study might have affected the findings of this study.

CONCLUSION

Results have shown that all the facets of physical learning environment (Accessibility, suitability and appropriateness) are significantly related to learner's academic achievement and most importantly that the accessibility and suitability of the physical learning environment were the most statistically significant predictors of learner's academic achievement. We concluded that physical learning environment is fundamental determinant of academic achievement of learners in inclusive secondary education in Uganda

RECOMMENDATION

Secondary school systems should consider the accessibility and suitability of their school physical learning environment in their programming if high academic achievement is to be achieved with keen interest on an inclusive architectural design of the school, classrooms, toilets and wash rooms.

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COMPLIANCE WITH ETHICAL STANDARDS

The Uganda national council for science and technology and Gulu University research and ethics committee approved this research no: (GUREC-2023-523)

CONFLICT OF INTEREST

The authors declare no conflict of interest

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The Interface between Self-Determination Attributes and Inclusion: A Cross-Sectional Survey of Secondary School Students in Uganda

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Abstract:
This study examined the interface between self-determination attributes and inclusion in secondary education in Uganda. We examined the interface between the attributes of self-determination (perceived autonomy, Competence and relatedness) and inclusion of learners with and without special educational needs in secondary education. Data was collected using closed ended self-administered questionnaires from 309 students. Data was analyzed using statistical package for social scientist (SPSS) version 25.0. Results showed that there was a moderate positive statistically significant relationship between self-determination attributes and inclusion (r=. 409, P<0.01). The table also shows that all the attributes of self-determination had a moderate positive statistically significant relationship with inclusion; Perceived autonomy satisfaction (r=. 318, P<0.01), Perceived competence satisfaction (r=. 346, P<0.01) and Perceived Relatedness satisfaction (r=. 336, P<0.01). This implies that there is a positive interface between all the attributes of self-determination and inclusion of learners in secondary education in Uganda. Results of multiple regression analysis show that 57% of the variance on inclusion could be attributed to the elements of self-determination namely; perceived autonomy satisfaction (P=. 002 B=. 523 t=2.263), Perceived competence satisfaction (P=. 007 B=. 563 t= 2.263) and Perceived Relatedness satisfaction (P=. 004 B=. 693 t= 2.692). The above results show that perceived autonomy satisfaction and perceived relatedness satisfaction were the only statistically significant predictors of inclusion. Interventions aimed at improving inclusion should therefore emphasize development of autonomy and relatedness as psycho-educational interventions.

Keywords: Self-determination, Attributes, Inclusion

INTRODUCTION

The population of regular secondary schools has become more diverse over the past 30 years, the diversity of the completion rate has remained low, possibly as a result of the low enrollment of students with special needs in regular secondary schools (Ainscow, 2020). International funding agencies and government ministries have become fixated on increasing the number of students with special educational needs in inclusion under the banner of achieving inclusion excellence in recent years. Significant inclusion in secondary education requires changes at many levels, from the individual student to the school as an institution, and should involve a variety of stakeholders, according to research and practice (Parents, teachers, PTA, BOG, Administration, religious/cultural leaders, community around the school, Policy makers, NGOs and funding agencies). The conceptual conundrum around inclusion, which makes it challenging to have an

accurate assessment of its effectiveness, exacerbates these difficulties (Slee, 2018; Metcalf et al, 2018; Ainscow, 2020). Furthermore, a large number of inclusive schools are managed by educators and administrators who are not proficient in the fundamentals of inclusion and special education (Metcalf, Russell, Hill, 2018).

According to research on inclusion, interventions aimed at fostering and developing self-determination qualities are crucial in deciding how learners, especially those with special educational needs perform and flourish in an inclusive environment (Farrar, 2021). Van den Broek et al (2016) define self-determination in terms of six indicators:, autonomy, freedom barriers, and facilitators; decision making; social skills; self-confidence; autonomy; and Ryan and Deci (2000, 2017) observed that self-determination is a psychological construct that they operationalized to mean autonomy, competence, and relatedness, contending that the belief that these psychological needs are met essentially determines a learner's inclusion or exclusion in the educational system (Cuming et al, 2020;Ryan &Deci, 2017).

The present study will be guided by Ryan and Deci (2000) conceptualization of self-determination as a basic psychological construct manifesting as autonomy, competence and relatedness and how these psychological needs contribute to learners' inclusion.

Conceptual Clarifications

Inclusion:

The idea and viewpoint of inclusion gained global consideration when the United Nations promoted the idea of Education for all at the world conference on Education for all in Thailand in 1990. Furthermore, a policy statement on inclusive education originating from 1994 Salamanca conference in Spain contested all Nations, schools and educators to deliver applicable education for all students including those with special needs (Engelbrecht, 2020; Asamoah et al, 2018;). These frameworks noted that providing all students in regular education classes with high quality instruction and support is a guarantee of inclusive education because inclusion has respectful school culture where students' educational needs are supposed to be accomplished, helped to develop positive relationship with peers, and are full contributing members of the school community (Vorapanya & Dunlap, 2014; Asamoah et al 2018)

The term inclusion has given rise to global scholastic deliberations, involving a mixture of various and conflicting viewpoints and as such, the term inclusion remains controversial, deficient of a conceptual application (Liasidou, 2012) and because of this distinct assortment of connotations and ambiguities, inclusion can be portrayed as a "semantic Chameleon" (Liasidou, 2012). According to Slee (2018) the definition of inclusion falls into two categories namely; those who detail features of inclusion (Loreman 2009) and those who identify and describe barriers to inclusion that must be removed (Ainscow et al, 2013; Ainscow 2015), to Slee (2018) this has led to delineation of inclusion as lacking a conceptual focus. To him therefore inclusion refers to securing and guaranteeing the right of all children to access, presence, participation and academic achievement in their local regular schools (Slee 2018), to this end therefore, Slee argues that inclusion calls upon neighborhood schools to build their capacity to eliminate barriers to access, presence, participation and achievement in order to be able to provide excellent educational experience and outcomes for all children and young people. Similarly, other scholars define inclusion as a continuous process of increasing the presence, participation and achievement of all learners and young people in local community schools (Qvortrup & Qvortrup 2018). Others have defined Inclusion as educational system that enhances access, participation and Outcomes for all

diverse student population who have been traditionally excluded from formal education (Kozleski et al, 2014; Li & Ruppar, 2020)

Studies have revealed that since there is no uniform definition of inclusion measuring its success becomes problematic (Schwab, Sharma & Loreman, 2018; Slee 2019). To Schwab et al, (2018) it is arduous to query the efficacy of inclusive education system since every nation seems to have their own definition. However, they mention some of the attempts that have been made to measure inclusion for instance the efficacy of inclusive educational system was measured in terms of number of students considered as having additional needs accessing mainstream classrooms, Identifying the academic outcomes for these students and investigating the well-being of the school (Schwab et al 2018). Other studies have noted that measuring inclusion is a notion that is difficult to quantify arguing that in order to measure something one must first know what it is that is to be measured (Anderson & Boyle, 2015). They note that most definitions of inclusion do not itemize the constructs of inclusion and this makes it impossible to measure inclusion (Anderson & Boyle 2015). They argue that most studies that have attempted to measure diverse constructs of inclusion from different viewpoints such as Teacher attitudes, Teacher efficacy (Boyle, Topping & Jindal-Snape, 2013; Boyle, Topping, Jindal-snape & Norwich, 2012; Hoskin, Boyle & Anderson, 2015) even if Valid within their own countries, cannot be accurately the principle for the education of all students who are in various countries with varied definitions.

Loreman (2014) attempted to overcome these challenges in his proposal to measure inclusive education through the lens of its outcomes rather than trying to measure the construct itself. He identified the areas of Participation, Student achievement and post school outcomes as being valid measures of Inclusive education success. Loreman's Idea is currently used in Canada and Australia to measure the success of inclusive education (loreman, 2014). While Cox (2016) noted that to measure success of inclusion focus should be on, Access to education, Access to Quality Education and Access to Success in Learning. He emphasized Access as an important determinant of any inclusive educational system because inclusion underscores Access to education for all learners. UNESCO (1990) noted that while other education laws and policies allude to or mention Inclusive education, they often fail to define the construct. Regrettably the ambiguity and range of Inclusive education definitions make inclusive Education challenging to conceptualize, operationalize and measure in schools, a view (Slee, 2019) also share. These challenges slow the trajectory of effective inclusive education practices (Miles & Singal, 2010).

According to Slee (2011) since there are challenges in definition of inclusive education world over there is no need to focus on finding a definitive definition for inclusion to the abolition of restricted educational practices but rather focus should be placed on the inclusion matrix as stipulated in the Salamanca statement and as such the success or failure of inclusion can be assessed by interrogating the issue of Access to school and classrooms, Presence of learners in school and classes, participation of all learners school , Academic Achievement and social outcomes from school (Slee, 2011, 2018)

This study adopted the definition and operationalization of Inclusion based on (Slee, 2018) inclusion refers to securing and guaranteeing the right of all children to access, presence, participation and academic achievement in their local regular schools. The study will also Measure the efficacy of Inclusion in Uganda based on Slee (2011,2018) Measures looking at the Inclusion Matrix namely Access, Presence, Participation and Academic achievement. The inclusion matrix

as a measure of the success of inclusive education systems have been widely adopted and used by scholars in many African countries (Zimbabwe, South Africa and Kenya).

Self-Determination Attributes

Self-determination is an entrenched theoretical framework in educational psychology, which states that an individual learner's inner motivation is strongly interconnected with the perceived satisfaction of three specific psychological needs or attributes namely; Autonomy, Competence and Relatedness (Ryan & Deci, 2000; 2017). Self- determination has been refered in literature as a psychological construct because of the satisfaction associated with the psychological needs in that the more the learner perceives that his/her psychological needs (autonomy, competency and relatedness) are met, the more internally they will be motivated in that particular situation (Ryan & Deci, 2017).

Autonomy refers to the need to feel self-endorsed and engaged in activities willingly and is met when motivation for one's action is determined from volitional factors and not controlled either internally or externally (Ryan &Deci, 2017). Studies have shown that a learner's psychological need for autonomy in learning is conceptualized as the degree of control someone perceives they have over their learning environment. It is considered a difficult need to satisfy because it demands more attention from the teacher by providing students with multiple options from which they can choose (Ryan& Deci, 2000). Autonomy varies from individual learner to another because it takes the form of our likes, dislikes, past experiences and environmental and social context (Ryan & Deci, 2007). Because of the complexity of autonomy as a psychological need research suggests that providing students more choices will lead to increase in persistence and resilience, which are major, attributes for successful inclusion (Ratelle, Guay, Vallerand, Larose, Senecal, 2007). Competency refers to the desire to have an effect on one's environment therefore a learner's psychological need for competency in learning refers to their perception that they have mastered a task (Ryan & Deci, 2006; Rodgers, Markland, Selzler, Murray, Wilson, 2014). Competency has been positively associated with interest in accessing learning and academic achievement which are important attributes for inclusion, therefore interventions targeting learners with low perception of competence have the potential to increase inclusion (Khalaila, 2015), perceived competence satisfaction has also been shown to be a statistically significant predictor of inclusion. Relatedness is being sensitive and responsive to others and is satisfied when learners feel that they belong to a school or community (Ryan &Deci, 2000). A learner's sense of relatedness is defined as a feeling of connection to another individual or group for instance if a learner feels that his homework is valued by others, they will feel a sense of connectedness (Ryan & Deci, 2017). Research has shown that perceived relatedness satisfaction is associated with ones level of participation in inclusion (Farrar, 2020) therefore interventions that increase students perception of relatedness satisfaction have been shown to improve health, participation and academic achievement which are basic constructs of inclusion, (Walton &Cohen, 2011) similarly relatedness satisfaction is correlated with autonomy, mastery goal orientation and performance goal orientation which are motivational goals (Kaufman & Dodge,2009).

We noted that although these studies show how to improve inclusion, they dwell so much on regular learner without special educational needs. Our study will examine all these attributes on all learners and determine how we can improve inclusion for all learners. The current study suggests that to achieve comprehensive inclusion changes need to take place at all levels starting from the individual learner, teachers, administration and the school.

The Interface Between Self-Determination and Inclusion

Literature is abundantly clear about the predictive role of self-determination attributes (Autonomy, Competence, Relatedness) on inclusion of all learners in inclusion (Ryan & Deci, 1985; 2000; Farrar, 2020; Howard et al, 2021; Wehemeyer et al, 2011). To Ryan & Deci (2000) perceived relatedness was greatly associated with inclusion of learners with visual impairment because they have better social skills and needed to interact with other learners cordially in order to guarantee their retention in inclusion while the other attributes of mastery was particularly more visible among learners without special educational needs while to Ryan and Deci (2000) all the three attributes (Autonomy, competence and relatedness) were significant predictors of learning for all learners in inclusion. To them, the perceived satisfaction of these psychological attributes fundamentally determines how the learner relates with his learning environment (relatedness), makes choices (Autonomy) and shows mastery and command of tasks (Competence), which are attributes which determine, access, participation and academic achievement in inclusion setting (Ryan &Deci, 2000).

Similarly, Farrar (2020) noted that the development and nurturing self- determination attributes must be incorporated into the teaching learning process since it significantly determines the success or failure of inclusion and that all learners must be trained to develop these attributes since they relate to socialization, participation and academic achievement. While for Luckner and Sebald (2004), they noted that lack of self-determination is associated with higher prevalence of mental disorders and maladaptive behaviors in persons with intellectual disability and mental retardation and Wehmeyer et al (2011) noted that students with mental retardation demonstrated more self-determination behaviors in resource rooms than in mainstream classes this is because they are more likely to feel more intimidated in mainstream classrooms (Wehmeyer et al, 2011). This therefore suggests that promoting the development of self-determination for learners with and those without special educational needs is considered the best educational practice worldwide because it is associated with desirable school and post school outcomes such as independent living, Quality of life, enhancing the ego, self-esteem, thinking, personal development and objective utilization of learners with special educational needs who face difficulties in socialization and poor performance in class (Shrogen et al,2015;Shrogen et al 2017). The present study contributes to the ongoing conversation on how to improve inclusion in Uganda by examining the interface between self-determination attributes and inclusion in Uganda. Most of the studies reviewed are Eurocentric and therefore alien to Ugandan situation. This study will illuminate the contribution of self-determination attributes as an individual learner's psychological resource which when tapped as a psycho-educational intervention will improve learners' resilience in inclusion and thereby increasing enrolment, retention and completion of all learners in inclusion.

- Ho: There is a statistically significant relationship between self-determination attributes and inclusion in secondary education in Uganda.

METHODS

Research Design

This study was purely quantitative in nature employing Cross-sectional survey research design to capture a representative sample of the population (Creswell, 1999). According to Cresswell, cross-sectional survey design involves collecting data from a representative sample at the same point in time; analyzing this data, and making generalization of the findings to the target population (Bougie & Sekaran, 2020). Using cross-sectional survey research design, the study derived

insights, opinions, and perception on self-determination attributes and inclusion of learners in secondary education in Uganda from students, parents, teachers and school administration. All data was collected at the same point in time.

Participants and Procedures

The study collected data from all-inclusive secondary schools in three Northern Ugandan districts (Gulu, Lira, and Arua) using a cross-sectional survey research approach. 309 secondary school students (61.8% men, 38.2% females) made up the sample; 63.8% of the pupils had disabilities, while 36.2% did not. The participants' disabilities were as follows: 18.8% had visual impairments, 17.2% had physical impairments, 13.6% had hearing impairments, 4.5% had deafness, 5.7% had blindness, and 4.0% had mental retardation. Based on the following criteria, these participants were included in the study: (1) all students with disabilities enrolled in the school; (2) regular students who have close friendships with students with disabilities or their companions; and (3) students from secondary schools that are inclusive. The secondary schools with special needs annexes that are designated as all-inclusive are those that are established regionally by the ministry of education and sport. Examples of such schools are Gulu High Secondary School in Northern Uganda, Nancy Secondary School in the Lango sub-region, and Nvara Secondary School in the West Nile region. Data was collected from those who met the above criteria with permission from the district education officer, school administration and active involvement of the department of special needs and inclusive education in the selected school.

Sample Size Determination

A multi-stage sampling strategy was used to determine the sample size (Cohen et al, 2018). We started by determining sample size from the unit of analysis i.e., the schools, this was followed by determining sample size from the unit of analysis (i.e., the students, instructors, head teachers, PTA, Board of Governors, DEO, DIS). Therefore, the study employed Krejcie and Morgan's (1970) sample size determination table to establish the sample size for a particular population. After the instruments were administered, 309 out of the 312 participants in the selected sample participated, yielding a response rate of 99%.

Table 1.0 Sampling Frame

Category	Population	Sample Size	Sampling Procedure
Schools	3	3	Purposive
Learners	320	175	Stratified random
Teachers	120	92	Simple Random
Support staff	25	24	Simple Random
Head teacher	3	3	Purposive
PTA	12	12	Purposive
DEO	3	3	Purposive
Total	**486**	**312**	

Source: Primary data

Sampling Technique

A concurrent sampling design was employed, combining purposive sampling with basic random sampling. While learners with special educational needs were selected using stratified random sampling (disproportionate stratified random sampling) based on their uniqueness, regular learners, teachers, and support staff were given equal chances of being selected using simple random sampling (lottery method) to ensure that the perspectives from the samples can be

generalized to the larger population (Cohen et al, 2018) and the head teachers, DEO and DIS were selected using purposive sampling. The advantage of stratified random sampling is that it gives all members of a particular strata an equal chance to be selected in the study (Bougie & Sekeran, 2020) for purposive sampling only, Head teachers PTA, District Special needs officers and District inspector of schools will be selected purposively because of their roles in special and inclusive education (Cohen et al, 2018)

Instruments and Measurements

Self-determination Attributes was measured using Basic psychological needs Scale (BPNS) by (Deci & Ryan, 2000) which comprised of (21) items with (4) items measuring Autonomy satisfaction, 4 items measuring Competency satisfaction and (4) items measuring relatedness satisfaction while the other (9) items measuring frustration with (3) items measuring Autonomy frustration, (3) measuring competence frustration and 3 items measuring relatedness frustration. This scale was modified to (9) items only measuring satisfaction by Samman (2007). These items have alpha estimates of reliability of 0.82 (Competence), 0.91(Autonomy) and 0.87(Relatedness). The items were scored on a five-point likert scale ranging from 1= Strongly Disagree, 2= Disagree, 3= neither disagree nor agree, 4=Agree and 5=Strongly Agree. The potential score ranges 18 to 90. Thus, the lowest score on each of the item indicated low satisfaction of psychological needs of Autonomy, Competence and Relatedness while higher scores on the instrument reflected high satisfaction of the psychological needs of Autonomy, Competence and Relatedness.

RESULTS

Table 1 shows show results of a correlation analysis of the interface between Self-determination attributes (Perceived autonomy satisfaction, Perceived Competence satisfaction and perceived relatedness satisfaction) and inclusion. Findings show that there is a moderate but positive statistically significant relationship between self-determination attributes and inclusion (r=. 409, P<0.01). The table also that all the attributes of self-determination had a moderate positive statistically significant relationship with inclusion; Perceived autonomy satisfaction (r=. 318, P<0.01), Perceived competence satisfaction (r=. 346, P<0.01) and Perceived Relatedness satisfaction (r=. 336, P<0.01). This implies that there is a positive interface between all the attributes of self-determination and inclusion of learners in secondary education in Uganda therefore we accept the Hypothesis Ho and conclude that the development self-determination attributes must be considered when programming for inclusion of all learners in secondary education.

Results from the multiple regression analysis showed that 57% of the variance on inclusion could be attributed to the elements of self-determination namely; perceived autonomy satisfaction (P=. 002 *B*=. 523 t=2.263), Perceived competence satisfaction (P=. 007 *B*=. 563 t= 2.263) and Perceived Relatedness satisfaction (P=. 004 *B*=. 693 t= 2.692). The above results show that perceived autonomy satisfaction and perceived relatedness satisfaction were the only statistically significant predictors of inclusion. Interventions aimed at improving inclusion should therefore emphasize development of autonomy and relatedness as psycho-educational interventions.

Finally, the P-P results show that both self-determination and inclusion have normal distribution justifying choice and use of parametric tests (Pearson product moment correlation coefficient at Bivariate level and multiple regression analysis at multi-variate level of analysis regression in processing data for this study.

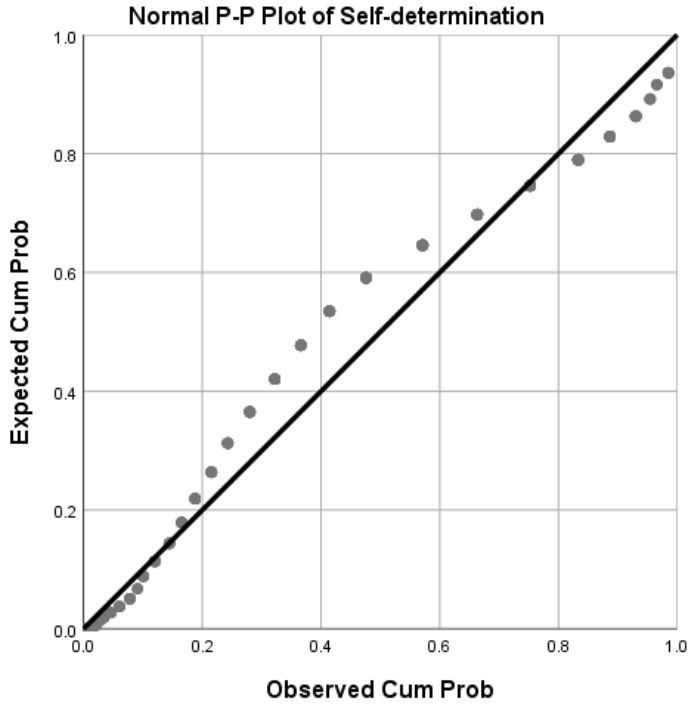
Correlations						
		Level of inclusion	Self-determination	Perceived autonomy satisfaction	Perceived competence	Perceived relatedness
Level of inclusion	Pearson Correlation	1	.409**	.318**	.346**	.336**
	Sig. (2-tailed)		.000	.000	.000	.000
	N	309	309	309	309	309
Self-determination	Pearson Correlation	.409**	1	.816**	.839**	.784**
	Sig. (2-tailed)	.000		.000	.000	.000
	N	309	309	309	309	309
Perceived autonomy satisfaction	Pearson Correlation	.318**	.816**	1	.528**	.442**
	Sig. (2-tailed)	.000	.000		.000	.000
	N	309	309	309	309	309
Perceived competence	Pearson Correlation	.346**	.839**	.528**	1	.507**
	Sig. (2-tailed)	.000	.000	.000		.000
	N	309	309	309	309	309
Perceived relatedness	Pearson Correlation	.336**	.784**	.442**	.507**	1
	Sig. (2-tailed)	.000	.000	.000	.000	
	N	309	309	309	309	309
**. Correlation is significant at the 0.01 level (2-tailed).						

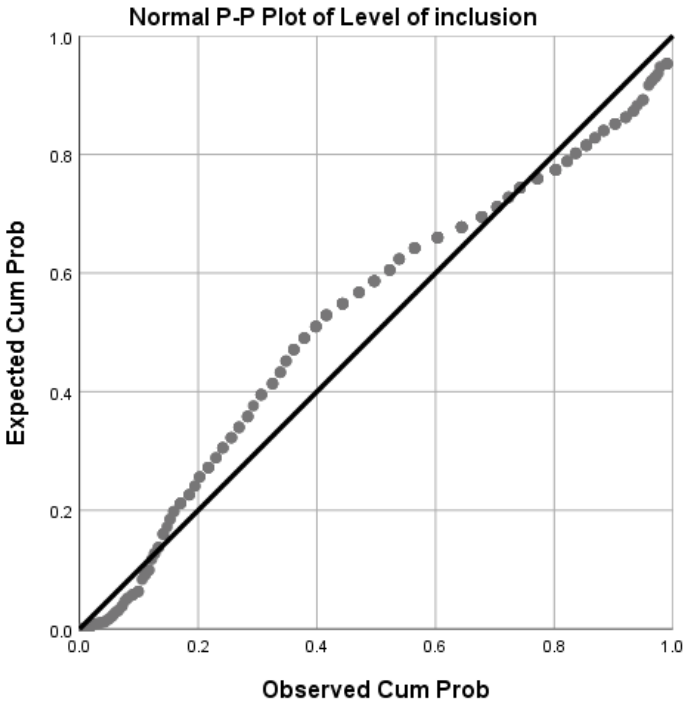
Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.410[a]	.168	.565	18.88893
a. Predictors: (Constant), Perceived relatedness, Perceived autonomy satisfaction, Perceived competence				

ANOVA[a]						
Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	22041.781	3	7347.260	20.593	.000[b]
	Residual	108821.469	305	356.792		
	Total	130863.249	308			
a. Dependent Variable: Level of inclusion						
b. Predictors: (Constant), Perceived relatedness, Perceived autonomy satisfaction, Perceived competence						

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	100.090	7.837		12.771	.000
	Perceived autonomy satisfaction	1.001	.442	.523	2.263	.002
	Perceived competence	1.252	.464	.563	2.698	.007

	Perceived relatedness	1.411	.482	.693	2.925	.004
a. Dependent Variable: Level of inclusion						





DISCUSSIONS

The study sought to establish the interface between self-determination attributes and inclusion of learners in secondary education in Uganda. It has been suggested that Self-determination attributes is a fundamental determinant of inclusion of all learners in secondary education (Ryan &Deci, 2000). In this study we argue that self-determination attributes are an important

determinant of inclusion for learners in inclusion. We noted that the self-determination attributes of autonomy, competence and relatedness was an antecedent to enhanced inclusion of all learners in inclusion.

We hypothesized that there was a significant relationship between Self-determination attributes and inclusion of all learners in inclusion. Results showed that there was a moderate positive statistically significant relationship between self-determination attributes and inclusion of all learners in secondary education in Uganda. These findings are supported by studies by Ryan and Deci (2000) who noted that for inclusion of all learners in education there was need for the school system to deliberately program development of self-determination attributes (Autonomy, Competence and Relatedness) as a key psycho-educational intervention to improve inclusion. To them, learners with special educational needs are gifted differently and therefore require customized intervention that caters for their uniqueness. Similarly, a study by Shrogen et al (2015) showed that relatedness and autonomy was positively related to inclusion of learners with special educational needs while Farrar (2020) posits that for inclusion to succeed learners perceived competence satisfaction was fundamental. Other studies have noted that self-determination is key to the success of inclusion for all learners at all learners of education (wehemeyer &Kingston, 2013; Clark et al, 2014; Zhang, 2001).

Results from the multiple regression analysis showed that 57% of the variance on inclusion could be attributed to the elements of self-determination namely; perceived autonomy satisfaction (P=. 002 *B*=. 523 t=2.263), Perceived competence satisfaction (P=. 007 B=. 563 t= 2.263) and Perceived Relatedness satisfaction (P=. 004 *B*=. 693 t= 2.692). The above results show that perceived autonomy satisfaction and perceived relatedness satisfaction were the only statistically significant predictors of inclusion. This is in agreement with Shrogen et al (2015) who emphasized the development of autonomy and relatedness as a necessary psycho-educational intervention to improve inclusion. Similarly, studies by Zhang (2001), Farrar (2021) and Moore et al (2020) articulated succulently the role of self-determination attributes to inclusion.

CONCLUSION

We concluded that learner's self-determination attributes (Autonomy, competence and relatedness) are essential for the realization of inclusion in secondary education in Uganda. Therefore, Learner's self-determination attributes are the best psycho-educational crucial to improve inclusion in secondary education in Uganda. All the attributes of self-determination should be emphasized.

RECOMMENDATIONS

Inclusive school systems should emphasize the development of learner's self-determination attributes (autonomy, competence and relatedness) for all learners by incorporating it in the curriculum and co-curriculum activities. The counseling and guidance departments in inclusive schools should also be empowered with specialized counselors and program for routine counseling and guidance.

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COMPLIANCE WITH ETHICAL STANDARDS

The Uganda national council for science and technology and Gulu University research and ethics committee approved this research no: (GUREC-2023-523)

CONFLICT OF INTEREST

The authors declare no conflict of interest

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An Exact Solution for Decay of Grid Produced-Turbulence

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Abstract:
A new approach to the exact solution for decay of grid-produced turbulence in the final period has been proposed. The governing equations are the two-point and three-point velocity correlation equations in which the quartic correlations are neglected as the closure assumption, and the pressure-velocity correlations are neglected tentatively. Without recourse to the isotropic conditions, these equations are found to be separable into a pair of Oseen (type) equations. As a result, the double- and triple-correlations are solved analytically as an initial value problem. The effect of the triple correlation adds a correction term proportional to x^{-4} to the well-known decay law $x^{-5/2}$ for the turbulent energy in the final period: $<(\Delta u)^2>=Ax^{-5/2}+ Bx^{-4}$, where $<(\Delta u)^2>$ is the turbulent energy, A and B are constants determined by the initial conditions, and x is the streamwise coordinate.

PART: 1
INTRODUCTION

"Turbulence" has been one of the most mysterious problems to scientists for several centuries. The nature of grid produced-turbulence has been an unsettled problem for almost one century. Partly for practical requirements (wind tunnel design) and partly for its theoretical tractability (homogeneous and isotropic turbulence) the research has been concentrated on grid-produced turbulence. However, it is impossible to over-emphasize the fact that mainly because of the nonlinearity of the Navier-Stokes equation, no-one has ever solved any problem about turbulence theoretically in concrete situations. Tsugé [3] has proposed to use the sequence of separated points velocity correlation equation, viz. the two-point velocity correlation equation, the three-point velocity correlation equation, and so on rather than conventional velocity correlation equation, say one-point velocity correlation equation [1,2]. Though Tsugé [3] has derived the two-point counterpart of the Navier-Stokes equation based on Klimontovich [4] formalism, those equations can be formally derived by using the Navier-Stokes equation: It should be noted that the formal derivation of his correlation equation is similar to Hinze's [5] two-point velocity correlation equation, which has been thought of a "entirely intractable" dueto the six-dimensional nature under general three-dimensional flow situations. Tsugé [3], however, has shown that these types of correlation equations [3, 5] are separable into a pair of Orr-Sommerfeld type equations at the respective points. In the present paper, it will be shown how the double correlations can be solved analytically with the aim of analyzing the unexplained phenomena of fully developed grid-produced turbulence. Using the experimental initial values in preference to the Loitsyanskii invariant [6], the double correlations will be solved analytically.

THE CORRELATION EQUATIONS

The two-point and the three-point velocity correlation equations will be formally derived for the general case of inhomogeneous and anisotropic turbulence.

The two-point velocity correlation equation has the form

$$<\Delta u_i(a)NS[\mathring{u}(b), \mathring{p}(b)]_1 + \Delta u_1(b)NS[\mathring{u}(a), \mathring{p}(a)]_i>=0 \quad (2.1)$$

with the following definition

$$NS(u, p) \equiv (\partial/\partial t + u_j \cdot \partial/\partial x_j - \upsilon\nabla^2)\, ui + 1/\rho \cdot \partial p/\partial x_i \quad (2.2)$$

where bracket <> denotes an ensemble average, arguments (a) and (b) mean point A and point B, respectively, $\mathring{z}$ stands for instantaneous fluid dynamic quantity, z is its ensemble average, Δz is the fluctuation given by

$$\Delta z = \mathring{z} - z, \quad (2.3)$$

and u_i Eulerian velocity, t time, x_j Eulerian Cartessian coordinates, ρ density, p static pressure, ∇^2 Laplacian operator, and υ kinematic viscosity. It may be worth noting here that Eq. (2.1) is similar to Hinze's two-point velocity correlation equation. The solenoidal conditions of the two-point velocity correlations are

$$\partial R^{(,1)}{}_{I,I}(a, b)/\partial x_i = \partial R^{(,1)}{}_{I,I}(a, b)/\partial x_I = 0, \quad (2.4)$$

Where,

$$R^{(,1)}{}_{I,I}(a, b) = <\Delta u_i(a)\Delta u_I(b)>$$

is the two-point double velocity correlation.

THE APPLICATION TO GRID-PRODUCED TURBULENCE

As a matter of course, the turbulence produced by the grid mesh is not what is called isotropic. The former has a definite spatial directivity, viz. the direction of the main flow

$$u = (\dot{U}, 0, 0), \quad (3.1)$$

while the latter has not, where $\dot{U}$ is the constant main flow velocity. Now it will be shown that the present method enables the solution for the double and triple correlations to be obtained without introducing the isotropic condition.

In the case of the present flow field, i.e., condition (3.1), eq (2.1) and (2.5) become, respectively,

$$\{\dot{U}[\partial/\partial x_1(a) + \partial/\partial x_1(b)] - \upsilon[\nabla^2(a) + \nabla^2(b)]\}\, R_{ij}^{(1,1)}(a, b) = -\partial R_{ijr}^{(1,1,1)}(a, b, a)/\partial x_r(a) - \partial R_{ijr}^{(1,1,1)}(a, b, b)/\partial x_r(b), \quad (3.2)$$

$$\{\dot{U}[\partial/\partial x_1(a) + \partial/\partial x_1(b) + \partial/\partial x_1(c)] - \upsilon[\nabla^2(a) + \nabla^2(b) + \nabla^2(c)]\}\, R_{ijr}^{(1,1,1)}(a, b, c) = 0, \quad (3.3)$$

where the time derivative terms have been neglected because a time-dependent solution for fluctuation is not to be expected under the steady primary flow, and where the pressure-velocity

correlations are also neglected; The pressure-velocity correlations were shown by Batcheor [7] to be identically zero for the case of homogeneous turbulence. For later convenience, the non-dimensional length x, double correlations R_{ij}, and triple correlations R_{ijr} are introduced by the following re-definition,

$$X=x/M, \tag{3.4}$$

$$R_{ij}=R_{ij}/\dot{U}^2, \tag{3.5}$$

$$R_{ijr}= R_{ijr}/\dot{U}^3, \tag{3.6}$$

and the Reynolds umber is defined as follows,

$$R=M\dot{U}/\upsilon, \tag{3.7}$$

where M is the mesh size of the grid. Then, the non-dimensional versions of eq s (3.2) and (3.3) ae simply obtainable by replacing in these equations,

$$\dot{U}=1, \upsilon=R^{-1}. \tag{3.8}$$

Therefore, the two equations become, respectively,

$$[\partial/\partial x_1(a)+ \partial/\partial x_1(b)]-1/R \cdot[\nabla^2(a)+ \nabla^2(b)]\} Rij^{(1,1)} (a, b)=-\partial R_{ijr}^{(1,1,1)} (a, b, a)/\partial x_r(a)-\partial R_{ijr}^{(1,1,1)} (a, b, b)/\partial x_r(b), \tag{3.9}$$

$$[\partial/\partial x_1(a)+ \partial/\partial x_1(b)+ \partial/\partial x_1(c)]-1/R \cdot[\nabla^2(a)+ \nabla^2(b)+ \nabla^2(c)]\} R_{ijr}^{(1,1,1)} (a, b, c)=0, \tag{3.10}$$

It is obvious that eq (3.10) is solvable by the method of variable disparation, viz.

$$R_{ijr}^{(1,1,1)}(a, b, c)=\varphi_i(a)\varphi_j(b)\varphi_r(c), \tag{3.11}$$

and φ_s follows the following equation

$$(\partial/\partial x_1-R^{-1}\nabla^2-i\lambda)\varphi_s=0, \tag{3.12}$$

where iλ is the separation constant such that the general solution is expressible in the form

$$R_{ijr}^{(1,1,1)}(a, b, c) = \int \varphi_i(a) \varphi_j(b)\varphi_r(c)\delta[\lambda(a)+ \lambda(b)+\lambda(c)]d\lambda(a) \lambda(b) \lambda(c), \tag{3.13}$$

where δ is the Dirac delta function.

It is easily seen that eq (3.12) corresponds to the special case of the Oseen equation for waves travelling in a uniform flow with frequency λ. Such waves decay due to viscous effects and dispersion. This fact immediately suggests that a solution of the following form is sought,

$$\varphi_s=\int A_s(\mathbf{k}, \beta, \lambda)\exp(-\beta x_1+ik_ix_i)dk_2dk_3, (\beta -ik_1)^2+R(\beta -ik_1)+i\lambda R-k_2^2-k_3^2=0, \tag{3.15}$$

which assures that φ_s is the solution of eq (3.12). After eq (3.15) is decomposed into the real and the imaginary parts, respectively, β and λ become as the first approximation,

$$\beta \cong k^2/R, \tag{3.16}$$

$$\lambda \equiv k_1, \tag{3.17}$$

where $k^2=k_1^2+ k_2^2 + k_3^2$. If the expression like eq (3.14) for points a, b, and c, respectively, are substituted into eq (3.13), we obtain the general solution for the triple correlations.

$$R_{ijr}^{(1,1,1)}(a, b, c) =\int C_{ijr}\exp\{-1/R[k^2(a)x_1(a)+k^2(b)x_1(b)+k^2(c)x_1(c)]+i[k_i(a)x_i(a)+ k_i(b)x_i(b)+ k_i(c)x_i(c)\ _i(a)]\}\ \delta[\mathbf{k}(a)+ \mathbf{k}(b)+ k_i(c)]dk(a)\ k(b)\ k(c), \tag{3.18}$$

where we put $C_{ijr}=A_i\ A_j\ A_r$, and we use the relations (3.16) and (317). Furthermore, we use the condition that the triple correlations are homogeneous in planes parallel with the grid. Once we can determine the C_{ijr} from the initial conditions, we will be able to solve $R_{ij}^{(1,1)}(a, b)$ in eq (3.9) formally,

$$R_{ij}^{(1,1)}(a, b)= [R_{ij}^{(1,1)}(a, b)]_c+ [R_{ij}^{(1,1)}(a, b)]_p\ , \tag{3.19}$$

Where $[R_{ij}^{(1,1)}\ (a, b)]_c$ and $[R_{ij}^{(1,1)}(a, b)]_p$ are the complementary and the particular solutions, respectively.

THE SOLUTION N THE FINAL PERIOD OF DECAY

As is well known, the complementary solution is such a solution that can be obtained by putting the right-hand side of eq (3.9) to zero, viz.

$$[\partial/\partial x_1(a)+ \partial/\partial x_1(b)]-1/R\ \cdot[\nabla^2(a)+ \nabla^2(b)]\}\ [R_{ij}^{(1,1)}\ (a, b)]_c=0\ . \tag{4.1}$$

Similarly to the solution for $R_{ijr}^{(1,1,1)}\ (a, b, c)$ in eq (3.10), the complementary solution is solvable by the method of variable-separation in the following manner. The solution is expressible as follows,

$$[R_{ij}^{(1,1)}(a, b)]_c=\int \varphi_i(a)\varphi_j(b)\delta[\lambda(a)+ \lambda(b)]\ d\ \lambda\ (a)\ \lambda(b). \tag{4.2}$$

Moreover, φ_s has a similar form φ_s, i.e.

$$\varphi_s=\int A_s(k, \beta, \lambda)\exp(-\beta x_1+ik_ix_i)dk_2dk_3, \tag{4.3}$$

where β ad λ satisfy the same dispersion relation as eq (3.15). Hence, substituting the expression like eq (4.3) for points a and b into eq (4.2), we obtain the complementary solution,

$$[R_{ij}^{(1,1)}(a, b)]_c= \int C_{ij}\exp\{-1/R\ \cdot[k^2(a)x_1(a)+ k^2(b)x_1(b)] + i[k_i(a)x_i(a)+k_i(b)x_i(b)]\}\delta[\mathbf{k}(a)+\mathbf{k}(b)]d\mathbf{k}(a)d\mathbf{k}(b), \tag{4.4}$$

where we put $C_{ij}=A_i\ A_j$, and we use the relations (3.16) and (3.17) as well as the condition that the double correlations are homogeneous in the planes parallel with the grid.

For later convenience, we will rewrite eq. (4.4) as follows

$$[R_{ij}^{(1,1)}(a, b)]_c=\int C_{ij}\exp[-2k^2/R(x-x_0)+ik_i r_i]dk, \tag{4.5}$$

where $x - x_0=[x_1(a)+x_1(b)]$, $\mathbf{r}=\mathbf{x}(a) - x(b)$, and x_0 is a position behind the grid, where the longitudinal double velocity correlation has a Gaussian distribution: This fact is supported by many experiments, viz. Batchelor-Townsend (1948) (see Fig.3), Stewart (1951), and Van Atta Chen (1969). Using the longitudinal double velocity correlation measure by Batchelor-Townsend (1948) as an initial condition, the unknown constant C_{ij} can be determined as follows. Substituting the double velocity correlations at the point $x=x_0$ in eq. (4.5), we get

$$(f-g)\, r_i r_j/r^2 + g\delta_{ij}=\int C_{ij}\cdot\exp(ik_i r_i)dk. \tag{4.6}$$

Moreover, operating

$$1/(2\pi)^3\int exp(-ik'_i\cdot r_i)dr$$

to the both sides of eq. (4.6), we obtain

$$1/(2\pi)^3\int[(f-g)\, r_i r_j/r^2 + g\delta_{ij}]\exp(-ik'_i\cdot r_i)dr=C_{ij}, \tag{4.7}$$

where we use the definition of delta function, that is

$$1/(2\pi)^3\int exp\, ir\cdot(k-k')\, drdk=\int\delta[k-k']\cdot C_{ij}\cdot dk=C_{ij}$$

Before, we integrate the l.h.s. of eq. (4.7), we must notice the following facts. In order to integrate the l.h.s., we must use such a polar coordinate that the direction of k′ coincides with Z-axis; the direction of k′ always coincides with that of $r^*_3(=Z^*)$. Therefore, the direction of X^* is generally different from the stream-wise coordinate X (Figure 1).

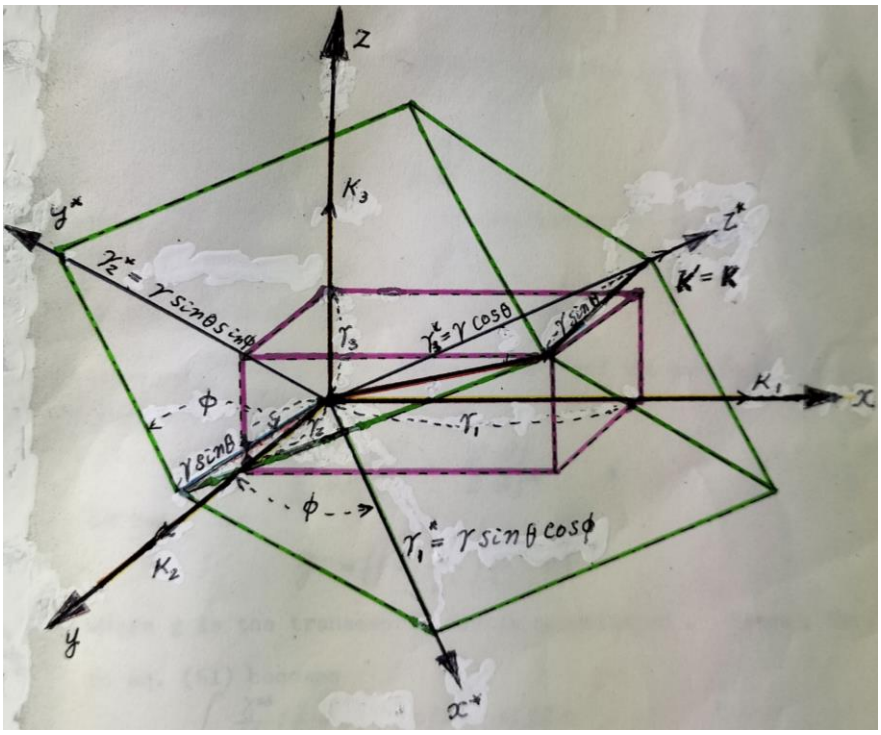

Figure 1: Definition sketch of coordinates.

Whereas we usually adopt the coordinate X as a reference axis in determining the double velocity correlations. In order to unify these two coordinate systems. We introduce next notation.

$$r_i=\hat{il}r^*_l, \tag{4.8}$$

where $\hat{il}$ is direction cosine between the two coordinate systems. For example, we will calculate the following term.

$$1/(2\pi)^3\int(r_1r_1/r^2)\,(f-g)\cdot\exp(-ik_i\cdot r_i)\,dr$$

$$=1/(2\pi)^3\int(\hat{1l}\hat{1m}r^*_lr^*_m/r^2)\,(f-g)\cdot\exp(-ik_i\cdot r_i)\,dr,$$

$$=1/(2\pi)^3\int(\hat{1}\hat{1}\hat{1}\hat{1}r^*_1{}^2+\hat{1}\hat{2}\hat{1}\hat{2}r^*_2{}^2+\hat{1}\hat{3}\hat{1}\hat{3}r^*_3{}^2)/r^2\cdot(f-g)\cdot\exp(-ik_i\cdot r_i)dr,$$

$$=1/(2\pi)^3\int(\hat{1}\hat{1}\hat{1}\hat{1}r^*_1{}^2+\hat{1}\hat{2}\hat{1}\hat{2}r^*_2{}^2+\hat{1}\hat{3}\hat{1}\hat{3}r^*_1{}^2-\hat{1}\hat{3}\hat{1}\hat{3}r^*_1{}^2+\hat{1}\hat{3}\hat{1}\hat{3}r^*_3{}^2)/r^2\cdot(f-g)\cdot\exp(-ik_i\cdot r_i)dr,$$

$$=1/(2\pi)^3\int[(\hat{1}\hat{1}\hat{1}\hat{1}r^*_1{}^2+\hat{1}\hat{2}\hat{1}\hat{2}r^*_2{}^2+\hat{1}\hat{3}\hat{1}\hat{3}r^*_1{}^2)+\hat{1}\hat{3}\hat{1}\hat{3}\,(r^*_3{}^2-r^*_1{}^2)]/r^2\cdot(f-g)\cdot\exp(-ik_i\cdot r_i)dr,$$

$$=1/(2\pi)^3\int[(\hat{1}\hat{1}\hat{1}\hat{1}r^*_1{}^2+\hat{1}\hat{2}\hat{1}\hat{2}r^*_1{}^2+\hat{1}\hat{3}\hat{1}\hat{3}r^*_1{}^2)+\hat{1}\hat{3}\hat{1}\hat{3}\,(r^*_3{}^2-r^*_1{}^2)]/r^2\cdot(f-g)\cdot\exp(-ik_i\cdot r_i)dr,$$

$$=1/(2\pi)^3\int[\hat{1}\hat{i}\hat{1}\hat{i}r^*_1{}^2+\hat{1}\hat{3}\hat{1}\hat{3}\,(r^*_3{}^2-r^*_1{}^2)]/r^2\cdot(f-g)\cdot\exp(-ik_i\cdot r_i)dr,$$

$$=1/(2\pi)^3\int[\hat{1}\hat{i}\hat{1}\hat{i}r^*_1{}^2+\hat{1}\hat{3}\hat{1}\hat{3}\,(r^*_3{}^2-r^*_1{}^2)]/r^{*2}\cdot(f-g)\cdot\exp(-ikr^*)d\mathbf{r}^*, \tag{4-9}$$

where we use the relations,

$$k'=k,$$

$$1/(2\pi)^3\int(\hat{1}\hat{1}\hat{1}\hat{2}r_1{}^*r_2{}^*)\,(f-g)\cdot\exp(-ik_i\cdot r_i)\,d\mathbf{r}=0,\ \ldots\ldots,$$

$$1/(2\pi)^3\int(r^*_1{}^2/r^2)\,(f-g)\cdot\exp(-ik_i\cdot r_i)\,dr=1/(2\pi)^3\int(r^*_2{}^2/r^2)\,(f-g)\cdot\exp(-ik_i\cdot r_i)\,d\mathbf{r}.$$

At this stage, we introduce Batchelor-Townsend (1948)'s longitudinal double velocity correlation,

$$f=\exp[-r^{*2}/(a^2M^2)], \tag{4-10}$$

where a is a constant, to be determined by the experiment. The normalized version of eq. (4.10) becomes

$$f=\exp(-r^{*2}/a^2), \tag{4-11}$$

where we use $r^* \rightarrow Mr^*$ for the normalization.

Furthermore, using the functional form f and the continuity relation of the double correlation,

$$g=f+r^*/2\cdot\partial f/\partial r^*,$$

we have

$$g=(1-r^{*2}/a^2)\exp(-r^{*2}/a^2), \tag{4-12}$$

where g is the transverse double correlation. Hence, the following term in eq. (4.9) becomes

$$\int r_1^{*2}/r^{*2}(f-g)\exp(-ikr^*)\,dr^*, =\pi\int_0^\infty r^{*2}[r^{*2}/a^2\cdot\exp(-r^{*2}/a^2)\,[4\sin kr^*/(k^3r^{*3})-4\cos kr^*/(k^2r^{*2})]\,dr^*, =\pi^{3/2}/2\cdot a^3\exp(-a^2k^2/4). \tag{4-13}$$

Similarly, to the above,

$$\int r_3^{*2}/r^{*2}(f-g)\exp(-ikr^*)\,dr^*, =\pi\int_0^\infty r^{*2}[r^{*2}/a^2\cdot\exp(-r^{*2}/a^2)\,[4\sin kr^*/(kr^*)+4\cos kr^*/(k^2r^{*2})-,4\cos kr^*/(k^3r^{*3})]\,dr^*, =\pi^{3/2}/2\cdot a^3\exp(-a^2k^2/4)-\pi^{3/2}/4\cdot a^5k^2\exp(-a^2k^2/4). \tag{4-14}$$

Substituting eq. (4-13) and (4-14) in eq. (4.9), we get

$$1/(2\pi)^3\int r_1r_1/r^{*2}(f-g)\exp(-ikr^*)\,d\mathbf{r}^*=a^3/(16\pi^{3/2})\cdot\exp(-a^2k^2/4)\,(1-a^2k_1^2). \tag{4-15}$$

In the same way, we can obtain the following relations,

$$1/(2\pi)^3\int r_1r_2/r^{*2}(f-g)\exp(-ikr^*)d\mathbf{r}^*=a^3/(16\pi^{3/2})\cdot\exp(-a^2k^2/4)(-a^2k_1k_2/2) \tag{4-16}$$

And

$$1/(2\pi)^3\int r_ir_i/r^{*2}(f-g)\exp(-ikr^*)\,d\mathbf{r}^*=a^3/(16\pi^{3/2})\cdot\exp(-a^2k^2/4)(3-a^2k^2/2). \tag{4-17}$$

Therefore, from eq. (4-15), (4-16) and (4-17), we can get the general expression, viz.

$$1/(2\pi)^3\int r_ir_j/r^{*2}(f-g)\exp(-ikr^*)d\mathbf{r}^*=A(\delta_{ij}-a^2k_ik_j/2), \tag{4-18}$$

Where,

$$A=a^3/(16\pi^{3/2})\cdot\exp(-a^2k^2/4).$$

Similarly, to the above, the term in eq. (4.7) becomes

$$\delta_{ij}/(2\pi)^3\int g\cdot\exp(-ikr^*)\,d\mathbf{r}^*=\delta_{ij}/(2\pi)^3\int(1-r^{*2}/a^2)\exp(-r^{*2}/a^2)\cdot\exp(-ikr*)d\mathbf{r}*=-A\delta_{ij}+A/2\cdot k^2a^2\delta_{ij}. \tag{4-19}$$

Substituting eq. (4-18) and (4.19) in eq. (4-7), we finally have

$$C_{ij}=Aa^2k^2/2\cdot(\delta_{ij}-k_ik_j/k^2). \tag{4-20}$$

Then, substituting C_{ij} in the above that are determined with the initial condition in eq. (4-5), we can obtain the turbulent energy decay law in the final period. Namely,

$$[R_{ij}^{(1,1)}(a,b)]_c=\pi^{1/2}a^5/32\int(k^2\delta_{ij}-k_ik_j)\exp(-a^2k^2/4)\cdot\exp[-2k^2/R\cdot(x-x_0)]+ikr^*]d\mathbf{k}. \tag{4-21}$$

By the definition of the turbulent energy, we put the subscripts i=j and r^*=0 in eq. (4-21), the energy decay law becomes

$$\bar{u}^2_c = a^5/(32\pi^{3/2}) \int (k^2\delta_{ij} - k_i k_j) \exp(-a^2k^2/4) \cdot \exp[-2k^2/R \cdot (x - x_0)] d\mathbf{k} = 3a^2/32 \cdot [a^2/4 + 2/R \cdot (x - x_0)]^{-5/2}, \quad (4\text{-}22)$$

where $\bar{u}^2_c$ is turbulent energy in the final period of decay. It may be worth noting that x_0 is the position where the longitudinal double velocity correlation possesses a Gaussian distribution. Now in Fig.2, it is clearly seen that turbulent energy in the final period decays according to $x^{-5/2}$. Owing to this reason, assume that the Gaussian distribution is realized at the position, viz. $x_0 = Ra^2/8$.

In this particular case, the energy decay law in the final period can be expressed by

$$\bar{u}^2_c = 3a^2/32 \cdot (R/2)^{5/2} \cdot x^{-5/2}. \quad (4.23)$$

Let us change the variable x in eq (4.23) to the timer t by introducing the so-called Taylor's hypothesis, t=x/U, the present decay law agrees with the existing theories in the final period of decay such as Loitsyyanskii [12], Batchelor [6], and Deissler [13]. However, Phillips [14] and Saffman [15] lead -3/2 power law in the final period theoretically.

The present decay law is also in good agreement with Batchelor & Townsend's by an experiment; both of these experiments show that turbulent energy decreases inversely as the square of decay time. Referring to eq (4.22), if the Reynolds number R is small compared with the distance $(x - x_0)$, the turbulent energy decays as $(x - x_0)^{-5/2}$. In fact, the previous experiments have been always performed under low Reynolds number, i.e., $R \leq 1000$. Thus, it is necessary to establish the effect of Reynolds number by conducting experiments at high Reynolds number. Based upon eq (4.22), we can suggest in case of high Reynolds number the initial stage of grid-produced turbulence must persist over a greater distance than in the case of low Reynolds number. In contrast to the final period of decay (e.g. [8], [12]), most experimental turbulence energy decays as t^{-1} (or x^{-1}) (e.g. [8],[13]). Therefore, the present theory conjectures that in the classical sense the initial period might be able to exist even more downstream of the grid under high Reynolds number.

In fact, when $8/(a^2R) \cdot (x - x_0) \ll 1$, eq (4.22) can be expressed by

$$\bar{u}^2_c = 3(2)^{1/2}/a^3 [1 - 20/(a^2R) \cdot (x - x_0)]. \quad (4.24)$$

The above relation indicates that the turbulence energy decays as x^{-1} essentially. In other words, we may not need the triple correlations in order to obtain the turbulent energy decay law covering the whole region behind the grid. It may be useful to know that the turbulent energy decay law behind the gris is an initial value problem mathematically

DISCUSSIONS

In support of this proposition, Uberoi & Wallis [14] examined the effects of the grid geometry. Also, Ling & Wan [15] made an experimental study of weak turbulence created by a mechanically agitated grid, and found that turbulent energy decay law depends on the velocity ratio of agitator to the mean flow.

There are two significant limitations in the present theory. Firstly, the pressure-velocity correlations are neglected, and secondly the initial conditions for the triple correlations are not given due to the lack of the experimental data. The former assumption, i.e., the pressure-velocity correlations are zero, has been shown to be valid only for the case of homogeneous turbulence [7], while the present theory only enquires homogeneity in planes parallel with the grid. It should be here noted that the present theory treats much more general flow field than the classical one, e.g. [1],[2] and [7].

Finally, the some works for including the pressure-velocity correlations into the present theory and for applying the present theory to oceanic turbulence have been conducted by Tsugé [16] and Nakagawa [17], respectively. For example, oceanic turbulence in the upper layers of the ocean, the turbulence is approximately homogeneous in horizontal planes [18], so that the present theory may be applicable easily. It is believed that the present theoretical approach to turbulence has great possibility in its applicability for various turbulence problems.

CONCLUDING REMARKS

Without using homogeneous and isotropic conditions, the double correlations are exactly solved as an initial value problem. The solution is expressed by

$$\bar{u}^2_c = 3a^2/32 \cdot (R/2)^{5/2} \cdot x^{-5/2},$$

where a is a constant to be determined by the measurement of the double velocity correlation at the initial point behind the grid, R is the Reynolds number defined by UM/υ, U is the flow velocity in the upstream of the grid, M is the mesh size, υ is the kinematic viscosity of the fluid, and x is the distance from the grid in the downstream. It has been, however, assumed that the flow field behind the grid is homogeneous in the planes parallel with the grid together with the pressure-velocity correlations have been neglected tentatively.

In part 2, it will be challenged to solve the triple correlations in the same way as the double correlations. Such work has, therefore, been left for this part.

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PART 2

This paper is concerned with an exact solution of grid-produced turbulence in the transitional period of decay. This is part 2 of our previous paper entitled an exact solution of grid-produced turbulence: part 1, in which the turbulent intensity $\bar{u}^2$ behind the grid is expressed as follows,

$$\bar{u}^2=3a^2/32\cdot(R/2)^{5/2}\cdot x^{-5/2},$$

where a is a constant to be determined by the measurement of the double velocity correlation at the initial point behind the grid, R is the Reynolds number defined by UM/υ, U is the flow velocity in the upstream of the grid, M is the mesh size, υ is the kinematic viscosity of the fluid, and x is the distance from the grid taking positive in the downstream. That is, because the present part is an extension of the part1, both of the introduction are references are common, so the mathematical argument to derive the correction term will be started immediately. It is found that the inclusion of the triple velocity correlations adds a correct term $\sim x^{-4}$ to the forgoing solution $\sim x^{-52}$. The comparison of the theory and experiment has revealed that the agreement is satisfactory, and the correction term contributes to improve the degree of the agreement significantly.

THEORETICAL ANALYSES FOR THE GRID-PRODUCED TURBULEN IN THE TRANSITIONAL PERIOD OF DECAY

The two-point and the three-point velocity correlation equations will be formally derived for the general case of inhomogeneous and anisotropic turbulence (Tsugé 1974). The two-point velocity correlation equation has the form

$$<\Delta u_i(a)NS[\mathring{u}(b), \mathring{p}(b)]_{I} + \Delta u_{I}(b)NS[\mathring{u}(a), \mathring{p}(a)]_i>=0 \quad (1)$$

with the following definition

$$NS(\mathbf{u}, p)\equiv(\partial/\partial t + u_j\cdot\partial/\partial x_j - \upsilon\nabla^2)\,ui + 1/\rho\cdot\partial p/\partial x_i, \quad (2)$$

where bracket <> denotes an ensemble average, arguments (a) and (b) mean point A and point B, respectively, $\mathring{z}$ stands for instantaneous fluid dynamic quantity, z is its ensemble average, Δz is the fluctuation given by

$$\Delta z=\mathring{z}-z, \quad (3)$$

and u_i Eulerian velocity, t time, x_j Eulerian Cartessian coordinates, ρ density, p static pressure, ∇^2 Laplacian operator, and υ kinematic viscosity. It may be worth noting here that (1) is similar to Hinze's two-point velocity correlation equation. The solenoidal conditions of the two-point velocity correlation are

$$\partial R^{(,1)}{}_{I,I}(a, b)/\partial x_i = \partial R^{(,1)}{}_{I,I}(a, b)/\partial x_I = 0, \quad (4)$$

Where,

$$R^{(,1)}{}_{I,I}(a, b)=<\Delta u_i(a)\Delta u_I(b)>$$

is the two-point double velocity correlation.

THE APPLICATION TO GRID-PRODUCED TURBULENCE

As a matter of course, the turbulence produced by the grid mesh is not what is called isotropic. The former has a definite spatial directivity, viz. the direction of the main flow

$$u = (\dot{U}, 0, 0), \tag{5}$$

while the latter has not, where $\dot{U}$ is the constant main flow velocity. Now it will be shown that the present method enables the solution for the double and triple correlations to be obtained without introducing the isotropic condition.

In the case of the present flow field, i.e., condition (5), eq (1) and (2) become, respectively,

$$\{\dot{U}[\partial/\partial x_1(a)+ \partial/\partial x_1(b)]-\upsilon[\nabla^2(a)+ \nabla^2(b)]\}\, R_{ij}^{(1,1)}(a, b)=$$

$$=-\partial R_{ijr}^{(1,1,1)}(a, b, a)/\partial x_r(a)-\partial R_{ijr}^{(1,1,1)}(a, b, b)/\partial x_r(b), \tag{6}$$

$$\{\dot{U}[\partial/\partial x_1(a)+ \partial/\partial x_1(b)+ \partial/\partial x_1(c)]-\upsilon[\nabla^2(a)+ \nabla^2(b)+ \nabla^2(c)]\}\, R_{ijr}^{(1,1,1)}(a, b, c)=0, \tag{7}$$

where the time derivative terms have been neglected because a time-dependent solution for fluctuation is not to be expected under the steady primary flow, and where the pressure-velocity correlations are also neglected; The pressure-velocity correlations were shown by Batcheor [7] to be identically zero for the case of homogeneous turbulence. For later convenience, the non-dimensional length x, double correlations R_{ij}, and triple correlations R_{ijr} are introduced by the following re-definition,

$$X=x/M, \tag{8}$$

$$R_{ij}=R_{ij}/\dot{U}^2, \tag{9}$$

$$R_{ijr}= R_{ijr}/\dot{U}^3, \tag{10}$$

and the Reynolds umber is defined as follows,

$$R=M\dot{U}/\upsilon, \tag{11}$$

where M is the mesh size of the grid. Then, the non-dimensional versions of (1) and (2) are simply obtainable by replacing in these equations,

$$\dot{U}=1, \upsilon=R^{-1}. \tag{12}$$

Therefore, the normalized two equations become, respectively,

$$[\partial/\partial x_1(a)+ \partial/\partial x_1(b)]-1/R\cdot[\nabla^2(a)+ \nabla^2(b)]\}\, R_{ij}^{(1,1)}(a, b)=$$

$$=-\partial R_{ijr}^{(1,1,1)}(a, b, a)/\partial x_r(a)-\partial R_{ijr}^{(1,1,1)}(a, b, b)/\partial x_r(b), \tag{13}$$

$$[\partial/\partial x_1(a)+ \partial/\partial x_1(b)+ \partial/\partial x_1(c)]-1/R \cdot[\nabla^2(a)+ \nabla^2(b)+ \nabla^2(c)]\} R_{ijr}^{(1,1,1)}(a, b, c)=0, \quad (14)$$

It may be obvious that (11) is solvable by the method of variable separation, viz.

$$R_{ijr}^{(1,1,1)}(a, b, c)=\varphi_i(a)\varphi_j(b)\varphi_r(c), \quad (15)$$

and φ_s follows the following equation

$$(\partial/\partial x_1-R^{-1}\nabla^2-i\lambda)\varphi_s=0, \quad (16)$$

where iλ is the separation constant such that the general solution is expressible in the form

$$R_{ijr}^{(1,1,1)}(a, b, c) = \int \varphi_i(a)\varphi_j(b)\varphi_r(c)\delta[\lambda(a)+ \lambda(b)+\lambda(c)]d\lambda(a)\,\lambda(b)\,\lambda(c), \quad (17)$$

where δ is the Dirac delta function.

It is easily seen that (16) is nothing more than a special case of the Oseen equation for waves travelling in a uniform flow with frequency λ. Such waves decay due to viscous effects and dispersion. This fact immediately suggests that a solution of the following form is sought,

$$\varphi_s=\int A_s(k, \beta, \lambda)\exp(-\beta x_1+ik_ix_i)dk_2dk_3, \quad (18)$$

$$(\beta -ik_1)^2+R(\beta -ik_1) +i\lambda R-k_2^2-k_3^2=0, \quad (19)$$

which assures that φ_s is the solution of (16). After (19) is decomposed into the real and the imaginary parts, respectively, β and λ become as the first approximation,

$$\beta \cong k^2/R, \quad (20)$$

$$\lambda\equiv k_1, \quad (21)$$

where $k^2=k_1^2+ k_2^2 + k_3^2$. If the expression like (18) for points a, b, and c, respectively, are substituted into (17), we obtain the general solution for the triple correlations.

$$R_{ijr}^{(1,1,1)}(a, b, c) =\int C_{ijr}\exp\{-1/R[k^2(a)x_1(a)+k^2(b)x_1(b)+k^2(c)x_1(c)]+i[k_i(a)x_i(a)+ k_i(b)x_i(b)+ k_i(c)x_i(c)\ {}_i(a)]\}\,\delta[k(a)+ k(b)+ k_i(c)]dk(a)\,k(b)\,k(c), \quad (22)$$

where we put $C_{ijr}=A_i\,A_j\,A_r$, and we use the relations (20) and (21). Furthermore, we use the

$$R_{ij}^{(1,1)}(a, b)= [R_{ij}^{(1,1)}(a, b)]_c+ [R_{ij}^{(1,1)}(a, b)]_p , \quad (23)$$

where $[R_{ij}^{(1,1)}(a, b)]_c$ and $[R_{ij}^{(1,1)}(a, b)]_p$ are the complementary and the particular solutions, respectively.

THE SOLUTION IN THE TRANSITIONAL PERIOD OF DECAY

As we have already derived the complementary solution in (13) in the part 1, it is sufficient to solve the particular solution to obtain the one in the transitional period of decay.

$$[\partial/\partial x_1(a)+\partial/\partial x_1(b)]-1/R\cdot[\nabla^2(a)+\nabla^2(b)]\}R_{ij}^{(1,1)}(a,b)=-\partial R_{ijr}^{(1,1,1)}(a,b,a)/\partial x_r(a)-\partial R_{ijr}^{(1,1,1)}(a,b,b)/\partial x_r(b)=-\int C_{ijr}[-\beta(a)\delta_{r1}-\beta(-a-b)\delta_{r1}-ik_r(b)]\exp\{-[\beta(a)+\beta(-a-b)]x_1(a)-\beta(b)x_1(b)+ik(b)[-x(a)+x(b)]dk(a)dk(b)-\int C_{ijr}[-\beta(b)\delta_{r1}-\beta(-a-b)\delta_{r1}-ik_r(a)]\exp\{-[\beta(b)+\beta(-a-b)]x_1(b)-\beta(a)x_1(a)+ik(a)[x(a)-x(b)]dk(a)dk(b), \quad (24)$$

where we use (20). Comparing with the both sides of (24), the particular solution must have the form as follows,

$$[R_{ij}^{(1,1)}(a,b)]_p=\int D_{ij}\exp\{-[\beta(a)+\beta(-a-b)]x_1(a)-\beta(b)x_1(b)+ik(b)[-\mathbf{x}(a)+\mathbf{x}(b)]d\mathbf{k}(a)d\mathbf{k}(b)-\int E_{ij}\exp\{-[\beta(b)+\beta(-a-b)]x_1(b)-\beta(a)x_1(a)+ik(a)[\mathbf{x}(a)-\mathbf{x}(b)]d\mathbf{k}(a)d\mathbf{k}(b). \quad (25)$$

Moreover, substituting (25) in (24), we obtain the expression for the l.h.s. as

$$\int D_{ij}\ 【-\beta(a)-\beta(-a-b)-\beta(b)-1/R\{[-\beta(a)-\beta(-a-b)-ik_1(b)]^2-2k_2^2(b)-2k_3^2(b)+[-\beta(b)+ik_1(b)]^2\}】\exp\{-[\beta(a)+\beta(-a-b)]x_1(a)-\beta(b)x_1(b)+ik(b)[-\mathbf{x}(a)+\mathbf{x}(b)]\}d\mathbf{k}(a)d\mathbf{k}(b)-\int E_{ij}\ 【-\beta(a)-\beta(-a-b)-\beta(b)-1/R\{[-\beta(b)-\beta(-a-b)-ik_1(a)]^2-2k_2^2(a)-2k_3^2(b)+[-\beta(a)+ik_1(a)]^2\}】\exp\{-[\beta(b)+\beta(-a-b)]x_1(b)-\beta(a)x_1(a)+ik(a)[\mathbf{x}(a)-\mathbf{x}(b)]\}d\mathbf{k}(a)d\mathbf{k}(b). \quad (26)$$

Then, compare the r.h.s. of (24) with (26), we get the following two relations,

$$D_{ij}\ 【-\beta(a)-\beta(-a-b)-\beta(b)-1/R\{[-\beta(a)-\beta(-a-b)-ik_1(b)]^2-2k_2^2(b)-2k_3^2(b)+[-\beta(b)+ik_1(b)]^2\}=-C_{ijr}[-\beta(a)\delta_{r1}-\beta(-a-b)\delta_{r1}-ik_r(b)], \quad (27)$$

And

$$E_{ij}\ 【-\beta(a)-\beta(-a-b)-\beta(b)-1/R\{[-\beta(b)-\beta(-a-b)-ik_1(a)]^2-2k_2^2(a)-2k_3^2(a)+[-\beta(a)+ik_1(a)]^2\}】=-C_{ijr}[-\beta(b)\delta_{r1}-\beta(-a-b)\delta_{r1}-ik_r(a)]. \quad (28)$$

It is, therefore, evident if the three-point triple correlations, in which each of three points is definitely separated one another, are given by the measurement, it is possible to obtain the particular solution firmly; such a solution does not contain any undetermined constant in it.

It is the problem to specify the value of the constant C_{ijr} in (27) and (28) by using the three-point correlations within a plane behind the grid, where the plane is parallel with it. The three-point correlations play a role in the initial conditions in this mathematical problem. The particular solution (25) will be able to be derived once D_{ij} and E_{ij} are obtained as the function of wave numbers in principle.

Let's demonstrate how to obtain the triple correlation mathematically. Firstly, it is necessary for us to make the measurement to get an analytical expression of the three-point triple correlations at a position within a plane of $x_1(a)=x_1(b)=x_1(c)=0$ behind the grid, which is parallel to the plane. In this case, the three-point triple correlation

$$R_{ijr}^{(1,1,1)}(a,b,c)=\int C_{ijr}\exp\{-1/R[k^2(a)x_1(a)+k^2(b)x_1(b)+k^2(c)x_1(c)]+i[k_i(a)x_i(a)+k_i(b)x_i(b)+k_i(c)x_i(c)_i]\}\delta[\mathbf{k}(a)+\mathbf{k}(b)+k_i(c)]dk(a)\,k(b)\,k(c),$$

Becomes

$$[R_{ijr}^{(1,1,1)}(a, b, c)]_{x1(a)=x1(b)=x1(c)=0} = \int C_{ijr} \exp[i[k_i(a)x_i(a)+k_i(b)x_i(b)- k_i(a)x_i(c) -k_i(b)x_i(c)]\} d\mathbf{k}(a)\, \mathbf{k}(b)$$
$$= \int C_{ijr} \exp\{i[k_i(a)\xi_i+k_i(b)\eta_i]\} d\mathbf{k}(a)\, \mathbf{k}(b), \quad (29)$$

where,

$$\boldsymbol{\xi}=\mathbf{x}(a)-\mathbf{x}(c) \text{ and } \boldsymbol{\eta}=\mathbf{x}(b)-\mathbf{x}(c).$$

Then, operating

$1/(2\pi)^3 \int e\exp[-i\xi_i k_i'(a)]\, d\boldsymbol{\xi}$ to the both sides of (29), we get

$$1/(2\pi)^3 \int [R_{ijr}^{(1,1,1)}(a,b,c)]_{x1(a)=x1(b)=x1(c)=0} \exp[-i\xi_i k_i'(a)] d\boldsymbol{\xi}=1/(2\pi)^3$$
$$\int C_{ijr}\exp\{i[k_i(a)\xi_i-k_i'(a)\xi_i+k_i(b)\eta_i]\} d\boldsymbol{\xi}\, d\mathbf{k}(a)\, d\mathbf{k}(b)$$
$$= \int C_{ijr}\exp[ik_i(b)\eta_i]\delta[\mathbf{k}(a)-\mathbf{k}'(a)]d\mathbf{k}(a)\, d\mathbf{k}(b)= \int C_{ijr}\exp[ik_i(b)\eta_i]\, d\mathbf{k}(b). \quad (30)$$

This time, operating

$$1/(2\pi)^3 \int e\exp[-i\eta_i k_i'(b)]\, d\boldsymbol{\eta}$$

to the both sides of (30), we obtain

$$1/(2\pi)^6 \int [R_{ijr}^{(1,1,1)}(a, b, c)]_{x1(a)=x1(b)=x1(c)=0} \exp[-i\xi_i k_i'(a)-i\eta_i k_i'(b)] d\boldsymbol{\xi} d\boldsymbol{\eta}$$
$$= 1/(2\pi)^3 \int C_{ijr} \exp[ik_i(b)\eta_i-ik_i'(b)] d\boldsymbol{\eta}\, d\mathbf{k}(b)= \int C_{ijr}\exp[ik_i(b)\eta_i-ik_i'(b)] d\boldsymbol{\eta}\, d\mathbf{k}(b)$$
$$= \int C_{ijr}\delta[\mathbf{k}(b)-\mathbf{k}'(b)]d\mathbf{k}(b)=C_{ijr}, \quad (31)$$

That is, if the three-point triple correlations are given experimentally as the function of vectors ξ and $\boldsymbol{\eta}$, C_{ijr} will be determined. Then, using C_{ijr}, we can obtain E_{ij} and D_{ij} easily, and the wanted particular solution $[R_{ij}^{(1,1)}(a, b)]_p$ in (.25) is derived.

According to the diagram with respect to the turbulent energy spectrum function (Batchelor 1956), most of turbulent energy is concentrated to the narrow range of wave-number, viz. $|\mathbf{k}(a) \ll 1, and\ |\mathbf{k}(b)| \ll 1$. Thus, by expanding D_{ij} and E_{ij} in (25) asymptotically, and examining carefully each of these expansion coefficients, we could find how D_{ij} and E_{ij} depend on the wave-numbers, $\mathbf{k}(a)$ and, k(b). Having done those tasks as well as substituting D_{ij} and E_{ij}, which are expressed by wave-numbers, in (25), we can find how the particular solution $[R_{ij}^{(1,1)}(a, b)]_p$ varies depending on the main stream-wise coordinate x.

Substituting (23) in the solenoidal condition

$$\partial R_{i,l}^{(1,1)}(a, b)/\partial x_i(a)= \partial R_{i,l}^{(1,1)}(a, b)/\partial x_l(b) =0, \quad (32)$$

we det the following relations,

$$\partial R_{i,l}^{(1,1)}(a, b)/\partial x_i(a)= \partial [R_{i,l}^{(1,1)}(a, b)]_c/\partial x_i(a)+ \partial [R_{i,l}^{(1,1)}(a, b)]_p/\partial x_i(a)=0, \quad (33)$$

And

$$\partial R_{i,l}^{(1,1)}(a, b)/\partial x_l(b)= \partial [R_{i,l}^{(1,1)}(a, b)]_c/\partial x_l(b)+ =0. \quad (34)$$

In general, it is known that any complementary solution multiplied by arbitrary constant is also another complementary solution. In case of any particular solution, the situation is also same. By considering these facts, (33) and (34) provide us the following relations,

$$\partial[R_{i,I}^{(1,1)}(a, b)]_c/\partial x_i(a) = 0, \tag{35}$$

$$\partial[R_{i,I}^{(1,1)}(a, b)]_p/\partial x_i(a)=0, \tag{36}$$

$$\partial[R_{i,I}^{(1,1)}(a, b)]_c/\partial x_I(b)=0, \tag{37}$$

And

$$\partial[R_{i,I}^{(1,1)}(a, b)]_p/\partial x_I(b)=0. \tag{38}$$

For the later convenience, let's rewrite (23) in the form,

$$[R_{ij}^{(1,1)}(a, b)]_p= \int D_{ij} \exp\{-[\beta(a)+\beta(-a-b)-\beta(b)]x+r_1/2\cdot[\beta(a)+\beta(-a-b)-\beta(b)]- ik(b)[\mathbf{x}(a)\mathbf{x}(b)]\}d\mathbf{k}(a)d\mathbf{k}(b)+ \int E_{ij}\exp\{-[\beta(a)+\beta(-a-b)+\beta(b)]x+ r_1/2\cdot[\beta(a)-\beta(-a-b)-\beta(b)]+ik(a)[\mathbf{x}(a)-\mathbf{x}(b)]\}d\mathbf{k}(a)d\mathbf{k}(b), \tag{39}$$

Where,

$$x=[x_1(a)+x_1(b)]/2, \text{ and } r_1=x_1(a)-x_1(b).$$

Because relations $x \gg r_1$ and

$$\beta \cong k^2/R \ll 1,$$

we obtain

$$[\beta(a)+\beta(-a-b)-\beta(b)]x \gg r_1/2\cdot[\beta(a)+\beta(-a-b)-\beta(b)],\ r_1/2\cdot[\beta(a)-\beta(-a-b)-\beta(b)]. \tag{40}$$

By using (40), (39) becomes

$$[R_{ij}^{(1,1)}(a, b)]_p= \int D_{ij}\exp\{-[\beta(a)+\beta(-a-b)-\beta(b)]x-ik(b)[\mathbf{x}(a)-x(b)]\}d\mathbf{k}(a)d\mathbf{k}(b)+ \int E_{ij}\exp\{-[\beta(a)+\beta(-a-b)+\beta(b)]x+ik(a)[\mathbf{x}(a)-\mathbf{x}(b)]\}d\mathbf{k}(a)d\mathbf{k}(b). \tag{41}$$

To know how the particular solution depends on the coordinate x, it may be sufficient to obtain the forms of D_{ij} and E_{ij} at x=0. Hence, when x=0, (41) reduces to

$$[R_{ij}^{(1,1)}(a, b)]_p= \int D_{ij}\exp\{-ik(b)[\mathbf{x}(a)-x(b)]\}d\mathbf{k}(a)d\mathbf{k}(b)+ \int E_{ij}\exp\{ik(a)[\mathbf{x}(a)-\mathbf{x}(b)]\}d\mathbf{k}(a)d\mathbf{k}(b). \tag{42}$$

Then, by using (36) and (42), we obtain

$$\partial[\mathrm{Rij}(1,1)(a, b)]p/\partial x_i(a)\int[-ik_i(b)]\ D_{ij}\exp\{-ik(b)[\mathbf{x}(a)-x(b)]\}d\mathbf{k}(a)d\mathbf{k}(b)+ \int[ik_i(a)]E_{ij}\exp\{ik(a)[\mathbf{x}(a)-\mathbf{x}(b)]\}d\mathbf{k}(a)d\mathbf{k}(b)=0. \tag{43}$$

As the result, we have the following two conditions regarding to D_{ij} and E_{ij}

$$k_i(b)D_{ij}=0, \tag{44}$$

$$k_i(a)E_{ij}=0. \tag{45}$$

Similarly, to the above, by using (38) and (42), we have

$$k_j(b)D_{ij}=0, \tag{46}$$

$$k_j(a)E_{ij}=0. \tag{47}$$

At this stage, expand D_{ij} near $|\mathbf{k}(a)| = |\mathbf{k}(b)| = 0$ asymptotically, we get

$$\begin{aligned} D_{ij}[\mathbf{k}(a)\,\mathbf{k}(b)] = {} & D_{ij}^{(0)} + k_k(a)D_{ijk}^{(a)} + k_k(b)D_{ijk}^{(b)} + k_k(a)k_l(a)D_{ijkl}^{(a,a)} \\ & + k_k(a)k_l(b)D_{ijkl}^{(a,b)} + k_k(b)k_l(b)D_{ijkl}^{(b,b)} + O(k^3). \end{aligned} \tag{48}$$

Then, we have by using (44),

$$\begin{aligned} k_i(b)D_{ij} = {} & k_i(b)D_{ij}^{(0)} + k_i(b)k_k(a)D_{ijk}^{(a)} + k_i(b)k_k(b)D_{ijk}^{(b)} + k_i(b)k_k(a)k_l(a)D_{ijkl}^{(a,a)} + \\ & k_i(b)k_k(a)k_l(b)D_{ijkl}^{(a,b)} + k_i(b)k_k(b)k_l^{(b)}D_{ijkl}^{(b,b)} + O(k^4) = 0. \end{aligned} \tag{49}$$

Similarly, to the above, by using (46), we obtain

$$\begin{aligned} k_j(b)\,D_{ij} = {} & k_j(b)\,D_{ij}^{(0)} + k_j(b)k_k(a)D_{ijk}^{(a)} + k_j(b)k_k(b)D_{ijk}^{(b)} + k_j(b)k_k(a)k_l(a)D_{ijkl}^{(a,a)} + \\ & k_{ij}(b)k_k(a)k_l(b)D_{ijkl}^{(a,b)} + k_j(b)k_k(b)k_l(b)D_{ijkl}^{(b,b)} + O(k^4) = 0. \end{aligned} \tag{50}$$

(49) and (50) give us the following relations regarding to expansion coefficients of D_{ij}.

$$D_{ij}^{(0)}=0, \tag{51}$$

$$D_{ijk}^{(a)}=0, \tag{52}$$

$$D_{ijk}^{(b)}=\varepsilon_{ijk}D^{(b)}+\varepsilon_{jik}D^{(b)*}, \tag{53}$$

where $D^{(b)*}$ is the complex conjugate of $D^{(b)}$. ε_{ijk} is the alternating tensor, where $\varepsilon_{ijk}=0$, 1, or -1 when suffixes are not all different, in cyclic order or not in cyclic order, respectively. In addition, we use the following relations,

$$D_{ijk}^{(b)}+D_{kji}^{(b)}=0, \tag{54}$$

$$D_{ijk}^{(b)}+D_{ikj}^{(b)}=0, \tag{55}$$

where the tensor $D_{ijk}^{(b)}$ is Hermitian with respect to subscripts I and j,

$$D_{ijk}^{(b)}=D_{jik}^{(b)*}, \tag{56}$$

$$D_{ijkl}^{(a,a)}=\varepsilon_{klm}\hat{D}_{ijm}, \tag{57}$$

where we use the condition

$$D_{ijkl}^{(a,a)} + D_{ijlk}^{(a,a)}. \tag{58}$$

And

$$D_{ijkl}^{(a,b)} = \varepsilon_{ijl}\hat{D}_k^{(a,b)} + \varepsilon_{jil}\hat{D}_k^{(a,b)*}, \tag{59}$$

where we use the following relations,

$$D_{ijkl}^{(a,b)} + D_{ljki}^{(a,b)} = 0, \tag{60}$$

And

$$D_{ijkl}^{(a,b)} + D_{ilkj}^{(a,b)} = 0, \tag{61}$$

where tensor $D_{ijkl}^{(a,b)}$ is Hermitian with respect to subscripts I and j, so that

$$D_{ijkl}^{(a,b)} = D_{jikl}^{(ab)*}. \tag{62}$$

Now, consider how tensor $D_{ijkl}^{(b,b)}$ can be described. (49) and (50) give us immediately the following two relations

$$k_i(b)k_k(b)k_l(b)D_{ijkl}^{(b,b)} = 0, \tag{63}$$

and

$$k_j(b)k_k(b)k_l(b)D_{ijkl}^{(b,b} = 0. \tag{64}$$

Let's introduce the second-order tensor as follow,

$$A_{ij} = k_k(b)k_l(b)D_{ijkl}^{(b,b)}, \tag{65}$$

Since (63) and (65) give us $k_i(b)A_{ij}=0$, it may be possible to express A_{ij}, as

$$A_{ij} = \varepsilon_{ipq}k_p(b)C_{qj}. \tag{66}$$

Because A_{ij} is a linear quadratic form of the components in $\mathbf{k}(b)$, C_{qj} may be expressed by

$$C_{qj} = \Gamma_{qjr}k_r(b), \tag{67}$$

Thus, substituting (67) in (66), we have

$$A_{ij} = \varepsilon_{ipq}\Gamma_{qjr}k_p(b)k_r(b). \tag{68}$$

Similarly, to the above,

$$A_{ij}=\varepsilon_{ipq}\Gamma'_{qip}k_p(b)k_r(b). \tag{69}$$

Because (65) and (68) must be valid for all **k**(b), the former relation can be rewritten as

$$A_{ij}=k_p(b)k_r(b)D_{ijpr}^{(b,b)}. \tag{70}$$

Hence, (67)-(69) give us

$$D_{ijpr}^{(b,b)}= \varepsilon_{ipq}\Gamma_{qjr}=\varepsilon_{jrq}\Gamma'_{qip}. \tag{71}$$

Note that the last term in (71) becomes zero when r=j, for it is antisymmetric with respect to the interchange in r and j. It is, therefore, required that Γ_{qjr} has those properties, so it can be expressed by

$$\Gamma_{qjr} =\varepsilon_{jrb}\hat{D}_{qb}^{(b,b)}, \tag{72}$$

where $\hat{D}_{qb}^{(b,b)}$ is an arbitrary tensor. (71) and (72) give us the general form of $D_{ijkl}^{(b,b)}$ as follow,

$$D_{ijkl}^{(b,b)}=\varepsilon_{ika}\varepsilon_{jlb}\hat{D}_{ab}^{(b,b)} . \tag{73}$$

Subtituting (51)-(61) and (73) in (48), we get

$$D_{ij}=k_k(b)(\varepsilon_{ijk}D^{(b)}+\varepsilon_{jik}D^{(b)*})+k_k(a)k_l(a)\varepsilon_{klm}\hat{D}_{ijm}^{(a,a)}+ k_k(a)k_l(b)(\varepsilon_{ijl}\hat{D}_{k}^{(a,b)}+\varepsilon_{jil}\hat{D}_{k}^{(a,b)*})+ k_k(b)k_l(b)\epsilon_{ika}\epsilon_{jlb}\hat{D}_{ab}^{(b,b)}+O(k^3). \tag{74}$$

At this stage of the analyses, it is necessary for us to quote Cramér's theorem (1940), to specify the coefficients of $k_k(b)$ in (74) to become zero. His theorem may be stated in such a way "the necessary and sufficient condition that $R_{ij}(\mathbf{r})$ is the correlation tensor of a continuous stationary random process is that it can be expressed of the form

$$R_{ij}(\mathbf{r})=\int \Phi_{ij}(\mathbf{k}) \exp(ik_ir_i)d\mathbf{k},$$

where $\Phi_{ij}(\mathbf{k})$ is a complex tensor that satisfies the following two conditions,

$$\text{(a)} \qquad \int \left|\Phi_{ij}(\mathbf{k})\right| d\mathbf{k}< \infty,$$

and

$$\text{(b)} \qquad \Phi=x_ix_j^*\Phi_{ij}(\mathbf{k}),$$

is a non-negative quadratic form. That is, $\Phi \geq 0$ for an arbtrary choice of the complex constants x_i. "In his theorem, dk is written by $dk_1dk_2dk_3$, the integrals are taken over the whole wave-number space, and x_i^* denotes the complex conjugate of x_i. The behavior of the spectrum $\Phi_{ij}(k)$ at small values of k may be determined with the aid of his theorem and the incompressible condition. We may be required to assume that a few of the first derivatives for $\Phi_{ij}(k)$ at k=0 exist. It is known that stationary random functions do not necessarily satisfy such conditions in general, but some experiments confirm the validity of the present assumption in case of homogeneous turbulence.

In the neighborhood of k=o, the spectrum tensor can be expressed by

$$\Phi_{ij}(\mathbf{k}) = B_{ij} + k_k B_{ijk} + k_k k_l B_{ijkl} + O(k^3), \tag{75}$$

where the tensor coefficients B_{ij}, B_{ijk}, and B_{ijkl} depend on time only. The incompressible condition, $k_i\Phi_{ij}(\mathbf{k})=k_j\Phi_{ij}(\mathbf{k})=o$ requires

$$k_i B_{ij} + k_i k_k B_{ijk} + k_i k_k k_l B_{ijkl} + O(k^4) = o, \tag{76}$$

being satisfied by every vaue of k only if $B_{ij}=o$. Then, noting that Cramér's theorem assures us

$$x_i x_j^* k_k B_{ijk} \geq o \tag{77}$$

for all sufficiently small k and arbitrary x_i. Because the sign of (77) could be altered by reversing the direction of k, the only possibility is $B_{ijk}=o$. The expression of $\Phi_{ij}(k)$ in the vicinity of k=o must be

$$\Phi_{ij}(\mathbf{k}) = k_k k_l B_{ijkl} + O(k^3). \tag{78}$$

The energy spectrum tensor of $R_{ij}^{(1,1)}(a,b)$ in (23) is no more than $\Phi_{ij}(k)$. The tensor coefficient of the first-order wavenumber corresponding to B_{ijk} in the above relation, becomes zero. On one hand, the energy spectrum tensor C_{ij} of the complementary solution has also not the tensor coefficient for the first-order wave-number, as already being showed in (4-20) in part 1 of the present paper. It is, therefore, evident that the tensor coefficient of $k_k(b)$ in (74) reduces to zero. That is,

$$D_{ij}=k_k(a)k_l(a)\varepsilon_{klm}\hat{D}_{ijm}^{(a,a)} + k_k(a)k_l(b)(\varepsilon_{jil}\hat{D}_k^{(a,b)}+\varepsilon_{jil}\hat{D}_k^{(a,b)*})+k_k(b)k_l(b)\epsilon_{ika}\epsilon_{jlb}\hat{D}^{(b,b)}+O(k^3). \tag{79}$$

In particular, when i=j for the energy spectrum of turbulent intensity, we obtain

$$D_{ii} = k_k(a)k_l(a)\varepsilon_{klm}\hat{D}_{iim}^{(a,a)}+k_k(b)k_l(b)\epsilon_{ika}\epsilon_{ilb}\hat{D}_{ab}^{(b,b)}+O(k^3). \tag{80}$$

Similarly to D_{ij}, expanding E_{ij} in the vicinity of $|\mathbf{k}(a)| = |\mathbf{k}(b)| = o$ in terms of conditions (45) and (47), we get the following relations with respect to the expansion coefficients,

$$E_{ij}^{(o)}=o, \tag{81}$$

$$E_{ijk}^{(b)}=o, \tag{82}$$

$$E_{ijk}^{(a)}=\varepsilon_{ijk}E^{(a)} + \varepsilon_{jik}E^{(a)*}, \tag{83}$$

$$E_{ijkl}^{(b,b)} = \varepsilon_{klm}\hat{E}_{ijm}^{(b,b)}, \tag{84}$$

$$E_{ijkl}^{(a,b)} = \varepsilon_{ijk}\hat{E}_l^{(a,b)} + \varepsilon_{jik}\hat{E}_l^{(a,b)*}, \tag{85}$$

$$E_{ijkl}^{(a,a)} = \varepsilon_{ika}\varepsilon_{jlb}\hat{E}_{ab}^{(a,a)}. \tag{86}$$

Based on Cramér's theorem, (83) becomes zero, viz.

$$E_{ijk}^{(a)}=\varepsilon_{ijk}E^{(a)} + \varepsilon_{jik}E^{(a)*} =0. \tag{87}$$

Hence, the concrete expression of E_{ij} may be expressed by

$$E_{ij} = k_k(b)k_l(b)\varepsilon_{klm}\hat{E}_{ijm}^{(b,b)} + k_k(a)k_l(b)(\varepsilon_{ijk}\hat{E}_l^{(a,b)}+\varepsilon_{jik}\hat{E}_l^{(a,b)*})+ k_k(a)k_l(a)\varepsilon_{ika}\varepsilon_{jlb}\hat{E}_{ab}^{(a,a)} + O(k^3). \tag{88}$$

In particular, when i=j, corresponding the power spectrum of the turbulent intensity,

$$E_{ii} = k_k(b)k_l(b)\varepsilon_{klm}\hat{E}_{iim}^{(b,b)} + k_k(a)k_l(a)\varepsilon_{ika}\varepsilon_{ilb}\hat{E}_{ab}^{(a,a)} + O(k^3). \tag{89}$$

To derive the turbulent intensity relating to the particular solution, by definition, put i=j,

$$\begin{aligned}\dot{u}_p^2 =[R_{ii}^{(1,1)}(a, b)]_p =&\int D_{ii}\exp\{-2x/R[k^2(a)+k_i(a)k_i(b)+k^2(b)]\}d\mathbf{k}(a)d\mathbf{k}(b)+\\ &\int E_{ii}\exp\{-2x/R[k^2(a)+k_i(a)k_i(b)+k^2(b)]\}d\mathbf{k}(a)d\mathbf{k}(b),\end{aligned} \tag{90}$$

where $\dot{u}_p^2$ is the turbulent intensity due to the particular solution. Now, substituting (80) and (89) in (90), we get

$$\begin{aligned}\dot{u}_p^2 =&\int[(\varepsilon_{klm}\hat{D}_{iim}^{(a,a)}+ \varepsilon_{ika}\varepsilon_{ilb}\hat{E}_{ab}^{(a,a)})k_k(a)k_l(a) +(\epsilon_{ika}\epsilon_{ilb}\hat{D}_{ab}^{(b,b)}+ \varepsilon_{klm}\hat{E}_{iim}^{(b,b)})k_k(b)k_l(b)]\cdot\\ &\exp\{-2x/R[k^2(a)+k_i(a)k_i(b)+k^2(b)]\}d\mathbf{k}(a)d\mathbf{k}(b),\end{aligned} \tag{91}$$

where we use the relation $O(k^2) \gg O(k^3)$. For the sake of future convenience, rewrite (91) as

$$\begin{aligned}\dot{u}_p^2 =&\int[G^{(a,a)}k_k(a)k_l(a) +H^{(b,b)}k_k(b)k_l(b)]\cdot\\ &\exp\{-2x/R[k^2(a)+k_i(a)k_i(b)+k^2(b)]\}d\mathbf{k}(a)d\mathbf{k}(b),\end{aligned} \tag{92}$$

with

$$G^{(a,a)}= \varepsilon_{klm}\hat{D}_{iim}^{(a,a)}+ \varepsilon_{ika}\varepsilon_{ilb}\hat{E}_{ab}^{(a,a)}, \tag{93}$$

And

$$H^{(b,b)}= \epsilon_{ika}\epsilon_{ilb}\hat{D}_{ab}^{(b,b)}+ \varepsilon_{klm}\hat{E}_{iim}^{(b,} . \tag{94}$$

Let's rewrite (92) as follow,

$$\dot{u}_p^2 =\int[G^{(a,a)}k_k(a)k_l(a) +H^{(b,b)}k_k(b)k_l(b)]\cdot \exp\{-2x/R\cdot[k_i(a)+k_i(b)/2]^2-3xk^2(b)/(2R)\}d\mathbf{k}(a)d\mathbf{k}(b), \tag{95}$$

Finally, let's us change variables in (95) in the following manner,

$$V_i=k_i(b), \tag{96}$$

And

$$W_i=k_i(a) + k_i(b)/2=k_i(a)+V_i/2. \tag{97}$$

Thus, the Jacobian becomes as

$$J_1=\partial(W_1, W_2, W_3, V_1, V_2, V_3)/\partial[k_1(a), k_2(a), k_3(a), k_1(b), k_2(b), k_3(b)] =1. \quad (98)$$

Using (96)-(98), we can rewrite (95) of the form,

$$\bar{u}_p^2 =\int [G^{(a,a)}(W_kW_l-W_kV_l/2-V_kW_l/2+V_kV_l/4) +H^{(b,b)}V_kV_l]\cdot \exp\{-2x/R\cdot W^2-3xV^2/(2R)\}d\mathbf{W}d\mathbf{V}. \quad (99)$$

Having done this preparation, let's change the variables in (99) from Wi and V_i to w_i and v_i, respectively, as follows,

$$W_i =1/2\cdot (R/x)^{1/2} w_i, \quad (100)$$

and

$$V_i=[R/(3x)]^{1/2} v_i. \quad (101)$$

The Jacobian can be expressed by

$$J_2 =\partial(W_i, V_i)/\partial(w_i, v_i) =$$

$$\begin{vmatrix} \partial W_i/\partial w_i & \partial W_i/\partial v_i \\ \partial V_i/\partial w_i & \partial V_i/\partial v \end{vmatrix}$$

With (100) and (101), we can calculate each of the elements in the above determinant as follow.

$$\begin{vmatrix} 1/2\cdot (R/x)^{1/2} & 0 \\ 0 & [R/(3x)]^{1/2} \end{vmatrix}$$

$$= 1/2\cdot (R/x)^{1/2} \cdot [R/(3x)]^{1/2}$$

$$=1/2\cdot 1/3^{1/2}\cdot (R/x)$$

$$=(1/12)^{1/2}\cdot (R/x)$$

Thus, finally Jacobian becomes

$$J_2 = (1/12)^{1/2}\cdot (R/x). \quad (102)$$

By using (100) – (102), we can rewrite (99) as follow,

$$\bar{u}_p^2 =\int [G^{(a,a)}([1/2\cdot (R/x)^{1/2}]^2 w_kw_l-1/4\cdot (R/x)^{1/2}[R/(3x)]^{1/2}w_kv_l-1/4\cdot (R/x)^{1/2}[R/(3x)]^{1/2}v_kw_l+ R/(3x)/4) v_kv_l+ H^{(b,b)}(R/(3x) v_kv_l]\cdot \exp(w2/2-v2/2)[1/2\cdot (R/x)1/2[R/(3x)]dw.\, dv, \quad (103)$$

Now, let's define Hermite polynomials in the following way,

$$w_i = £_i^{(1)}(w), \tag{104}$$

$$v_i = £_i^{(1)}(v), \tag{105}$$

$$w_i w_j - \delta_{ij} = £_{ij}^{(2)}(w), \tag{106}$$

$$v_i v_j - \delta_{ij} = £_{ij}^{(2)}(v). \tag{107}$$

Then, substituting (104)-(107) in (103), we get

$$\dot{u}_p^2 = \int \{G^{(a,a)}\{[1/2\cdot (R/x)^{1/2}]^2 [£_{kl}^{(2)}(w)+\delta_{kl}] - 1/4\cdot (R/x)^{1/2}[R/(3x)]^{1/2} £_k^{(1)}(w)\, £_l^{(1)}(v) - 1/4\cdot (R/x)^{1/2}[R/(3x)]^{1/2}[£_k^{(1)}(v) £_l^{(1)}(w)] + R/(3x)/4)\,[£_{kl}^{(2)}(w)+\delta_{kl}]\} + H^{(b,b)}[R/(3x)\,[£_{kl}^{(2)}(w)+\delta_{kl}]\cdot \exp(w^2/2 - v^2/2)[1/2\cdot (R/x)^{1/2}[R/(3x)]^{1/2} d\mathbf{w}.d\mathbf{v}. \tag{108}$$

Moreover, using the orthogonality of Hermite function, together with the following relations

$$\int £_{kl}^{(2)}(w)\cdot \exp(-w^2/2)\, d\mathbf{w} = \int £_{kl}^{(2)}(v)\cdot \exp(-v^2/2)\, d\mathbf{v} = 0, \tag{109}$$

(108) becomes

$$\dot{u}_p^2 = 2\pi^3/(93^{1/2})\cdot \delta_{kl}(G^{(a,a)} + H^{(b,b)})(R/x)^4, \tag{110}$$

Recalling the notation $G^{(a,a)}$ and $H^{(b,b)}$, we obtain the final form;

$$\dot{u}_p^2 = 2\pi^3/(93^{1/2})\cdot \delta_{kl}((\hat{E}_{aa}^{(a,a)} + \hat{D}_{aa}^{(b,b)})R^4 x^{-4}, \tag{111}$$

Finally, referring to (23) for the decay law $\dot{u}_c^2$ for turbulent energy in the final period as well as (111), we have the decay law for turbulent energy in the transitional period as follow

$$\dot{u}^2 = \dot{u}_c^2 + \dot{u}_p^2 = 3a^2/32\cdot (R/2)^{5/2}\cdot x^{-5/2} + 2\pi^3/(93^{1/2})\cdot \delta_{kl}((\hat{E}_{aa}^{(a,a)} + \hat{D}_{aa}^{(b,b)})R^4 x^{-4}, \tag{112}$$

Comparison between the present theory with an experiment

Figure 2 shows the comparison between the present theory with the experiment by Batchelor-Townsend (1948). The curve 1 is the present theory of the decay law for turbulent energy in the final period, which is expressed by (4.23) in Part 1. This problem has been solved exactly as an initial value problem based on reliable data as depicted in Figure 3.

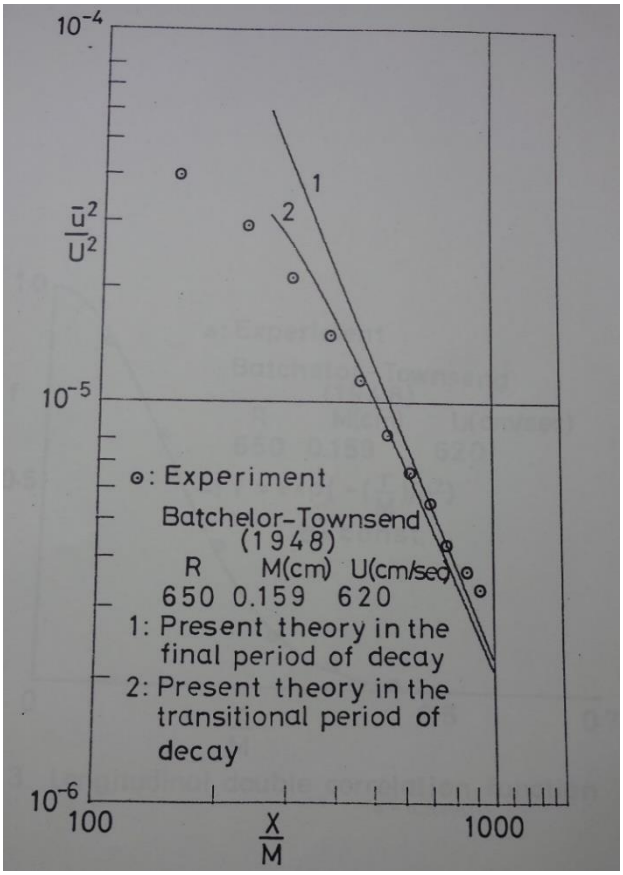

Figure 2: Energy decay of grid-produced turbulence.

The comparison is done for the final period corresponding to x/M≥ 600 in the experiment. It is evident that the curve 1 is in good agreement with the experimental data for this period. In terms of Taylor's hypothesis, the present decay law for turbulent energy $\overline{u}^2$ depending on $x^{-5/2}$ in the final period is consistent with the classical one. Present curve 2 that is expressed by (112) represents the decay law for turbulent energy in the transitional period, for it includes effects of the double as well as triple correlations,

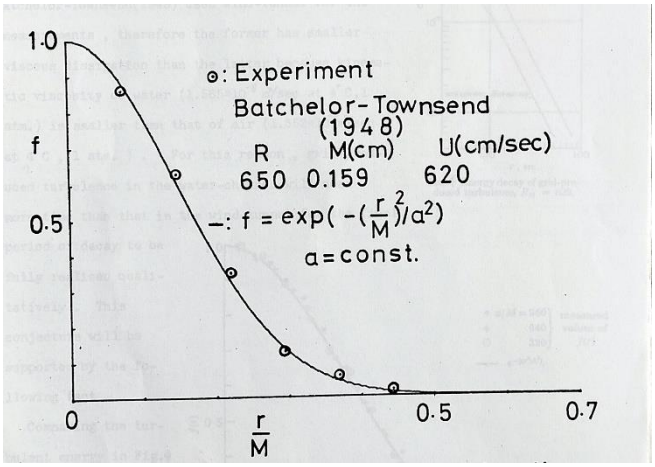

Figure 3: Longitudinal double correlation function.

a = 0.208934

but neglects the quadruple correlations or assumes four-particle molecular chaos. This curve agrees well with the experimental data corresponding to x/M≥ 460. However, it must be noted

that owing to the deficit of the experimental data for the triple correlations at the initial plane behind the grid, we could not determine the constant value in front of x^4 in (112). In another words, the mathematical expression of the triple correlations to be used as the initial condition required in the present theory does not exist currently as far as the present author knows. Thus, such an experiment is strongly required to get the expression of triple correlations. So, this work is left for the future, but for tentative comparison with the data on the turbulent intensity $\overline{u^2}$, the value of B is set to be of -1.5×10^5. In another words, this is the assumption that both of the double correlation and the triple correlation are given at the same plane behind the grid.

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Appendix 1: Determinant

If in the determinant $|a|$, we delete the ith row and jth column, and form a determinant from all the elements remaining, we shall have a new determinant of n-1 rows and columns. This new determinant is defined to be the minor of the element a_{ij}. For example, if $|a|$ is a determinant of the third order, the minor of the element a_{32} is denoted by M_{32}.

The cofactor of an element of a determinant a_{ij} is the minor of that element with a sign attached to it determined by the numbers i and j which fix the position of a_{ij} in the determinant $|a|$ The sign is chosen by the equation

$$A_{ij}= (-1)^{i+j}M_{ij},$$

where A_{ij} is the cofactor of the element a_{ij} and M_{ij} is the minor of the element a_{ij}.

In case of the nth-order determinant, as the unique nth order homogeneous polynomial

$|a|$ is given by

$$|a| =\sum_{j=1}^{n} a_{ij}A_{ij},$$

where the a_{ij} quantities must be taken either from a single row or a single column. In this case the cofactors A_{ij} are determinants of the (n-1) st order, but they may be in turn expanded by the above rule, and so forth, until the result is a homogeneous polynomial of the nth order.

Appendix 2: Hermite Function

The function $\varphi_n(x)=\exp(-x^2/2)\, Hn(x)$ (n=0, 1,2, ...), which are often referred to as Hermite functions, satisfy the differential equation

$$d^2w/dz^2 + (2n+1-z^2)\, w = 0, \quad (n=0, 1, 2, \ldots)$$

and

$$\int_{-\infty}^{\infty} \varphi_n(x)\varphi_{n'}(x)dx=2^n n!\, \pi^{1/2}\delta_{n'n}.$$